Intertie Restoration Project

AESO – BCH Joint Planning Study

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Executive Summary

As per the WECC path rating catalogue the rating of the Alberta - BC interconnection (Path 1) is 1200 MW import from BC to AB and 1000 MW export from AB to BC. Due to various constraints, the current operational limit on Path 1 is less than the full path rating. Alberta's Transmission Regulation requires AESO to restore the capability of the interties to or near to their WECC path ratings [9]. The regulation also requires AESO to plan the AIES so that the anticipated in-merit energy could flow without congestion under normal conditions [10] and that intertie flows are considered to be in-merit energy [11]. The AESO initiated a study in 2012 [1] to assess:

a) The required reinforcement to restore the capability of Path 1 to or near to their WECC path ratings
b) The required reinforcement to accommodate the intertie flows as they are considered to be in-merit energy

The study was conducted in three stages. The study results of stage 1 and 2 of the studies [2][3] revealed that following the connection of the Chapel Rock substation the AB-BC interconnection would have Total Transfer Capability (TTC) of 1200 MW from BC to AB and 1000 MW from AB to BC flow under certain scenarios and system assumptions such as winter peak load, the availability of 480 MW LSSi (Load Shed Service for Import) to be armed for high import scenarios, and Alberta's current largest single generator contingency. Therefore the restoration requirement for Path 1 will be complete following the Chapel Rock project.

While the focus of stage 1 and 2 of the studies were solely on the AIES, a joint study with BC Hydro was planned for stage 3 to identify possible issues in AIES or BCH systems under further stressed scenarios and also identify what reinforcement is required to accommodate intertie flows as in-merit energy. The AESO and BC Hydro jointly developed study scopes [4][5] and a set of common base cases and study scenarios. This report summarizes the results of stage 3 of the studies performed by the AESO. BC Hydro has prepared a separate report for the studies that they performed focusing on the BCH system [6].

The studies examined two fundamental operating conditions. The first is to examine the transfer capability of the interties for contingencies other than interties. The second is to examine the performance of controlled separation where the contingency is the intertie and the result is islanding of the Alberta system from WECC.

The AESO's analysis of the joint study scenarios revealed that before Chapel Rock project, there would be criteria violation in the AIES due to facility rating limitations if Path 1 operates at its WECC path rating. This study also showed that in addition to completion of Chapel Rock, Foothills Area Transmission Development (FATD)-East, and the ongoing implementation of parts of the southern Alberta transmission reinforcement (SATR) projects in Alberta, the following AIES issues[1] need to be resolved in order for Path 1 to operate at full WECC path rating under all anticipated scenarios:

1- Overload on 1201L from Chapel Rock to BC border
2- Overload on Goose Lake to Windy Flats 240 kV lines
3- Frequency response issues in Alberta following an AB-BC intertie trip under high import/ high export scenarios.
4- Voltage issues in southern Alberta

In addition to these AIES issues, the following issues on the BC system were identified:

1- Overload on the Natal to Pocaterra 138 kV transmission path in the BC Hydro system[2]
2- Voltage issues at Cranbrook[3]

Based on the technical performance and the order of magnitude (+100/-50%) cost estimates by AESO, the following mitigation measures[4] and system reinforcements, in conjunction with the Chapel Rock and FATD-East projects are recommended to restore Path 1 to its existing WECC path rating and enable full simultaneous transfers on Path 1 and Path 83 (MATL):

1- Resolve the issues on 1201L line from Chapel Rock to BC border (assuming 20 km). Cost estimate: up to $65M. This resolves the overload issue on 1201L from Chapel Rock to BC border.

2- Implement DTLR on Goose Lake to Windy Flats lines. Cost estimate: $1M. This resolves the overload issue on Goose Lake to Windy Flats 240 kV lines.

3- Implement a RAS to trip Path 1 following the outage of the Chapel Rock to Bennett 500 KV line (1235L) under certain scenarios. Cost estimate: $0.5M. This helps to resolve the overload issue on Goose Lake to Windy Flats 240 kV lines as well as the voltage issue in Cranbrook and southern Alberta.

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[1] The AESO's criteria allow generation trip and load shedding for Cat C contingencies. All C5 constraints identified in this report can be addressed by RASes. Therefore they are not deemed criteria violations and identified as issues.

[2] BCH current practice is to open 1L274/887L at Pocaterra and 1L275/786L at Natal to mitigate overload or expected overload on the 138 kV transmission path, as per BCH Operating Order 7T-17.

[3] Cranbrook voltage issue exists for the scenario of 1200 MW BC to Alberta flow and 1000 MW wind generation in the Alberta Pincher Creek area, and upon trip of Genesee 3 generator or 1235L.

[4] Recommended RASes to mitigate Cat C5 contingencies are listed in Table 6.7-8.

4- Install a 300 MW back-to-back HVDC converter along MATL. Cost estimate: $150M. This helps with the frequency response issue.

5- Resolve the overload issues on the Natal to Pocaterra path – BCH has indicated that it plans to continue with the existing operation practice of opening the 138kV tie to mitigate overload concerns.

Study results show that with implementation of the planned transmission projects, assumed availability of around 480 MW LSSi, and implementation of the above mitigation measures, Path 1 could operate at the WECC path rating under most of the anticipated scenarios[5]. Figure E-1 shows how the recommended mitigation measures increase the import capability under varying levels of wind generation in the Pincher Creek area in summer. The green bar represents the maximum import capability and other bars represent different criteria violations as the import increases.

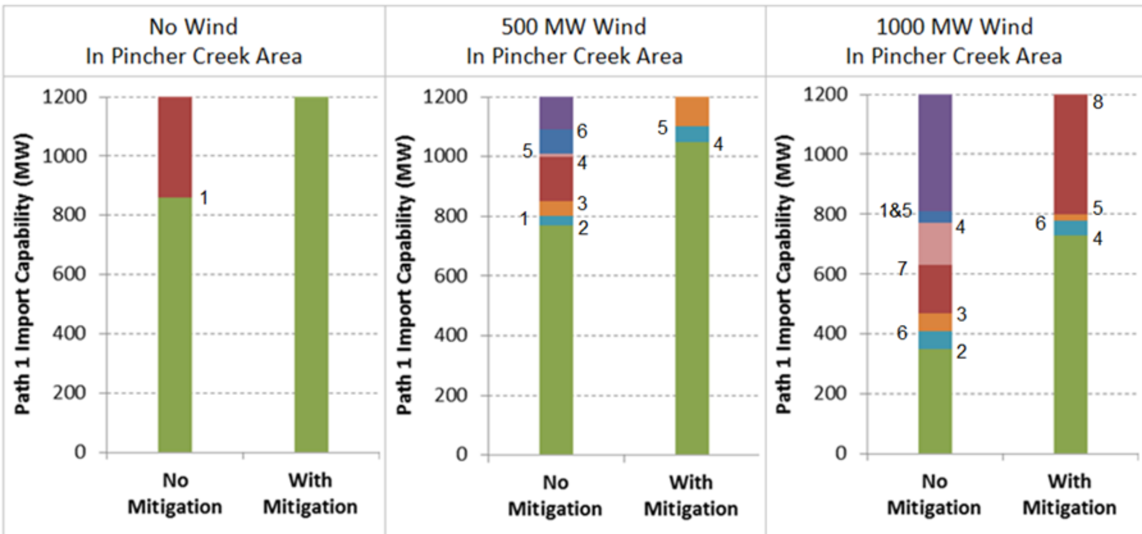
Since the green bar doesn't extend to 1200 MW for all wind levels, Figure E-1 reveals that even after implementation of the recommended mitigation measures there would be criteria violations under 1200 MW import and more than approximately 300 MW wind generation in Pincher Creek area which is expected to be rare given AESO's current assessment of the market. However a high level analysis of AESO's hourly wind and import forecast data shows that the anticipated Path 1 import up to 1200 MW could be accommodated for more than 5 years after the Chapel Rock connection in almost all hours[6]. The AESO will continue to monitor the generation development in Alberta and plan further mitigation measures or system reinforcements if more capacity is required to accommodate 1200 MW import and high generation in Pincher Creek area. The following are the issues that need additional reinforcement to be resolved if 1200 MW import from BC and 1000MW or more wind in Pincher Creak area are to be accommodated:

- Re-conductor the Goose Lake to Windy Flats lines with high temperature conductors. Cost estimate: $37M
- Resolve the issue on 1235L from Chapel Rock to Bennett (around 200 km). Cost estimate: $261M
- Resolve issue on Bennett 1200MVA transformer. Cost estimate: $16M
- Resolve the voltage issues at Cranbrook and southern Alberta (The optimum location for voltage support will be determined later): cost estimate: TBD

[5] See Figure 6-5 and Figure 6-6 for the anticipated scenarios covered by proposed mitigation measures.

[6] See Table 6.7-10 for details on % of time

Figure E-1: Impact of Mitigation Measure on Path 1 Import Capability in Summer



1: 1201L overload – Genesee 3 outage
2: 1049L overload – 1235L outage
3: 955L overload – 1235L outage
4: Bennett Tx overload – Genesee 3 outage
5: 1235L overload – Genesee 3 outage
6: 1049L overload – 1048L outage
7: 1072L overload – 1235L outage
8: Intertie Trip (CBK low voltage) – Genesee 3 outage

It should be noted that this study is a planning study to determine the system capability under reasonable planning assumptions. A detailed operations planning study will be performed at a later stage which will determine the interchange capability under various operational scenarios such as varying levels of load, varying levels of available LSSi, and combination of forced outages and maintenance outage of transmission elements.

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1 Introduction

The interconnection between Alberta and British Colombia, also known as WECC Path 1, consists of the following elements:

- 1201L/5L94 Langdon (now Bennett) to Cranbrook 500 kV
- 887L/1L274 Pocaterra to Natal 138 kV
- 786L/1L275 Coleman to Natal 138 kV

While the WECC path rating for Path 1 is 1200 MW import from BC to Alberta and 1000 MW export from Alberta to BC, currently the AB-BC interconnection is operated with a maximum import capability of 800 MW in summer and 830 MW in winter due to transmission issues in Alberta. Export is limited to 800 MW in both summer and winter. The following are the issues in the AIES and BC Hydro systems which currently cause criteria violation should the flow on Path 1 reaches the full WECC path rating:

- Overload on the Langdon to Janet 240 kV lines (936L/937L)
- Overload on the Bennett 500/240 kV transformer
- Overload on 1201L
- Overload on the Natal to Pocaterra 138 kV transmission path
- Voltage issues at Cranbrook

Alberta's Transmission Regulation requires AESO to restore the capability of the interties to or near to their WECC path ratings [9]. The regulation also requires AESO to plan the AIES so that the anticipated in-merit energy could flow without congestion under normal conditions [10] and that intertie flows are considered to be in-merit energy [11].

Several transmission projects are planned in southern Alberta which under certain scenarios will help to remove some of the constraints that limit the power transfer between Alberta and BC. Figure 1-1 shows a schematic diagram of the system in southern Alberta after the implementation of the planned transmission projects.

Among the planned projects, the Chapel Rock substation and the double circuit 240 kV lines that connect the future Chapel Rock substation to the existing Castle Rock Ridge substation (highlighted in blue color Figure 1-1) play a significant role in the restoration of Path 1 to its WECC path ratings (1200 MW import from BC to Alberta and 1000 MW export from Alberta to BC). These projects are part of the Southern Alberta Transmission Reinforcement (SATR) project that has already received Needs Identification Document (NID) approval. Chapel Rock project resolves the overload issues on the Bennett 500/240 kV transformer as well as 1235L (the 500 kV line from Chapel Rock to Bennett substations) by providing an alternative transmission path for the import from BC. The voltage support elements (+200/-100 MVAr SVC and 2 x 100 MVAr capacitor banks) that will be installed in Chapel Rock substation will help to resolve the voltage issue at Cranbrook as well.

The FATD-East transmission development (highlighted in green color Figure 1-1) is another critical project that is currently in the construction phase. As part of the FATD-East project, a new double circuit 240 kV transmission line with approximately 1000 MVA capacity for each circuit will be built from Langdon to Janet substations. The existing 240 kV lines between Langdon and Janet (936L/937L) with approximately 500 MVA capacity for each circuit will be used to create a double circuit transmission line from Langdon to East Calgary. The added transmission capacity between Langdon and Janet, provided by the FATD-East project, resolves the overload issue on the existing 936L/937L from Langdon to Janet substations.

Schematic diagram of Figure 1-2 presents the connection of Langdon, Janet, East Calgary, and Sarcee 240 kV substations in Calgary area before and after the FATD-East project. As shown in Figure 1-2 there would be four 240 kV circuits from Langdon to the city of Calgary from which two of the circuits would have approximately 1000 MVA capacity.

Figure 1-1: Transmission System in Southern Alberta after Chapel Rock Connection

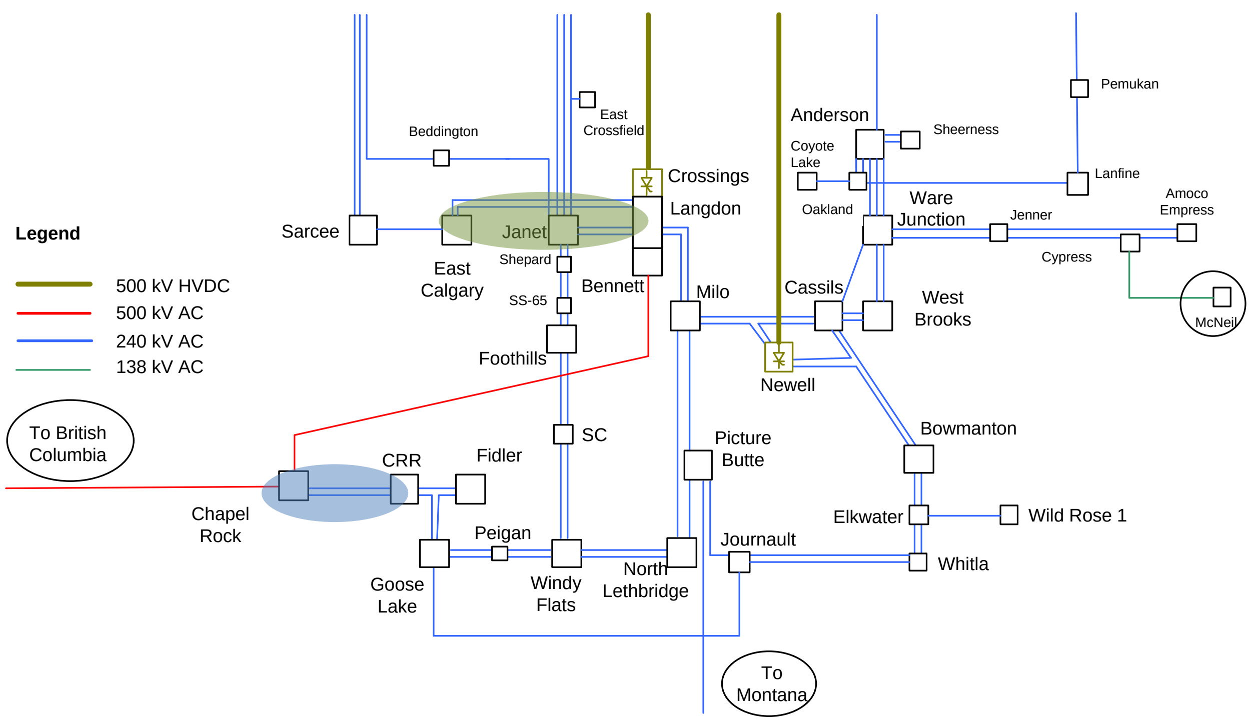
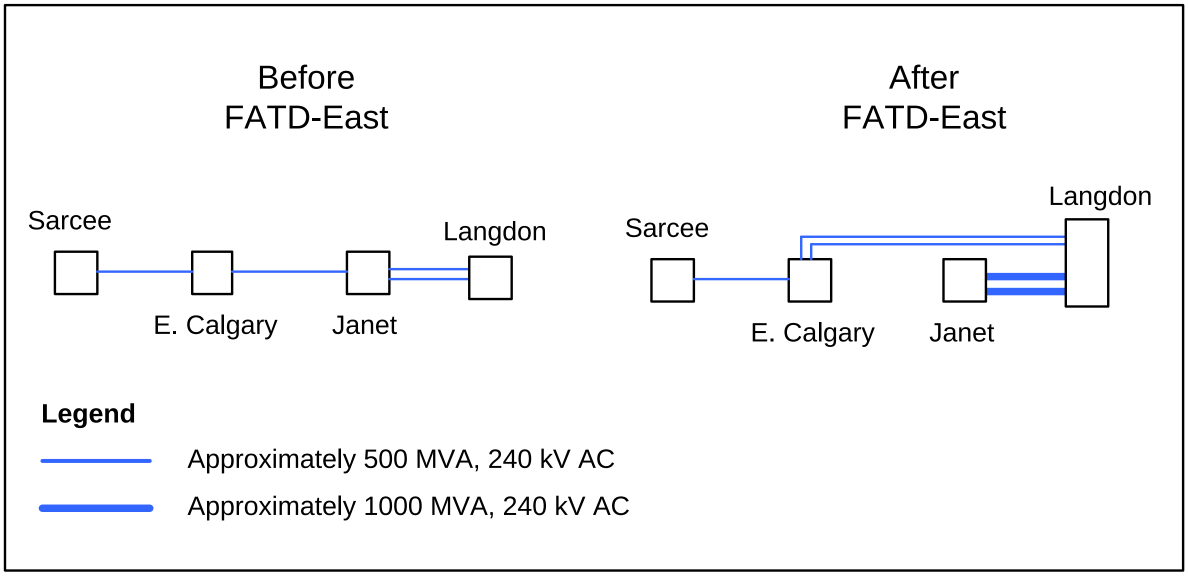


Figure 1-2: Connection of Calgary 240 kV substations before and after FATD-East



The AESO has completed other studies which revealed that with the Chapel Rock connection, the AIES would be capable of operating Path 1 at its WECC path rating under certain assumed operating conditions. Details of those AESO studies are given in the stage 1 and 2 reports [2][3]. Therefore the intertie restoration requirement for Path 1 will be achieved following the Chapel Rock connection.

While AIES would be capable of operating Path 1 at its WECC path rating under certain assumed operating conditions, consideration should be given to Path 83 (MATL) status and flow. With the existing transmission system configuration, the trip of Path 1 will result in the trip of Path 83 due to a direct transfer trip scheme. Should the trip of Path 1 occur at simultaneous 1200 MW import from BC and 300 MW import Montana, AIES will face a supply shortage of 1500 MW which may result in frequency criteria violations and shedding of the firm load by UFLS action.

To ensure that the BC Hydro system has enough capacity and also to assess the Alberta Interconnected Electric System (AIES) performance if intertie flows are considered to be in-merit energy, a joint study was initiated with BC Hydro (BCH). The high level objective was to consider a wide range of stressed scenarios to perform a need assessment study to identify all the possible issues in either the AIES or the BCH system that limits the interchange below the WECC path ratings limits. Following the need assessment, the plan was to consider a range of feasible mitigation measures that could resolve those issues and select the ones that meet the technical requirements at minimum overall cost.

The scenarios in this study include maximum import/export with varying levels of wind generation in Alberta. In the base cases provided by BC Hydro, the generation scenarios are varied in the BC system as well. Base cases and study scenarios were created for years 2014, 2017 without Chapel Rock, 2017 with Chapel Rock, and 2022. While the AESO analyzed both pre and post Chapel Rock scenarios to demonstrate how Chapel Rock substation improves system reliability and performance, this report primarily focuses on the analysis of the system topology after the Chapel Rock connection. The reason, as detailed in the stage 1 study report, is that without the Chapel Rock connection it is not possible to implement practical non-wires mitigation measures that would enable the AIES to meet all the reliability criteria with 1200 MW import from BC. Any mitigation measure would be in the form of system reinforcement and essentially will be similar to Chapel Rock which diversifies the transmission paths for import and provides voltage support along the 1201L.

This report is organized in the following sections:

- Study objective, assumptions, criteria, base cases, and methodology
- Analysis of need assessment results
- Development of mitigation measures
- Summary and conclusions

2 Study Objectives

Alberta's Transmission Regulation requires the AESO to restore the capability of the interties to or near to their WECC path ratings [9]. The regulation also requires AESO to plan the AIES so that the anticipated in-merit energy could flow without congestion under normal conditions [10] and that intertie flows are considered to be in-merit energy [11]. Considering both of these mandates, the following are the main AESO objectives of this joint AESO-BCH planning study:

a) To assess the capability of both the Alberta and BC systems so that the AB-BC interconnection has total transfer capability (TTC) equal to the WECC path rating under several scenarios. Several scenarios will be considered for restoration purposes and several other scenarios will be considered to assess the capability of the AIES to accommodate anticipated in-merit energy.

b) Identify possible issues in the Alberta or BC systems that limit the flow on the AB-BC interconnection to values lower than the path rating.

c) Design and evaluate feasible mitigation measures to resolve possible limitations for anticipated in-merit intertie flows.

3 Scope of Study

The study was performed for the 2014, 2017 and 2022 timeframes to evaluate the impact of all the planned transmission development in Alberta and BC on the capability of the AB-BC interconnection. The 2012LTO[7] was used for Alberta's load forecast and generation scenarios for the study.

The main focus of the studies is to evaluate simultaneous transfers on the AB – BC Interconnection and MATL. In this scenario MATL was assumed to operate at its nominal rating (325 MW north to south and 300 MW south to north, both measured at Picture Butte substation in Alberta) and the limitation on the AB-BC tie was assessed.

The study evaluated the system limitation and if required assessed a number of alternatives to increase the System Operating Limits (SOL) on the AB – BC tie in the planning horizon to the current WECC path ratings under the studied scenarios.

[7] http://www.aeso.ca/downloads/AESO_LTO_Update_Final.pdf

In the following sections, study methodology, base case development and the criteria will be discussed.

4 Study Methodology and Criteria

The process of developing the base cases and details of the study scenario, methodology and criteria are presented in this section. AESO's FAC-010-AB-2.1, "System Operation Limits Methodology for the Planning Horizon" and FAC-014-AB-2, "Establish and Communicate System Operating Limits" were followed to ensure the requirements are met. Load flow, voltage and dynamic stability studies were performed to ensure reliability criteria are met[8].

4.1 Base Case Development

4.1.1 *Load Assumptions*

The load forecast for Alberta based on the 2012LTO is summarized in Table 4.1-1 under summer peak, summer light, and winter peak conditions.

Table 4.1-1: Forecast Alberta Load

Description	2014			2017			2022		
	SP (MW)	SL (MW)	WP (MW)	SP (MW)	SL (MW)	WP (MW)	SP (MW)	SL (MW)	WP (MW)
Alberta Load	10,533	8,084	11,695	11,823	9,148	12,848	13,428	10,276	14,608

4.1.2 *Wind and Intertie Assumptions*

Table 4.1-2 shows the forecast installed wind generation capacity in Alberta as well as the Pincher Creek area.

Table 4.1-2: Wind Forecast

Area	2014	2017	2022
Alberta	1247 MW	1694 MW	2544 MW
Pincher Creek	430 MW	588 MW	984 MW

With regards to interties, the assumption is that transfer capacities up to the WECC path rating are available over the interties under Category A conditions.

[8] AESO is relying on meeting some of the requirements of FAC-010 through the work done as part of the South Region Plan: http://www.aeso.ca/downloads/South_LRP_Report_Final.pdf.

4.1.3 *Transmission Project Assumptions*

Table 4.1-3 lists projects that are previously planned or are currently under construction in Alberta that could potentially impact the intertie restoration.

Table 4.1-3: Future Transmission Projects

System Addition No	Name	In-Service Date (ISD)
1	Genesee – Langdon HVDC (WATL)	2015
2	Heartland – West Brooks HVDC (EATL)	2015
3	SATR (GLEC, PBEC, ECW))	2018
4	Foothills Area Transmission Development (FATD-East)	2015

4.1.4 *HVDC Dispatch Assumptions*

As discussed in the transmission project assumptions section, the WATL and EATL HVDC lines in Alberta are planned to be in service in 2015. Therefore these HVDC lines are modelled in all the 2017 and 2022 study scenarios. The planned methodology for WATL and EATL dispatch in Alberta is to minimize the total real power loss in the AIES as long as it doesn't impact the system reliability and/or electricity market by creating congestion. In all the 2017 and 2022 scenarios in this study WATL and EATL are dispatched with the objective of minimizing total real power loss in the system. Considering that both HVDC links are bi-directional, in certain scenarios one or both HVDC links might be dispatched in a south-to-north flow direction.

4.1.5 *Off-Nominal Frequency Mitigation Assumptions*

It is assumed that 480 MW load shed service for import (LSSi) is available to be armed and tripped under high import controlled separation scenarios. In March 2014, the AESO released an assessment of LSSi performance[9] which indicates that 480 MW is currently contracted as part of LSSi program. However, there is some uncertainty about the availability of this product at all times. The AESO would mitigate this uncertainty through potential contracting of additional LSSi load of other potential supply sources, and development of alternative frequency mitigation products. There were no assumptions on any generator shedding services to be armed and tripped under high export controlled separation scenarios.

[9] http://www.aeso.ca/downloads/Review_of_Load_Shed_Service_for_Import_Product_Final.pdf

4.1.6 *Base cases and study scenarios*

Base cases were developed for 2014, 2017, and 2022 under summer light, summer peak and winter peak conditions to be used both by AESO and BC Hydro. The study years represent the existing, near term, and medium term planning horizons respectively.

The development of the base cases was done jointly between the AESO and BCH. BCH developed base cases for the BCH system and AESO integrated those along with latest Alberta system information in the agreed upon WECC base case.

Two sets of base cases were developed for year 2017. One set was prepared assuming that the Chapel Rock substation is in service and another set without Chapel Rock substation in service. Table 4.1-4 to Table 4.1-7 provide further details of each of the study cases. Note that in addition to the intertie flows and wind generation in Alberta, the study cases might be different with respect to generation scenarios ("BCH case name" column) in the BC Hydro system.

Table 4.1-4: 2014 Base Cases

Study Case	Load	BC-to-AB (MW)	BC-to-US (MW)	BCH case names	AIES wind	MT-to-AB (MW)	WECC reference case
y14c01	HW	1200	-1200	b14hw_p50d_HSI1_wecc	100%	300	14hw2ap
y14c02	HW	1200	-1200	b14hw_p50d_HSI1_wecc	75%	300	14hw2ap
y14c03	HW	1200	-1200	b14hw_p50d_HSI1_wecc	0	300	14hw2ap
y14c04	HS	1200	1200	b14hs_p50d_HSI2a_wecc	100%	300	14hsp1ap
y14c05	HS	1200	1200	b14hs_p50d_HSI2a_wecc	75%	300	14hsp1ap
y14c06	HS	1200	1200	b14hs_p50d_HSI2a_wecc	0	300	14hsp1ap
y14c07	HS	1200	1200	b14hs_p50d_MSI2a_wecc	100%	300	14hsp1ap
y14c08	HS	1200	1200	b14hs_p50d_MSI2a_wecc	75%	300	14hsp1ap
y14c09	HS	1200	1200	b14hs_p50d_MSI2a_wecc	0%	300	14hsp1ap
y14c10	HS	1200	-2400	b14hs_p50d_MSI3_wecc	75%	300	14hsp1ap
y14c11	HS	-1000	2000	b14hs_p50d_HSI4_wecc	100%	-325	14hsp1ap
y14c12	LS	-1000	-1000	b14ls_p50d_MSI5_wecc	100%	-325	14lw1ap

Table 4.1-5: 2017 Base Cases before Chapel Rock

Study Case	Load	BC-to-AB (MW)	BC-to-US (MW)	BCH case names	AIES wind	MT-to-AB (MW)	WECC reference case
y17c01	HW	1200	-1200	b17hw_p50d_HSI1_wecc	100%	300	17hw2ap
y17c02	HW	1200	-1200	b17hw_p50d_HSI1_wecc	75%	300	17hw2ap
y17c03	HW	1200	-1200	b17hw_p50d_HSI1_wecc	0	300	17hw2ap
y17c04	HS	1200	2000	b17hs_p50d_HSI2b_wecc	100%	300	17hs1ap
y17c05	HS	1200	2000	b17hs_p50d_HSI2b_wecc	75%	300	17hs1ap
y17c06	HS	1200	2000	b17hs_p50d_HSI2b_wecc	0	300	17hs1ap
y17c07	HS	1200	2000	b17hs_p50d_MSI2b_wecc	100%	300	17hs1ap
y17c08	HS	1200	2000	b17hs_p50d_MSI2b_wecc	75%	300	17hs1ap
y17c09	HS	1200	2000	b17hs_p50d_MSI2b_wecc	0%	300	17hs1ap
y17c10	HS	1200	-2400	b17hs_p50d_MSI3_wecc	75%	300	17hs1ap
y17c11	HS	-1000	2000	b17hs_p50d_HSI4_wecc	100%	-325	17hs1ap
y17c12	LS	-1000	-1000	b17ls_p50d_MSI5_wecc	100%	-325	17lw1asp

Table 4.1-6: 2017 Base Cases after Chapel Rock

Study Case	Load	BC-to-AB (MW)	BC-to-US (MW)	BCH case names	AIES wind	MT-to-AB (MW)	WECC reference case
y17c21	HW	1200	-1200	b17hw_p50d_HSI1_wecc	100%	300	17hw2ap
y17c22	HW	1200	-1200	b17hw_p50d_HSI1_wecc	75%	300	17hw2ap
y17c23	HW	1200	-1200	b17hw_p50d_HSI1_wecc	0	300	17hw2ap
y17c24	HS	1200	2000	b17hs_p50d_HSI2b_wecc	100%	300	17hs1ap
y17c25	HS	1200	2000	b17hs_p50d_HSI2b_wecc	75%	300	17hs1ap
y17c26	HS	1200	2000	b17hs_p50d_HSI2b_wecc	0	300	17hs1ap
y17c27	HS	1200	2000	b17hs_p50d_MSI2b_wecc	100%	300	17hs1ap
y17c28	HS	1200	2000	b17hs_p50d_MSI2b_wecc	75%	300	17hs1ap
y17c29	HS	1200	2000	b17hs_p50d_MSI2b_wecc	0%	300	17hs1ap
y17c30	HS	1200	-2400	b17hs_p50d_MSI3_wecc	75%	300	17hs1ap
y17c31	HS	-1000	2000	b17hs_p50d_HSI4_wecc	100%	-325	17hs1ap
y17c32	LS	-1000	-1000	b17ls_p50d_MSI5_wecc	100%	-325	17lw1asp

Table 4.1-7: 2022 Base Cases

Study Case	Load	BC-to-AB (MW)	BC-to-US (MW)	BCH case names	AIES wind	MT-to-AB (MW)	WECC reference case
y22c21	HW	1200	-1200	b22hw_p50d_HSI1_wecc	100%	300	22hw1a1p
y22c22	HW	1200	-1200	b22hw_p50d_HSI1_wecc	75%	300	22hw1a1p
y22c23	HW	1200	-1200	b22hw_p50d_HSI1_wecc	0	300	22hw1a1p
y22c24	HS	1200	2000	b22hs_p50d_HSI2b_wecc	100%	300	23hs1ap
y22c25	HS	1200	2000	b22hs_p50d_HSI2b_wecc	75%	300	23hs1ap
y22c26	HS	1200	2000	b22hs_p50d_HSI2b_wecc	0	300	23hs1ap
y22c27	HS	1200	2000	b22hs_p50d_MSI2b_wecc	100%	300	23hs1ap
y22c28	HS	1200	2000	b22hs_p50d_MSI2b_wecc	75%	300	23hs1ap
y22c29	HS	1200	2000	b22hs_p50d_MSI2b_wecc	0%	300	23hs1ap
y22c30	HS	1200	-2400	b22hs_p50d_MSI3_wecc	75%	300	23hs1ap
y22c31	HS	-1000	2000	b22hs_p50d_HSI4_wecc	100%	-325	23hs1ap
y22c32	LS	-1000	-1000	b22ls_p50d_MSI5_wecc	100%	-325	22lsp1sbp

Initial assessment of the study cases revealed that the following issues exist in the BCH and AIES systems under Category A conditions with 1200 MW import from BC.

- AIES issues and their solution assumptions:

In 2014 and under high wind and high import conditions, the existing Langdon to Janet lines (936L and 937L) will be overloaded under Category A conditions. To resolve these issues, in-service-dates for some of the transmission development such as FATD EAST project are assumed to be able to resolve the Category A issues. Therefore FATD EAST is modeled in 2014 cases. The actual in service date for the FATD-East project is 2015.

- BCH issues and their solution assumptions:

High flows from BC to Alberta overload the 138 kV transmission path from Natal to Pocaterra under certain scenarios. Flows above 800 MW potentially cause Category A overload on the 138 kV transmission line in BC as well as transformers at the Natal substation in the BC Hydro system under certain scenarios. To resolve this issue, BC Hydro suggested and the AESO has accepted that the 138 kV path to be initially opened in this study just as an assumption so that the focus would be on identifying possible issues on the higher voltage transmission system.

4.2 Contingency Analysis

A list of Category B and Category C5 contingencies was prepared by the AESO and BCH for their respective systems. The impact of contingencies was evaluated by load flow, voltage stability and dynamic stability analysis to ensure reliability criteria are met. If Category B load flow analysis showed that a scenario doesn't meet the reliability criteria, no further analysis was performed for that scenario before assuming any mitigation measure.

4.2.1 *Contingencies*

The following contingencies were assessed in the AESO's study:

- Individual outage of all 240 kV and 500 kV lines and select 138 kV transmission elements in the study area was considered for load flow analysis.

- The following outages in Alberta were considered for dynamic and voltage stability studies:
    - Janet to Langdon (1064L (2017 and 2022) and 936L in 2014)
    - Langdon to Chapel Rock (1235L in 2017 and 2022)
    - Foothills to Peigan/Windy Flats (1037L in 2017 and 2022)
    - Peigan to ENMAX No. 65 substation (911L in 2014)
    - Largest generator outage (typically Genesee 3 with 466 MW net to grid)
    - Langdon SVC
    - Chapel Rock SVC
    - AB-BC intertie (1201L/5L94, 786L/1L275, 887L/1L274)
    - AB-MT intertie (MATL)
    - AB-SK intertie (830L)
    - N-2 outage of Chapel Rock to Castle Rock Ridge (992L/1004L)
    - N-2 outage of Goose Lake to Fidler and Castle Rock Ridge (994L/1072L)
    - N-2 outage of Peigan to Goose Lake (955L/956L)
    - N-2 outage of Fidler to Castle Rock Ridge and Goose Lake (1071L/994L)
    - N-2 outage of Langdon to Janet lines (1064L/1065L (2017 and 2022) and 936L/937L in 2014)
    - N-2 outage of Foothills 240 kV to Windy flats 240 kV (1037L/1038L in 2017 and 2022)
    - Other contingencies

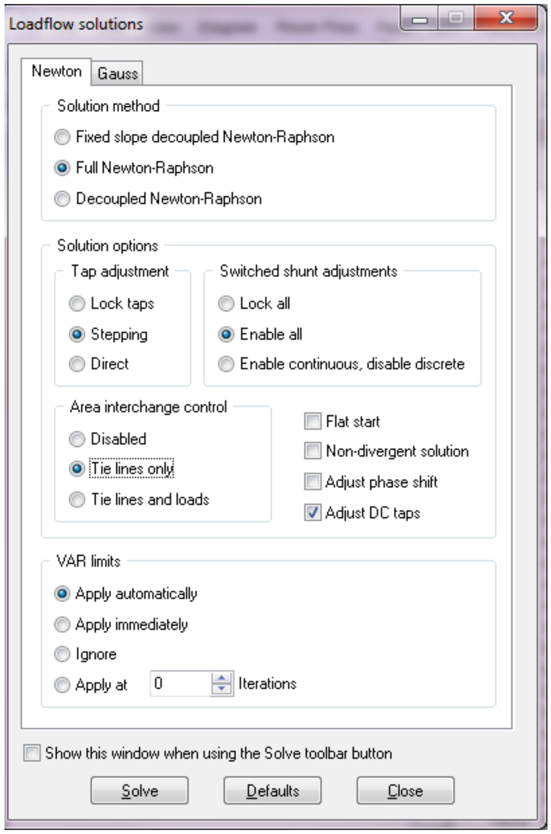
The above list was not applicable to all the study cases. For example an outage of the Langdon to Chapel Rock line is not applicable to the 2014 study scenarios because the in-service-date for the Chapel Rock substation is beyond 2014.

4.3 Details of Study Methodology

4.3.1 *Solution Parameters under Category A*

Under Category A conditions, the base cases are solved using the parameters shown in Figure 4-1.

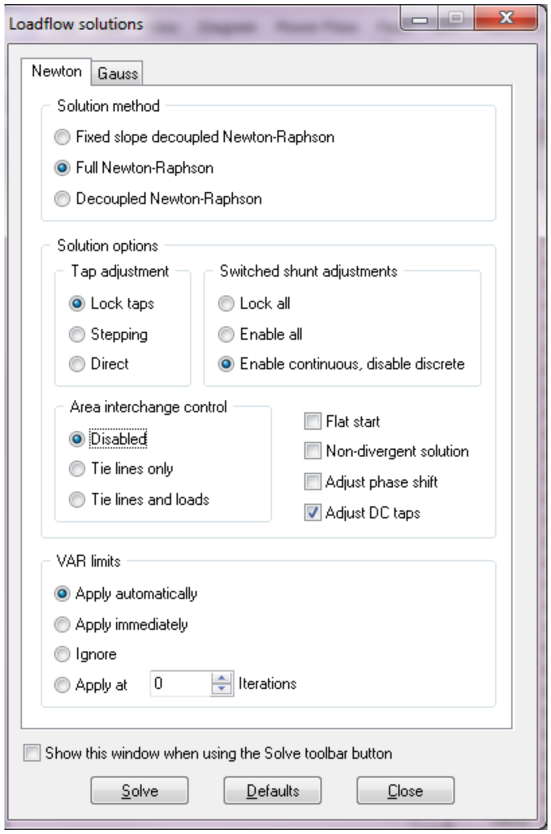
Figure 4-1: Solution Parameters for Category A condition



4.3.2 *Solution Parameters under Category B and C Contingencies*

The parameters shown in Figure 4-2 are used in the post-contingency solution in the contingency (ACCC) analysis. Some of the contingencies were also solved using other parameters to assess the impact of tap changer or manual shunt switching.

Figure 4-2: Solution Parameters for Category B and C conditions



4.3.3 *Generation Outage Simulation methodology*

A high level sensitivity assessment was done to evaluate the impact of different contingency solution methodologies on the study results especially with regards to generation outage studies. The following solution methods were tested in the sensitivity analysis:

- Typical contingency solution (as used for Category B and C contingencies),
- Typical contingency solution plus “Area interchange control” activated
- Inertial load flow
- Governor load flow

The conclusion of this assessment was that the typical contingency solution shown in Figure 4-2 will provide reasonably accurate results with regards to the objective of this study. Therefore the same parameters as defined for Category B and C contingencies will be used for generator outage assessment as well.

4.3.4 *Dynamic Simulation Methodology*

Three-phase to ground faults with normal clearing times were applied for Category B and C5 contingencies. The actual clearing times were used for the studies wherever possible. In case actual clearing times were not available, typical clearing times were considered in the dynamic simulations as per Table 4.3-1.

Table 4.3-1: Future Transmission Projects

Nominal	Near End	Far End
kV	**Cycles**	**Cycles**
500	4	5
240	5	6
138	6	8 / 30 [1]

[1] without telecommunication

4.3.5 *Voltage Stability (PV) Analysis Methodology*

To follow the AESO's planning criteria to assess the PV stability, the intertie flow was increased by 10% above the intertie capacity for Category B contingencies and 5% above the intertie capacity for Category C contingencies. If the load flow case solved following the contingency, it was assumed that PV margin criteria were met. Otherwise a PV curve was generated to calculate the PV margin which should be at least 5% for Category B and 2.5% for Category C contingencies as required in AESO's planning criteria. The interchange flow was adjusted by scaling the generation in northern Alberta and to compensate, the generation in southern California was adjusted as well.

4.4 Study Criteria and Standards

All the applicable criteria and standards were followed in this study. Specifically, the AESO's FAC-010-AB-2.1, "System Operation Limits Methodology for the Planning Horizon" and FAC-014-AB-2 were followed to ensure all the requirements are met. Details of the criteria and guidelines used in this study are discussed in this section. It includes criteria for facility rating, voltage range and deviation, dynamic stability, and frequency performance in AIES. Since a small portion of the BC Hydro system is also monitored in the AESO's study, certain criteria for the BC system is discussed as well.

4.4.1 *Thermal loading*

Under all contingencies (A, B, and C) the loading of transmission facilities should be below the normal rating (Rate A) in the planning studies. Note that in the 48 base cases created for this study, the "Rate A" corresponds to seasonal normal rating and is therefore different in winter and summer cases.

4.4.2 *Voltage range criteria*

Table 4.4-1 and Table 4.4-2 are developed based on AESO's planning criteria which defines an acceptable normal and emergency range for voltage across Alberta. In this study it is assumed that voltages are within normal range under category A conditions and within emergency range under contingency conditions.

Table 4.4-1: Category A voltage criteria

Nominal Voltage (kV)	Normal Minimum Voltage (kV)	Normal Maximum Voltage (kV)
500	500	525
240	234	252
260 *	247	266
144	137	151
138	135	145
72	68.5	75.5
69	65.5	72.5

* For 240 kV buses from Whitefish north and Sagitawah north

Table 4.4-2: Category B and C voltage criteria

Nominal Voltage (kV)	Emergency Minimum Voltage (kV)	Emergency Maximum Voltage (kV)
500	475	550
240	216	264
260 *	234	275
144	130	155
138	124	152
72	65	79
69	62	76

* For 240 kV buses from Whitefish north and Sagitawah north

Also as per the Alberta Reliability Standards, cascading outages are not acceptable. For example an outage of one generator should not cause the intertie to trip.

Under certain scenarios, bus voltages outside the ranges identified in the above tables could be acceptable. Those scenarios will be discussed and analyzed on a case by case basis.

4.4.3 *Voltage deviation criteria*

Table 4.4-3 shows the voltage and frequency swing criteria in the AIES which is the same as the WECC criteria. These criteria are applicable to all buses in the AIES. In this study it is assumed that the specified voltage performance criteria for "Post Transient" deviation should be achieved within a few minutes following the contingency without any manual action.

Table 4.4-3: Voltage and Frequency Swing Criteria

Contingency Category	Transient Voltage Dip	Minimum Transient Frequency	Post Transient Voltage Deviation
B	Not to exceed 25% at load bus and 30% at non-load bus Not to exceed 20% for more than 20 cycles	Not to go below 59.6 Hz for 6 cycles or more at load bus	Not to exceed 5% at any bus
C	Not to exceed 30% at any bus Not to exceed 20% for more than 40 cycles at load buses	Not to go below 59.0 Hz for 6 cycles or more at load bus	Not to exceed 10% at any bus

The AESO's planning criteria also provides voltage deviation criteria for the Point of Delivery (PODs) which are load busses at lower voltages. The criteria are shown in Table 4.4-4.

Table 4.4-4: Acceptable Post-Contingency Voltages

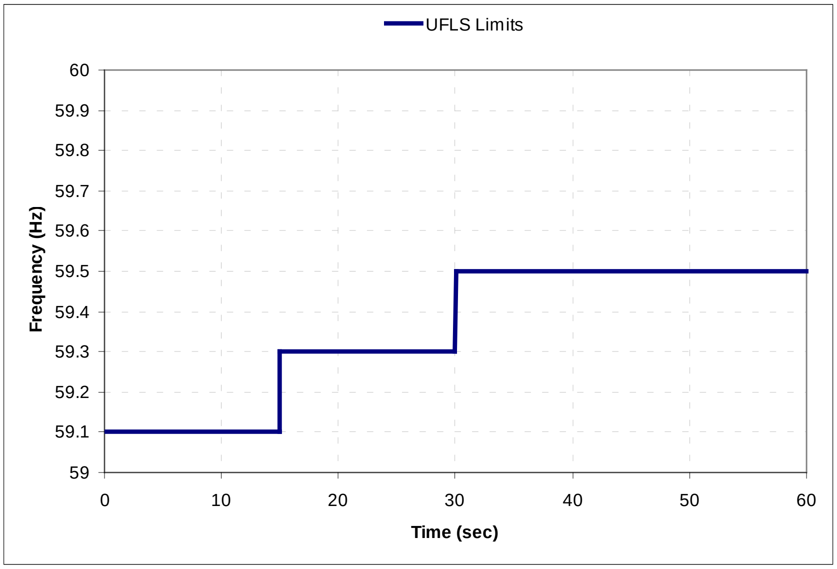
Parameter and Reference Point	**Time Period**		
	Post Transient (Up to 30 sec)	Post Auto Control (30 sec to 5 min)	Post Manual Control (Steady State)
Voltage Deviation from Steady State	± 10%	± 7%	± 5%

4.4.4 *Frequency Response Guideline*

In Alberta, the frequency criteria in Table 4.4-3 apply to all contingencies except for the intertie trip contingency. The frequency response guideline in this study is that following the intertie trip the frequency response should stay above the curve shown in Figure 4-3. The reason for adopting this guideline in this study is that if the frequency goes below the levels identified in the plot in Figure 4-3, a percentage of firm load will be shed according to the AESO's OPP 804 (Off-Nominal Frequency Load Shedding and Restoration). Therefore this guideline is adopted to prevent the shedding of the firm load.

The guideline used for over-frequency conditions is to ensure frequency doesn't go beyond 61 Hz for any time period.

Figure 4-3: Acceptable Frequency Range to Prevent Firm Load Shed



4.4.5 *Langdon and Chapel Rock SVC Guideline*

The Langdon SVC controls the Langdon 240 kV bus at 253 kV while its output is in the ±50 MVAr range under Category A conditions. Under stressed scenarios the scheduled voltage of Langdon SVC was adjusted so that under Category A condition the output stays in the ±50 MVAr range.

The voltage setpoint of the Chapel Rock SVC was also adjusted so that its output was in the ±50 MVAr range under Category A conditions. The fixed capacitor banks at Chapel Rock were used to help keep the SVC in the acceptable range.

The taps of the 500/240 kV transformers at Langdon and Chapel Rock were adjusted in the base cases to achieve acceptable voltage profile and SVC outputs. It should be noted that these transformers are not equipped with OLTC (on load tap changing) capability and therefor that tap settings should be adjusted when the transformers are offline. After running some test scenarios, the AESO is satisfied that this modeling of the transformers is acceptable.

4.4.6 *Dynamic Simulation Criteria*

A system dynamic response is considered to be acceptable if:

- No generator goes out of synchronism or trips
- No load trips due to under voltage or under frequency other than armed LSSi
- No intertie trips
- All the variables reach near steady state values within 20 seconds (no sustained or un-damped oscillations)

4.4.7 *Thermal loading criteria in BC system*

- Under Category A conditions the loading of transmission facilities should be below the normal rating (Rate A)
- Following Category B and C contingencies the loading of transmission facilities should be below the emergency rating (Rate B)

4.4.8 *Voltage range criteria in BC system*

Under Category A conditions it was assumed that the voltage should be between 0.95 pu and 1.05 pu. Under contingency conditions any voltage outside the 0.9 pu to 1.1 pu range was flagged and discussed with BCH.

4.4.9 *Voltage deviation criteria in BC system*

It was assumed that BC Hydro uses the same criteria as WECC for voltage deviation and frequency criteria[10].

Table 4.4-5: Voltage and Frequency Swing Criteria in BC system

Contingency Category	Transient Voltage Dip	Minimum Transient Frequency	Post Transient Voltage Deviation
B	Not to exceed 25% at load bus and 30% at non-load bus Not to exceed 20% for more than 20 cycles	Not to go below 59.6 Hz for 6 cycles or more at load bus	Not to exceed 5% at any bus
C	Not to exceed 30% at any bus Not to exceed 20% for more than 40 cycles at load buses	Not to go below 59.0 Hz for 6 cycles or more at load bus	Not to exceed 10% at any bus

[10] BCH has an internal exception for islanding conditions, minimum frequency 57.9 Hz.

5 Need Assessment

The purpose of the need assessment is to identify transmission constraints that limit the interchange between Alberta and BC to levels below the path rating. This analysis is based on the Alberta Reliability Standards, and tests the capacity, performance, and operability of the system under forecast future load, generation, and intertie flow conditions. The analysis identifies the time, location and type of criteria violations that are expected to occur and their implications.

The need assessment included a power flow analysis of the planned system under Category A, B, and C events, and dynamic stability study for selected contingencies, to assess the intertie capacity in the planning horizon. Category D events are studied for the annual WECC TPL compliance requirements and are not performed in this need evaluation. The power flow analysis was performed using the study scenarios outlined in Section 4.1.

5.1 Detailed Study Results

Detailed results of this need assessment studies are given in different appendices of the report. It includes all the power flow diagrams under normal and contingency conditions (Appendix A), detailed results of Category A, B, and C contingency analysis (Appendix B), and dynamic stability plots for 2 selected contingencies (loss of AB/BC tie, and Genesee 3 trip) (see Appendix C). Only a high level summary of results is presented in the body of the report to show how different conclusions are reached.

5.2 Import Capability before Chapel Rock

Contingency analysis of all the import scenarios in 2014 and 2017 without Chapel Rock (total of 20 study scenarios) indicated that system performance would not meet the reliability criteria under 1200 MW import for any of the studied scenario. The summary of the contingency analysis results is presented in Appendix B and power flow plots are shown in Appendix A.

To identify the limiting factors at different import levels, the import from BC was lowered and contingency analysis was performed on the case. Table 5.2-1 presents different levels of import at which different elements under different contingencies limit the import from BC based on N-1 power flow analysis. The results given in Table 5.2-1 are based on the most limiting system condition using the 2017 summer peak, full wind scenario (y17c04 scenario in Table 4.1-5); however, similar issues were observed for all other import scenarios before Chapel Rock coming into service.

Table 5.2-1: Limiting Elements before Chapel Rock Connection based on Power Flow Analysis[11]

Issue	Outage	Path 1 Import Limit	Total Path 1 + MATL
Overload on Bennett 500/240 kV Transformer	N-0	1190	1490
Path 1 trip due to low voltage at CBK	N-1 (Genesee 3)	1050	1350
Overload on 1201L (Bennett to BC)	N-1 (Genesee 3)	840	1140
Overload on Bennett Tx	N-1 (Genesee 3)	760	1060

Table 5.2-1 shows that for this specific scenario, the outage of fully dispatched Genesee 3 generating unit is the most critical contingency in Alberta before the Chapel Rock connection. A Genesee 3 outage overloads the Bennett transformer at 760 MW import, overloads 1201L at 840 MW import, and causes an intertie trip at 1050 MW import due to undervoltage at Cranbrook.

Analysis of other scenarios indicated that, although the import levels that cause overload might be slightly different, in general it is clear that there are many issues in the AIES that would not reliably allow 1200 MW import from BC.

Compiling the results of the contingency analysis for all the import scenarios with transmission topology before the Chapel Rock connection revealed that the followings criteria violations would limit the import to Alberta from BC before Chapel Rock based on Category A and B analysis:

- Overload on the Bennett 500/240 kV transformer (Page 3 in Appendix A)
- Overload on 1201L from Bennett to the BC border (Page 45 in Appendix A)
- Risk of intertie trip following large generator outages due to low voltage at Cranbrook (Page 10 in Appendix A)
- Lack of capability of the AIES to meet the AESO's frequency performance guidelines following an intertie trip. This is discussed in detail in Section 5.9.
- Overload issues on the Natal to Pocaterra 138 kV transmission path[12] in the BC system under Category A conditions (Page 882 in Appendix A)

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[11] The results are based on the most limiting system condition using the 2017 summer peak, full wind scenario (y17c04 scenario in Table 4.1-5).

[12] BC Hydro has indicated that they plan to continue with the current practice of opening the 138 kV tie when overload is expected or actually occurring as stated in the existing BCH system operating order for overload issues on the Natal to Pocaterra 138kV transmission path.

Due to the above issues, the import from BC will be limited to approximately 800 MW under certain scenarios before Chapel Rock as reflected in the AESO's Information Document (ID) (ID #2011-001R). Detailed study results are given in the Appendices. In the AESO's view, there are no practical mitigations to these issues which can be implemented before the expected in-service date of Chapel Rock project. In many cases, the only possible mitigation would essentially be the Chapel Rock project or equivalent equipment.

5.3 Export Capability before Chapel Rock

Compiling the results of the contingency analysis for all the export scenarios before the Chapel Rock connection revealed that the following criteria violations would limit the export to BC from AB before Chapel Rock connection:

- Overload on Bennett 500/240 kV transformer (on N-1 for loss of MATL, Page 143 in Appendix A)
- Overload on 1201L from Bennett to BC border (on N-1 for loss of MATL, Page 143 in Appendix A)
- Capability of the AIES to meet the AESO's frequency performance guidelines following an intertie trip. This is discussed in detail in Section 5.9.
- Overload issues on the Natal to Pocaterra 138 kV transmission path in BC system under Category A conditions[13] (Page 883 in Appendix A)

The critical contingencies with regards to AIES performance under export scenarios are the outage of MATL and the outage of Path 1. Detailed study results are given in the Appendices.

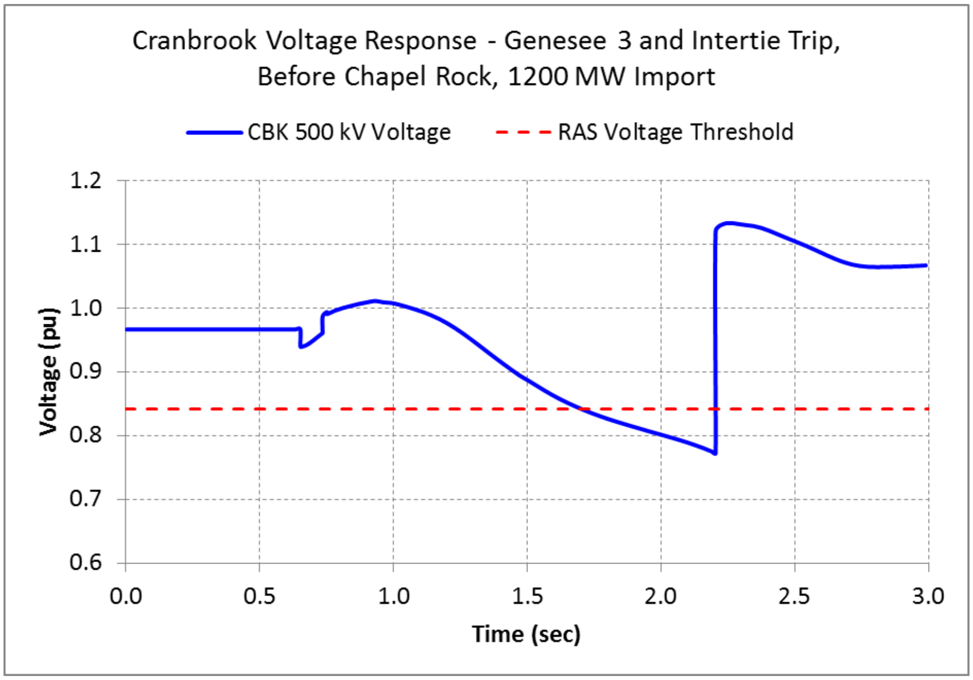
5.4 Voltage Issue at Cranbrook before Chapel Rock Under Import Conditions (Path 1 Trip due to Genesee 3 trip)

A RAS is currently in service at Cranbrook substation which trips the AB-BC intertie if the Cranbrook 500 kV bus voltage goes below 421 kV (0.842 pu) for more than 0.5 seconds. An outage of the fully dispatched Genesee 3 generator under high import conditions is the most critical outage in Alberta that results in a voltage drop at the Cranbrook bus. The dynamic response of the Cranbrook 500 kV bus voltage following a Genesee 3 trip due to a 3-phase fault on 500 kV side of the generator transformer is shown in Figure 5-1. As presented in the plot, the Cranbrook bus voltage goes below the threshold of 0.842 pu and therefore after 0.5 seconds

[13] BC Hydro has indicated that they plan to continue with the current practice of opening the 138kV tie when overload is expected or actually occurring as stated in the existing BCH system operating order 7T-17.

the intertie will trip due to RAS action. Such performance does not meet the requirements of the ARS (Alberta Reliability Standard) planning standards, which does not allow for subsequent outages due to a Category B contingency.

Figure 5-1: Intertie Trip following Genesee 3 outage before Chapel Rock[14]



5.5 Summary of Results and Conclusions before Chapel Rock

In summary, analysis of the study scenarios for the transmission configuration before the Chapel Rock connection shows the following:

- Overload on Bennett transformer and 1201L from Bennett to BC border are limiting factors for both import and export conditions. The 1201L overload is not a limiting factor in winter as the winter rating of 1201L is higher.
- The 138 kV transmission path from Natal to Pocaterra becomes overloaded under Category A conditions at high interchange levels[15].

[14] Page 2 of 3 in Appendix C

[15] BC Hydro has indicated that they plan to continue with the current practice of opening the tie when overload is expected or actually occurring as stated in the existing BCH system operating order 7T-17 for overload issues on the Natal to Pocaterra 138 kV transmission path.

- The subsequent trip of the intertie due to the outage of the largest Alberta unit (Genesee 3 with 466 MW net to grid) becomes a limiting factor at import levels higher than around 1000 MW. This occurs due to low voltage at Cranbrook.
- Frequency response does not meet the AESO Transmission System Planning Criteria and Guidelines following an intertie outage at maximum import or export conditions. This is discussed in detail in Section 5.9.

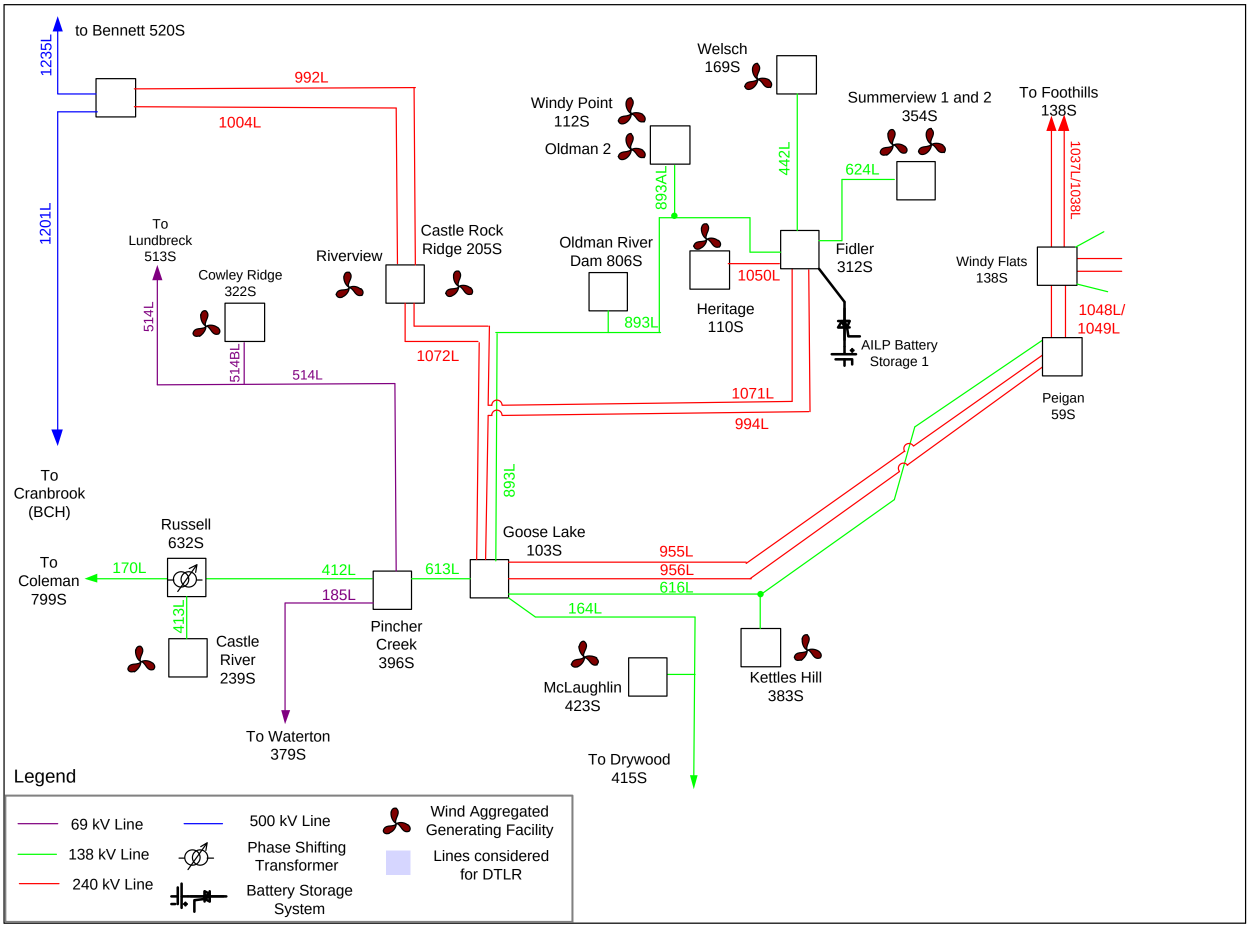
Given all the Category B contingency issues identified in load flow analysis of the system before Chapel Rock, no further studies such as Category C5 analysis, dynamic stability studies, or PV analysis were performed. Also since planned developments such as Chapel Rock will resolve most of the above issues, no mitigation measures were examined for the system before Chapel Rock. A detailed operational study will be conducted to determine the import/export capability of the system and potential increase of TTC in different scenarios before the Chapel Rock connection. Results of such operational studies will be reflected in AESO's Information Documents.

5.6 Import Capability after Chapel Rock

Pincher Creek is a major wind development area in Alberta. Figure 5-2 shows the schematic diagram of the transmission system in the Pincher Creek area after the Chapel Rock connection. Analysis of the study scenarios post Chapel Rock indicated that many of the issues identified before the Chapel Rock connection are resolved, mainly due to diversity of the transmission paths for import. As shown in Figure 5-2 after the Chapel Rock connection, part of the import from BC will flow on the 500 kV 1235L to Bennett and the rest will flow to Pincher Creek area through Chapel Rock.

Injection of part of the import to the Pincher Creek area will alleviate the overloads on 1235L and the Bennett transformer but at the same time may cause congestion on the Goose Lake to Windy Flats path under high wind scenarios. Analysis of the study scenarios show that as the wind level increases in the Pincher Creek area, more criteria violations occur in the area.

Figure 5-2: Pincher Creek Area Transmission System



In the following subsections different levels of import, wind conditions, and associated critical element and contingencies post Chapel Rock are discussed. It should be noted that these results are only based on overloads following Category B contingencies to obtain a high level assessment of the thermal issues under studied scenarios.

Note that the capabilities calculated in the following subsections are based on the assumption that the AIES would be able to withstand the simultaneous outage of both Path 1 and MATL. The validity of such an assumption will be discussed in Section 5.9 in this report.

A detailed analysis with the mitigation measures was performed to ensure all the reliability criteria are met. Details of the recommended mitigation measures and assessment of system performance with mitigation measures are discussed in Section 6.

5.6.1 *Import Capability after Chapel Rock – Winter Peak Load, No Wind*

The diagram in Figure 5-3 and the results in Table 5.6-1 show that under this scenario there are no limiting factors in the AIES to accommodate 1200 MW import from BC. The power flow diagrams on page 419 to 439 (year 2017) and 672 to 692 (year 2022) in Appendix A show the system performance under Category A, B, and C5 contingencies in this scenario. The power flow diagram for the contingency of a Genesee 3 outage on page 426 indicates that there are voltage issues in certain areas of the system. However dynamic stability analysis revealed that considering typical AIES generator responses, the bus voltages will return to a normal range and meet the criteria.

Figure 5-3: Path 1 Import Capability in Winter under No Wind Scenarios

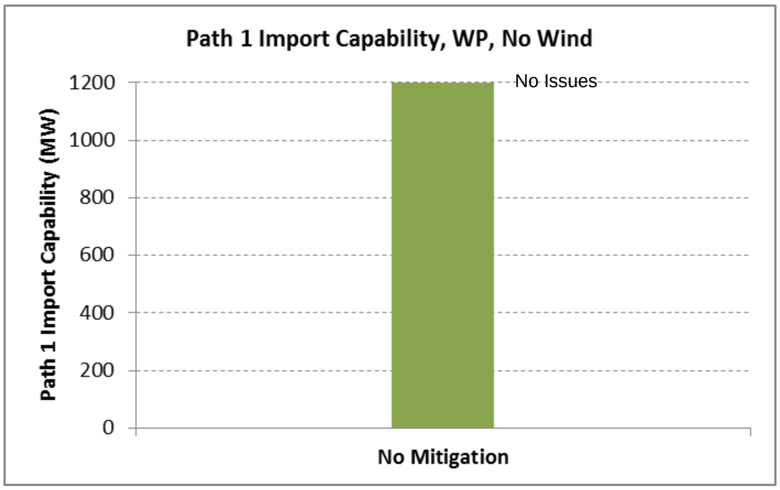


Table 5.6-1: Limiting Elements after Chapel Rock Connection (Winter, No Wind)

Issue	Contingency	Path 1 Import Limit	Total Path 1 + MATL
Overload on 956L (Peigan to Goose Lake)	N-1, 1235L	> 1200	> 1500
Overload on 1049L (Peigan to Windy Flats)	N-1, 1235L	> 1200	> 1500
Overload on 1072L (Goose Lake to CRR)	N-1, 1235L	> 1200	> 1500
Overload on 1201L (Chapel Rock to BC)	N-1, Genesee 3	> 1200	> 1500

5.6.2 *Import Capability after Chapel Rock – Summer Peak Load, No Wind*

The diagram in Figure 5-4 and the results in Table 5.6-2, based on 2022 cases, show that under the no wind condition in summer, the main limiting factor for import from BC is the overload on 1201L following a Genesee 3 outage. The import would be limited to 860 MW under this scenario.

Figure 5-4: Path 1 Import Capability in Summer under No Wind Scenarios

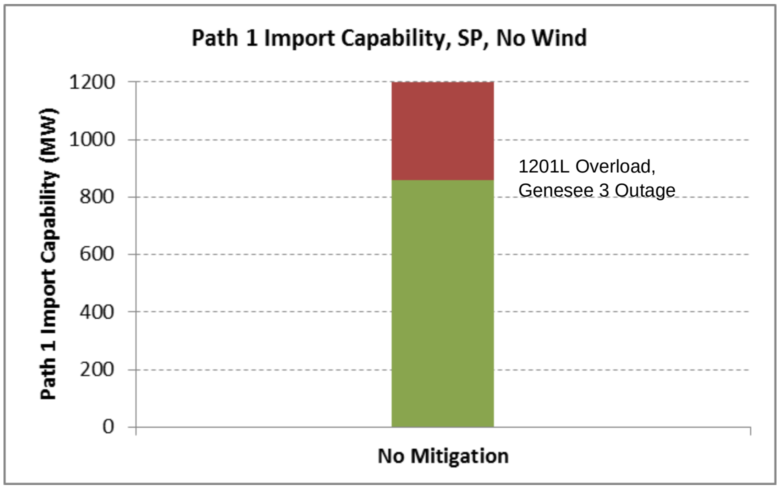


Table 5.6-2: Limiting Elements after Chapel Rock Connection (Summer, No Wind)

Issue	Contingency	Path 1 Import Limit	Total Path 1 + MATL
Overload on 956L (Peigan to Goose Lake)	N-1, 1235L	> 1200	> 1500
Overload on 1049L (Peigan to Windy Flats)	N-1, 1235L	> 1200	> 1500
Overload on 1072L (Goose Lake to CRR)	N-1, 1235L	> 1200	> 1500
Overload on 1201L (Chapel Rock to BC)	N-1, Genesee 3	860	1160

5.6.3 *Import Capability after Chapel Rock – Winter Peak Load , 1000 MW Wind in Pincher Creek*

The diagram in Figure 5-5 and the results in Table 5.6-3, based on both 2022 cases, show that with 1000 MW wind in the Pincher Creek area in winter, the main limiting factors for import from BC are the Peigan to Windy Flats 240 kV lines, the Bennett 500/240 kV transformer, and the Goose Lake to Castle Rock Ridge 240 kV line. As presented in Table 5.6-3, the most limiting condition that limits the import to around 700 MW is the overload on one of the Peigan to Windy Flats lines for the outage of the other.

Figure 5-5: Path 1 Import Capability in Winter under 1000MW Wind Scenarios

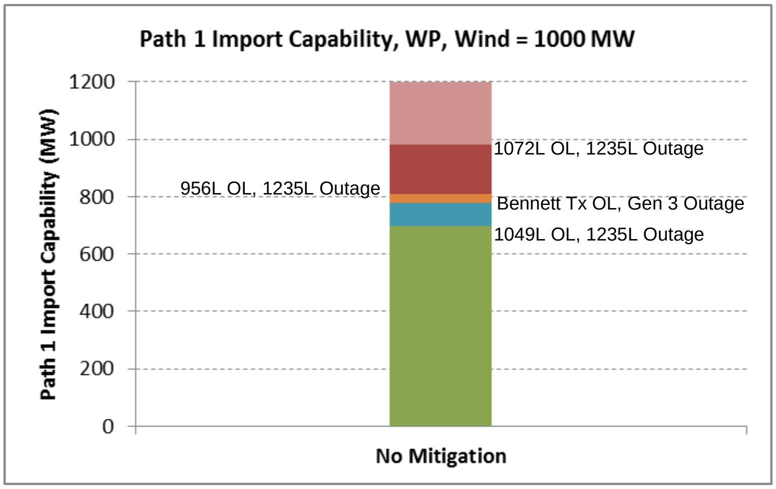


Table 5.6-3: Limiting Elements after Chapel Rock Connection (Winter, 1000 MW Wind)

Issue	Contingency	Path 1 Import Limit	Total Path 1 + MATL
Overload on 1072L (Goose Lake to CRR)	N-1 (1235L)	980	1280
Overload on 956L (Peigan to Goose Lake)	N-1 (1235L)	810	1110
Overload on Bennett Tx	N-1 (Genesee 3)	780	1080
Overload on 1049L (Peigan to Windy Flats)	N-1 (1235L)	700	1000

5.6.4 *Import Capability after Chapel Rock – Summer Peak Load, 1000 MW Wind in Pincher Creek*

The diagram Figure 5-6 and the results in Table 5.6-4, based on both 2022 cases, show that with 1000 MW wind in the Pincher Creek area in summer, the main limiting factors for import from BC are the Peigan to Windy Flats 240 kV lines, the Bennett 500/240 kV transformer, the Goose Lake to Castle Rock Ridge 240 kV line, and the 500 kV lines from the BC border to Bennett (1201L and 1235L). As presented in Table 5.6-4, the most limiting condition that limits the import to around 350 MW is the overload on one of the Peigan to Windy Flats lines for the outage of the other.

In addition to no wind and max wind scenarios, other wind generation levels were also analyzed to be able to create a capability nomogram. The nomograms showing the import capability of the AIES based on the results of a detailed Category A and Category B power flow analysis of the scenarios are shown in Figure 5-7 and Figure 5-8 for summer and winter respectively.

Figure 5-6: Path 1 Import Capability in Summer under Max Wind Scenarios

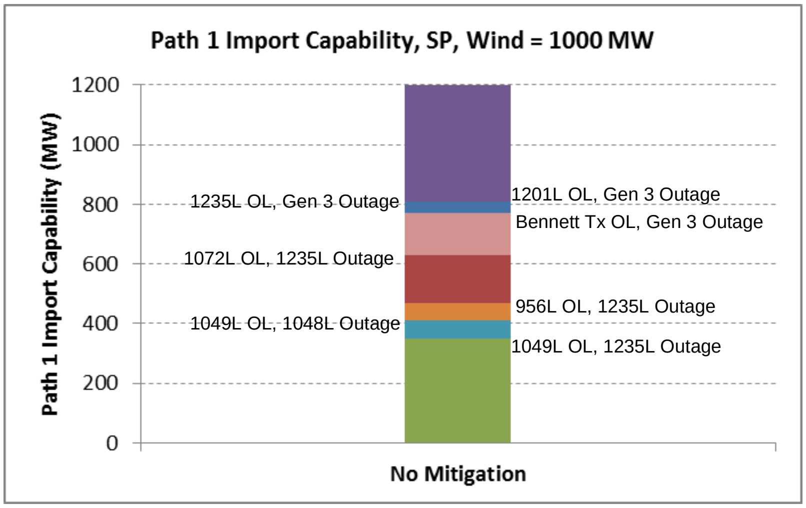


Table 5.6-4: Limiting Elements after Chapel Rock Connection (Summer, 1000 MW Wind)

Issue	Contingency	Path 1 Import Limit	Total Path 1 + MATL
Overload on 1201L (Chapel Rock to BC)	N-1 (Genesee 3)	820	1120
Overload on 1235L (Bennett to Chapel Rock)	N-1 (Genesee 3)	810	1110
Overload on Bennett Tx	N-1 (Genesee 3)	770	1070
Overload on 1072L (Goose Lake to CRR)	N-1 (1235L)	630	930
Overload on 956L (Peigan to Goose Lake)	N-1 (1235L)	470	770
Overload on 1049L (Peigan to Windy Flats)	N-1 (1048L)	410	710
Overload on 1049L (Peigan to Windy Flats)	N-1 (1235L)	350	650

All the criteria violations observed in the Category A and Category B power flow analysis of all the scenarios after the Chapel Rock connection could be summarized as follows. The criteria violations occur mostly under 1200 MW import and high/full wind scenarios:

- Overload on 1201L from Chapel Rock to BC border (Page 441 in Appendix A)
- Overload on Goose Lake to Windy Flats 240 kV lines (Page 449 in Appendix A)
- Overload on Goose Lake to Castle Rock Ridge line 240 kV (1072L) (Page 453 in Appendix A)
- Overload on 1235L from Chapel Rock to Bennett (Page 447 in Appendix A)
- Overload on Bennett 1200 MVA 500/240 kV transformer (Page 447 in Appendix A)
- Voltage issues at Cranbrook and southern Alberta (Page 453 in Appendix A)
- Overload issues on the Natal to Pocaterra 138 kV transmission path in the BC system under Category A conditions

The mitigation measures are discussed in the Section 6.

Figure 5-7: Path 1 Import Capability vs Pincher Creek Wind in Summer

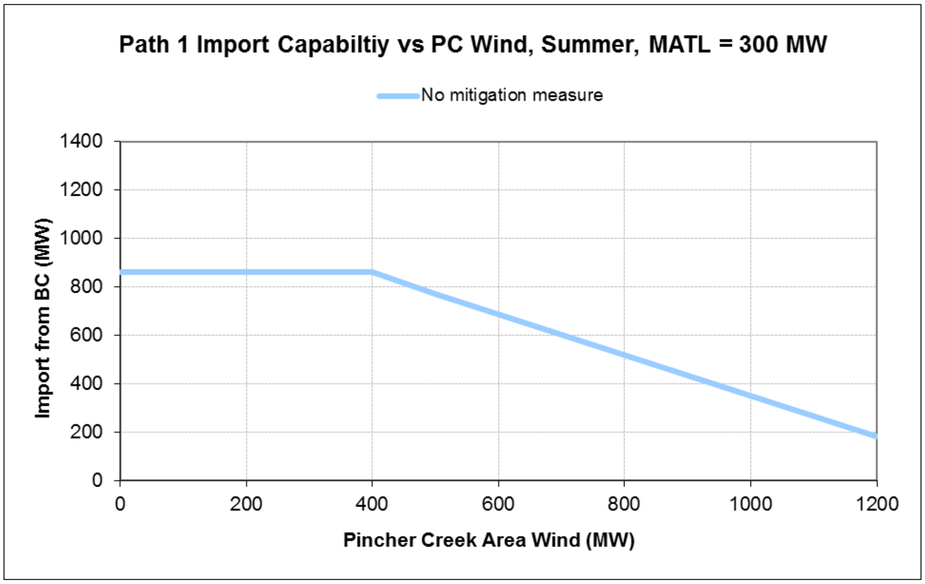
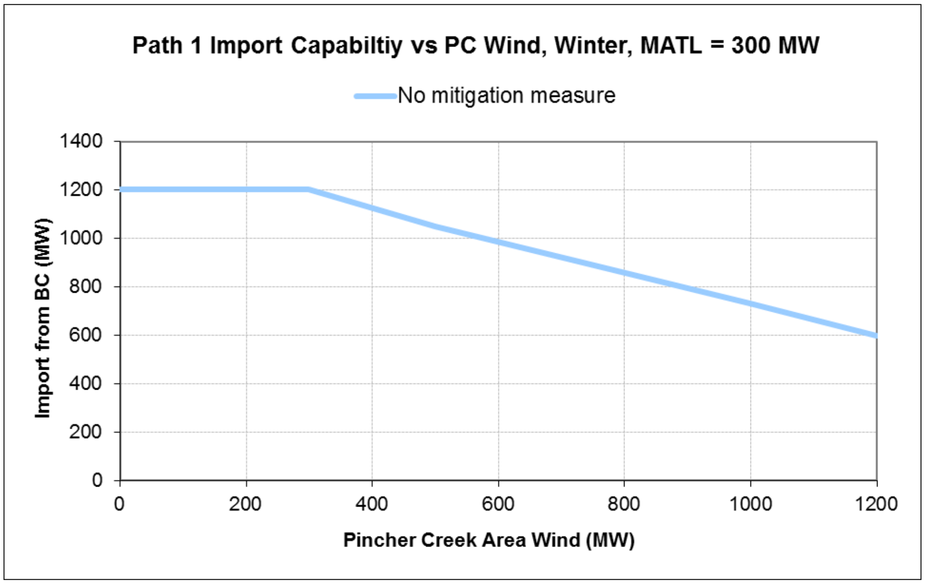


Figure 5-8: Path 1 Import Capability vs Pincher Creek Wind in Winter



5.7 Export Capability after Chapel Rock

The study shows that Chapel Rock connection will alleviate overload on Bennett 500/240 kV transformer under N-1. However following issues still remain under high export conditions after Chapel Rock connection:

- Overload on 1201L from Chapel Rock to BC border (on N-1 for loss of MATL, page 616 in Appendix A)
- Capability of the AIES to meet the AESO's frequency performance guidelines following an intertie trip. This is discussed in detail in Section 5.9.
- Overload issues on the Natal to Pocaterra 138 kV transmission path in BC system under Category A conditions[16] (Page 1045 in Appendix A)

The critical contingencies with regards to AIES performance under export scenarios after Chapel Rock connection are still the outage of MATL and the outage of Path 1. Detailed study results are given in the Appendices.

5.8 Comparison of Capability and the Anticipated Flows

To assess the need for any reinforcement or mitigation measures, the AIES capability for simultaneous wind and import was compared against the forecast wind and import. An hourly generation and intertie dispatch for year 2022 was obtained from the AESO's forecasting group based on an analysis of the 2012LTO. The assumption in developing the 2012LTO is based on a typical hydro year in BC and US. If the hydro generation is different from an average year it will have an impact on the forecast data. In this analysis it was assumed that 50% of wind generation in Alberta is coming from the wind farms in the Pincher Creek area. It is also assumed that 480 MW LSSi is armed and there are no frequency issues following the intertie outage (Frequency issues are discussed in Section 5.9).

Each dot in Figure 5-9 and Figure 5-10 represents one hour in which Alberta is importing from BC and the corresponding wind generation in the Pincher Creek area. As shown in Figure 5-9 and Figure 5-10 there are many hours in which the simultaneous high-wind and high intertie flow are beyond the import capability of the AIES. The percentage of hours that the anticipated wind and import could be accommodated is around 70% in summer and around 98% in winter. While there are no issues for the majority of hours in winter, the import will be constrained for approximately 30% of the time in summer.

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[16] BCH indicated that they plan to continue with the current practice of opening the tie when overload is expected or actually occurring as stated in the existing BCH system operating order 7T-17 for overload issues on the Natal to Pocaterra 138 kV transmission path.

Figure 5-9: Summer Import Capability vs Anticipated Wind and Import

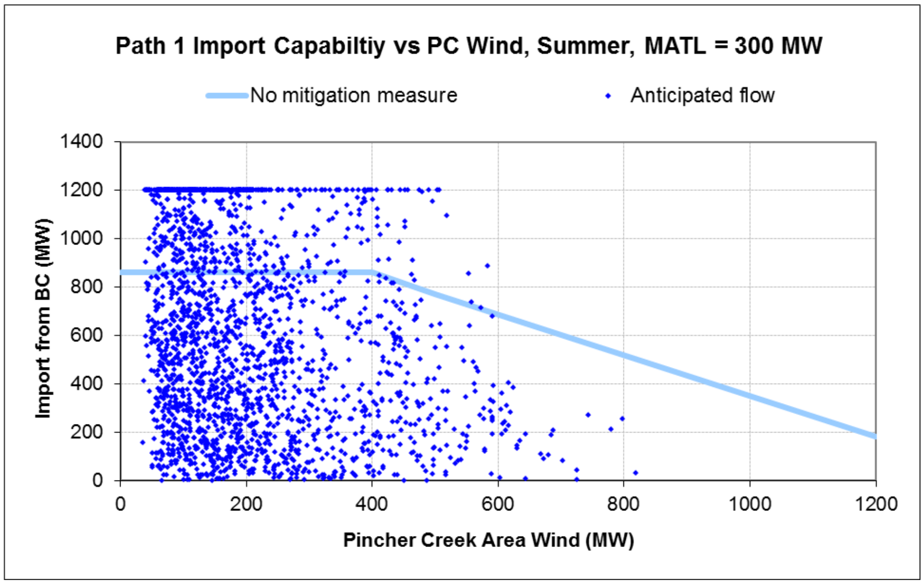
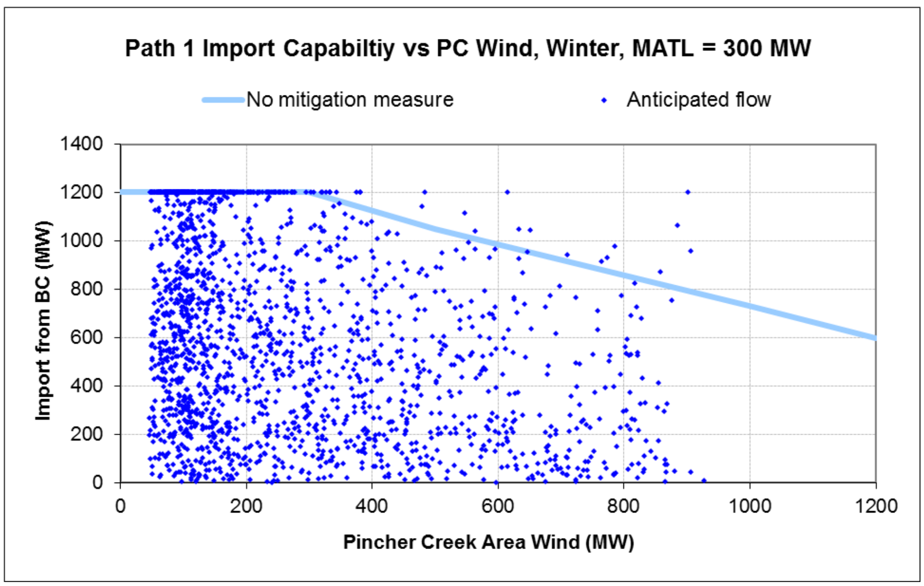


Figure 5-10: Winter Import Capability vs Anticipated Wind and Import



5.9 AIES Frequency Assessment following Intertie Outage

As discussed in Section 5.6, the capability plots shown in Figure 5-7 and Figure 5-8 are developed based on criteria related to facility rating and voltage limits for all the contingencies in the area except for an intertie outage. The main concern regarding an intertie outage is the capability of the AIES to maintain frequency within an acceptable range for both under frequency and over frequency conditions. Acceptable performance for an import trip resulting in under frequency is that no firm load is shed. Acceptable performance for an export trip resulting in over frequency does not exceed 61.0 Hz.

The under frequency response of the AIES is based on:

- Total AIES generator response to the low frequency conditions
- Alberta load response to the low frequency conditions
- Tripping of the armed LSSi following the import trip

The over frequency response of the AIES is based on

- Total AIES generator response to the high frequency conditions
- Alberta load response to the high frequency conditions
- Tripping of Armed GSSe following the export trip[17]

The maximum capability of the AIES to maintain an acceptable frequency response following a Path 1 and MATL outage is around 1200 MW total import and 1000 MW total export and can only occur under high generator response (no GSSe is assumed) and assuming 480 MW armed LSSi.

Based on the existing (2014) intertie configuration, the outage of the AB-BC path will unconditionally trip Path 83 (MATL) through a direct transfer trip (DTT) scheme. As a result, if Alberta is importing 1200 MW from BC and 300 MW from MATL (total of 1500 MW import on Path 1 and MATL) an outage of 1201L and subsequent outage of MATL will cause a supply shortage of 1500 MW in Alberta. Under this scenario, and without any reinforcement or mitigation measure, the frequency will drop below the load-shedding threshold levels and where load shedding occurs. If the objective was to accommodate a simultaneous maximum import on both ac ties (1500 MW combined), further mitigation measures beyond 480 MW LSSi need to be implemented to maintain acceptable frequency response in the AIES following the intertie trip.

Figure 5-11 shows the frequency response of the AIES under an extreme test condition of losing both Path 1 and MATL with total import of 1500 MW. In this example, typical load response, generation response, and 480 MW armed LSSi is assumed. Comparison of the plot in Figure 5-11 with the frequency response criteria indicates that firm load shedding has occurred at around 6 second, when the frequency reached 59.1 Hz which causes an instantaneous trip of the first block of under frequency load shed.

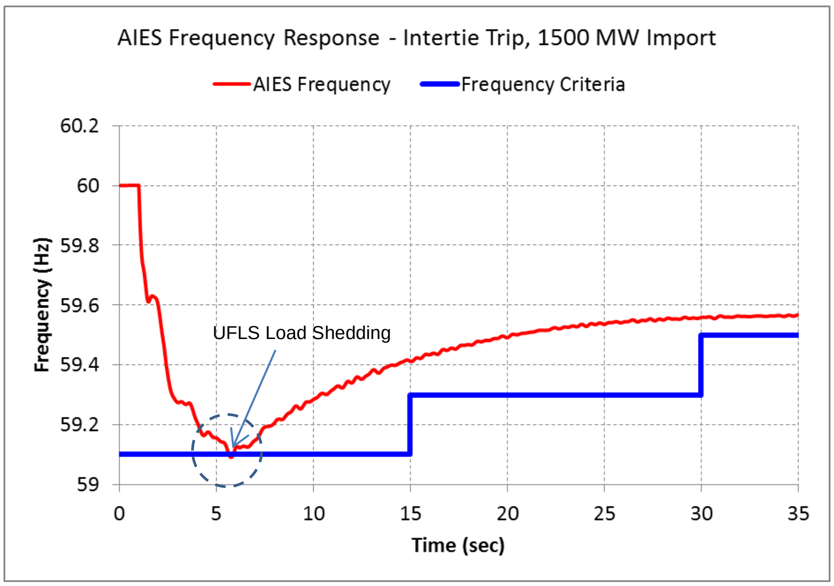
[17] There is currently no generation shedding service for export (GSSe) in Alberta.

The frequency issue exists under export scenarios as well. However unlike the import scenarios in which LSSi would help to increase the import capability, no similar measure such as GRAS has been currently implemented in Alberta and was not assumed for export scenarios. AIES frequency response following the trip of Path and MATL with around 1300 MW total export from Alberta, based on a heavy summer load case, is presented Figure 5-12. The analysis indicated that the frequency transiently goes beyond the 61.0Hz maximum limit set in Section 8.12 of AESO Transmission System Planning Criteria and Guidelines.

Study results presented on page 123 in Appendix F indicates that the AIES has the capability to control the frequency within an acceptable range following an intertie outage under 1000 MW combined export on Path 1 and MATL. Therefore mitigation measures need to be implemented if more than 1000 MW combined export on the ac interties is to be considered.

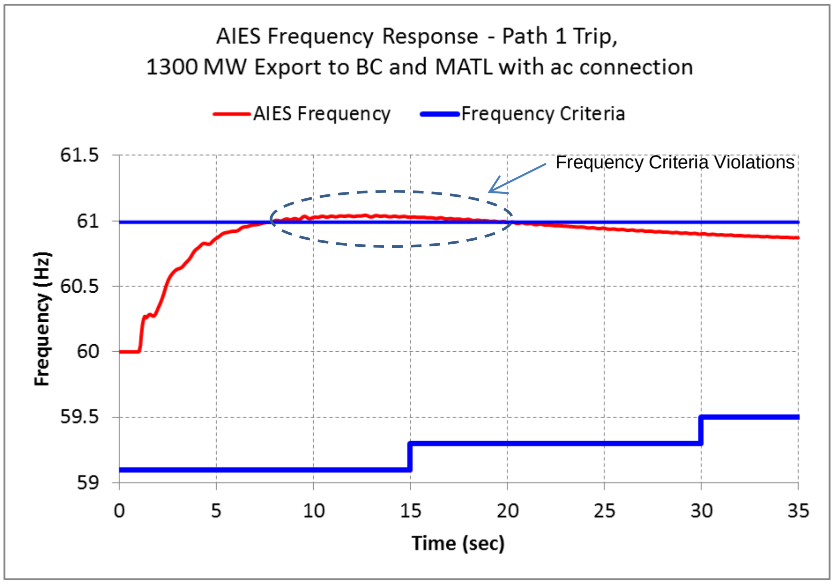
Dynamic plots for the need assessment analysis are presented in Appendix C.

Figure 5-11: Firm Load Shed due to Lack of Sufficient Generator Response and LSSi[18]



[18] Case y17c04 was used for this analysis.

Figure 5-12: Frequency Response - Intertie Trip with 1300 MW total Export[19]



5.10 Need Assessment Summary

The results of the need assessment analysis are summarized as follows:

1- The AESO's analysis of the Joint study scenarios shows that before the Chapel Rock project, for both import and export, there would be criteria violation in the AIES should Path 1 operate at its full WECC path rating (see Sections 5.6 and 5.7).

2- The capability of the transmission system in Alberta even with Chapel Rock is not sufficient to accommodate the forecast of simultaneous wind and import levels. The main issues are on two transmission paths:
   - o Goose Lake to Windy Flats 240 kV lines. An outage of one line will overload the other line. Also an outage of 1235L will overload both of the lines.
   - o In summer months, 1201L is a limiting factor for both imports and exports.

3- The maximum capability of the AIES to maintain an acceptable frequency response following a simultaneous Path 1 and MATL outage is 1200 MW combined import on Path 1 and MATL and 1000 MW combined export on Path 1 and MATL. Total combined import of 1200 MW on Path and MATL can only occur under typical generator

[19] Case y22c31 was used for this analysis.

response[20] and 480 MW armed LSSi. Total combined export of 1000 MW on Path 1 and MATL can only occur under typical generator response. Lower levels of generator response or LSSi volumes would decrease import capability to below 1200 MW.

4- Overloads on 1201L, the Bennett transformer, and the Natal to Pocaterra 138 kV transmission path are the only issues observed in the export scenarios before Chapel Rock with regards to facility ratings, voltage limits, and frequency stability limits. Overloads on 1201L and the Natal to Pocaterra 138 kV transmission path issues still remain under high export conditions after Chapel Rock connection

5- Import levels beyond approximately 800 MW from BC will cause an overload on the Natal to Pocaterra 138 kV transmission path under Category A conditions for certain scenarios. BCH plans to continue with the current practice of opening 1L274/887L at Pocaterra and 1L275L/786L at Natal to mitigate overload or expected overload on the 138kV transmission path, as per BCH Operating Order 7T-17.

[20] Approximate 90 to 100 MW/0.1Hz of generation bias is assumed in this study

6 Development and Analysis of Mitigation Measures

Mitigation measures were formulated with consideration to the type of issues observed in the near term and the long term.

The basic guidelines adopted in devising the mitigation measures include:

- Rebuild existing facilities to higher capacities.
- Build new facilities to alleviate existing constraints.
- Add reactive power support devices to improve system voltages.
- Utilize commercially available technology to increase the capacity of the existing system
- Prepare the order of magnitude (OOM) cost estimates for the mitigation measures. The AESO's OOM cost estimates are prepared on a +100/-50% basis

This section summarizes possible mitigation measures for each of the constraints.

6.1 FATD and SATR Projects

The following transmission projects have a major role in enabling the restoration of the AB-BC intertie:

- The FATD – East project is under construction and will remove the congestion on the transmission path from Langdon to Calgary. The in-service date for the FATD-East project is 2015.
- The NID for Chapel Rock substation and Chapel Rock to CRR 240 kV lines was approved as part of the SATR project. The transmission facility owner is in the process of preparing the Facility Application (FA) for these components of the SATR project. The anticipated in-service date for these projects is 2018.
- The NID for the 240 kV lines from Windy Flats to the Foothills substations was approved as part of SATR project. This project is under construction with in-service date of 2015

6.2 1201L from Chapel Rock to the BC border

The current thermal rating of 1201L is 1222 MVA in summer and 2474 MVA in winter. The summer rating of the line is the limiting factor for intertie restoration. The AESO has initiated discussions with the transmission facility owner (AltaLink) to identify the issues and formulate possible solutions to increase the summer thermal rating. The analysis has now been completed and evaluation is being performed on the next steps required. One possible outcome of this analysis would be to re-conductor or re-build 1201L from Chapel Rock to the BC border.

6.3 Goose Lake to Windy Flats path

This path consists of Goose Lake to Peigan (955L/956L) and Peigan to Windy Flats (1048L/1049L) 240 kV lines. These lines are relatively new with summer/winter ratings of 611/751 MVA. Results of the need assessment indicate that a 20% increase in the rating of these lines would be sufficient to accommodate the anticipated flows up to year 2022. Also the higher capacity would be required only when the BC imports and the wind generation in the Pincher Creek area are high. Since these lines are in the Pincher Creek area, it is expected that utilizing a Dynamic Thermal Line Rating (DTLR) technology would provide higher ratings on these lines when they are needed.

The AESO has initiated a project to implement DTLR technology on these lines as soon as possible. Early installation of DTLR would allow for monitoring and proper assessment of the increase in the line ratings under high wind scenarios that may be possible utilizing the DTLR technology.

Although the assumption is that DTLR increases the rating of the Goose Lake to Windy Flats lines, these lines still may be overloaded following the outage of 1235L under high import and wind conditions as presented in Table 5.6-1 to Table 5.6-4. The reason is that following the outage of 1235L, almost all the import, plus the wind generation in the Pincher Creek area, need to be transferred through the Goose Lake to Windy Flats lines and will overload the lines. This issue could be resolved by a RAS that trips the AB-BC intertie following the outage of 1235L under high import and wind scenarios. Further studies will determine at what level of wind and imports the RAS is required to be armed.

The AESO would consider other mitigation measures such as re-conductoring the Goose Lake to Windy Flats lines with high temperature conductor if the rating of Goose Lake to Windy Flats lines after implementation of DTLR and the RAS is not sufficient to accommodate the anticipated wind and import.

6.4 Frequency Control following a Controlled Separation of the Interties

This study has indicated that frequency mitigation measures will be required for high import or high export transfers on the interties. Assuming high Alberta load, high generator response, and 480 MW armed LSSi, the maximum capability of the AIES to maintain acceptable frequency response following a Path 1 and MATL outage is 1200 MW total import. However assuming that both Path 1 and MATL are simultaneously loaded to their WECC path ratings, the AIES will be importing a total of 1500 MW on these paths and therefore there will be frequency issues and risk of firm load shed following controlled separation of interties. The following mitigation measures will be evaluated to control the frequency:

- Increase LSSi

- Increase AIES total generators response by increasing spinning reserve
- Install a back to back HVDC converter on MATL

Currently the total export capability of the AIES to BC and MATL could reach 1000 MW under typical generator response and around 8000 MW Alberta load from an islanding frequency perspective. However if both Path 1 and MATL are operating at their maximum rating, AIES will be exporting a total of around 1300 MW on these paths and therefore will be subject to frequency issues following controlled separation of the interties. The following mitigation measures will be evaluated to control the frequency:

- Introduce GSSe (Generation Shedding Service for export). Currently GSSe does not exist in Alberta
- Increase AIES total generators response
- Install a back to back HVDC converter on MATL line

Installing a back to back HVDC converter on MATL would be an effective option to help to resolve frequency issues following the intertie trip in both the high import and high export scenarios.

6.5 Transmission path from Natal to Pocaterra

The Natal to Pocaterra transmission path will be overloaded under Category A condition for high interchange levels. In this study the 887L from Pocaterra to BC was switched off as per recommendations from BC Hydro to resolve the Category A issue on the 138 kV path from Natal to Pocaterra so that the focus would be on higher voltage transmission issues. This is consistent with the present BCH operation practice described in BCH System Operating Order 7T-17.

6.6 Mitigation Measures Cost Estimates

The following high level cost estimates are based on internal AESO evaluations and are an order of magnitude (OOM) level (+100/-50%) estimate at this stage. Following the selection of the mitigation measures, more accurate cost estimates will be provided by corresponding transmission facility owner.

Table 6.4-1: Cost Estimates for Mitigation Measures

Issue	Mitigation Measure Alternatives	OOM Cost Estimate (+100/-50%)
Overload on 1201L	Re-build 1201L (assuming 20 km)	$65M
	Re-conductor 1201L (assuming 20 km)	$26M
Overload on Goose Lake to Windy Flats lines	DTLR on Goose Lake to Windy Flats lines and RAS to trip the tie for 1235L outage	$1.5M
	Re-conductor Goose Lake to Windy Flats lines with high temperature conductor and RAS to trip the tie for 1235L outage	$37M
Overload on Natal to Pocaterra path	BCH has indicated that they plan to continue the present practice of opening the 138kV tie as described in bch SOO 7T-17.	NA
Frequency issues	MATL HVDC (300 MW rating) - reduces maximum controlled separation to loss of Path 1	$150M
	Additional 300 MW LSSi	$93M per year
	300 MW GSSe	TBD
	Increase spinning reserve	TBD

6.7 Analysis of System with all Recommended Mitigation Measures

Load flow, voltage stability (PV), and dynamic stability analysis were carried out to ensure that AIES and CBK meet all performance criteria under all relevant contingencies (Category A, B, C5) with the Chapel Rock connection and with the mitigation measures implemented. Study scenarios and study results are discussed in the following sections.

6.7.1 Study Scenarios

New study scenarios were developed based on import/export and wind levels at which the system meets the reliability and performance criteria. Study scenarios considered for analysis of the system with mitigation measures are listed in Table 6.7-1. A comprehensive analysis was performed on these study scenarios.

Table 6.7-1: Study Scenarios for Mitigation Measure Assessment[21]

Study Scenarios	Load	Path 1 flow into AB (MW)	Wind in Pincher Creek (MW)	MATL flow (MW)
MMA_sc1	HS	1200	0	300
MMA_sc2	HS	1200	300 [1]	300
MMA_sc3	HS	1050	500	300
MMA_sc4	HS	730	1000	300

[21] This new set of base cases with mitigation measures was developed from 24 post Chapel Rock cases listed in Section 4.

MMA_sc5	HW	1200	0	300
MMA_sc6	HW	1200	300	300
MMA_sc7	HW	1050	500	300
MMA_sc8	HW	730	1000	300
MMA_sc9	HS	-1000	1000	-325

[1] Wind and Import levels in base cases might be slightly different from what presented in this table

6.7.2 Study Assumptions

The study assumptions are as follows:

- All the issues in Table 6.4-1 have been mitigated.
- MATL HVDC has modulation capability that could increase the flow for certain outages such as a Genesee 3 trip.
- The overload issue on the Natal to Pocaterra 138 kV path in BC is resolved by opening the line under high interchange levels

6.7.3 Load Flow Analysis

Results of detailed load flow analysis under different contingency conditions for the study scenarios listed in Table 6.7-1 are discussed in the following sections.

6.7.3.1 Category A Analysis

Line loading and critical bus voltages under Category A conditions are given in Table 6.7-2 and Table 6.7-3 respectively. Output of Langdon and Chapel Rock SVCs are kept close to ± 50 Mvar. The power flow single line diagrams for N-0 conditions for all the study scenarios are given in Appendix D. No issues were identified in the study scenarios under N-0 conditions.

Table 6.7-2: Category A Thermal loading (over 90 % of ratings)

Issue	Outage	Case file	Observed Thermal Loading (%)	Observed Loading MVA	Rating (MVA)
None					

Table 6.7-3: Category A Voltage Violations

Bus and Substation	Contingency	Case file	Max of V observed	Max of V initial	V max (pu)	V min (pu)
None						

6.7.3.2 Category B Analysis

Line loading and bus voltages under Category B conditions are given in Table 6.7-4 and Table 6.7-5 respectively. Study results indicate that the Category B outages of concern are the following:

- 1235L from Chapel Rock to Bennett 500 kV line
- Genesee 3 dispatched at 466 MW net to grid
- Any of the 240 kV lines from Goose Lake to Windy Flats

Considering the above outages, the concerned line loadings and bus voltages are the following:

- Any of the 240 kV lines from Goose Lake to Windy Flats
- Cranbrook 500 kV bus voltage

The power flow single line diagrams for Category B conditions for all the study scenarios and outages are given in Appendix D.

Table 6.7-4: Category B Thermal Loadings in Year 2022 (Loading above 90% of Rating)

Monitored Element	Outage	Case file	Observed Thermal Loading (%)	Rating (MVA)
1235L Bennett to Chapel Rock	GENESEE #3	MMA_sc2	99	1222
		MMA_sc3	97	1222
		MMA_sc4	95	1222
Bennett Transformer	GENESEE #3	MMA_sc2	100	1200
		MMA_sc3	100	1200
		MMA_sc4	99	1200
		MMA_sc6	100	1200
		MMA_sc7	100	1200
		MMA_sc8	100	1200
1201L Chapel Rock to BC border	GENESEE #3	MMA_sc1	90	1777 [1]
		MMA_sc2	96	1777

[1] It is assumed that following the implementation of the mitigation measures, the rating of 1201L from Chapel Rock to the BC border is similar to the rating of the line on the BC side

Table 6.7-5: Category B Voltage Violations

Bus and Substation	Contingency	Case file	Max of V observed	Max of V initial	V max (pu)	V min (pu)
None						

6.7.3.3 Category C5 Analysis

Maximum line loading and bus voltages under Category C5 conditions are given in Table 6.7-6 and Table 6.7-7. The power flow single line diagrams for Category C5 conditions for all the study scenarios and critical outages are given in Appendix D. As shown in Table 6.7-6 and Table 6.7-7 the Category C5 outages are on the transmission path from Chapel Rock to Goose Lake, Windy Flats, and Foothills substations which are highlighted in Figure 6-1. Criteria violations following the double outages are given in Table 6.7-6 which shows severe overload and voltage issues. However since these issues are caused by Category C contingencies, load and generation shedding could be considered as mitigation measures under the AESO's planning criteria.

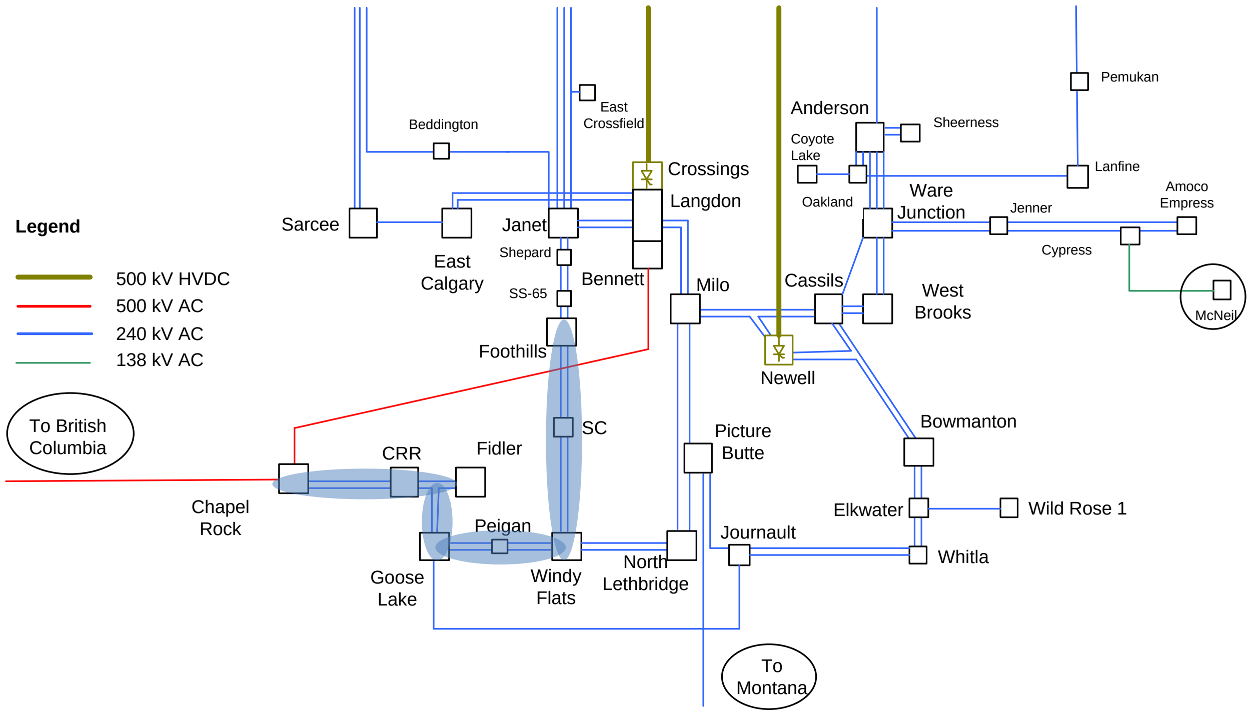
Table 6.7-6: Category C5 Thermal Loading (Over 100% of Normal Rating)

Overload Element	Outage	Case file	Observed Thermal Loading (%)	Rating (MVA)
1048L/1049L Peigan to Windy Flats	Bennett Transformer	MMA_sc8	128	1200
	1235L Bennett to Chapel Rock	MMA_sc4	122	1222
955L/956L Goose Lake to Peigan	Bennett Transformer	MMA_sc8	112	1200
	1235L Bennett to Chapel Rock	MMA_sc4	104	1222
	Peigan 240/138 kV Transformer	MMA_sc4	130	200
	138 kV 616L Peigan to Goose Lake	MMA_sc4	221	119
	138 kV 616L Peigan to Goose Lake	MMA_sc1	120	119
1071L/1072L CRR to Fidler and Goose Lake	Bennett Transformer	MMA_sc2	102	1200
	138 kV 170L Coleman to Russell	MMA_sc9	106	121
	138 kV 786L Coleman to Natal	MMA_sc9	122	99
1004L/992L Chapel Rock to Castle Rock Ridge	138 kV 170L Coleman to Russell	MMA_sc9	118	121
	138 kV 786L Coleman to Natal	MMA_sc9	137	99
1037L/1038L Foothills to Windy Flats	Bennett Transformer	MMA_sc4	114	1200
	1235L Bennett to Chapel Rock	MMA_sc4	109	1222
994L/1072L Goose Lake to Fidler and CRR	Bennett Transformer	MMA_sc8	127	1200
	1235L Bennett to Chapel Rock	MMA_sc4	117	1222
	138 kV 412L Pincher Creek to Russell	MMA_sc4	102	121
	138 kV 613L Pincher Creek to Goose Lake	MMA_sc4	122	119
	138 kV 786L Coleman to Natal	MMA_sc3	109	99

Table 6.7-7: Category C5 Voltage Violations

Bus and Substation	Contingency	Case file	Max of V observed	Max of V initial	V max (pu)	V min (pu)
Chapel Rock 240 kV	1004L/992L Chapel Rock to Castle Rock Ridge	MMA_sc4	1.11	1.05	1.10	0.90

Figure 6-1: Category C5 Outages of Concern under High Wind and High Import Conditions



Remedial Action Schemes (RAS) listed in Table 6.7-8 are recommended to resolve the criteria violations under Category C5 conditions. These RAS are not required to be armed at all times and most likely will only be armed under high import and high wind conditions. As per the AESO's practice, the high level RAS requirement is identified at the planning phase while detailed RAS design will be done at a later stage of project development. Hence the RASes are not specified as part of the planning mitigations and they not included in the planning mitigation cost estimates.

Table 6.7-8: Proposed Remedial Action Schemes for Category C5 Contingencies

Contingency	Remedial Action Schemes
1037L/1038L Windy Flats 138S to Foothill 237S	Trip approximately 300 MW load in AIES
1004L/992L Chapel Rock 491S to CRR 205S	Transfer trip 138 kV connections to BC
1048L/1049L Peigan 59S to Windy Flats 138S	Trip approximately 300 MW load in AIES
955L/956L Peigan 59S to Goose Lake 103S	Trip approximately 300 MW load in AIES Trip 616L Peigan to Goose Lake
994L/1072L Goose Lake 491S to CRR 205S and Fidler 312S	Trip approximately 300 MW load in AIES
1071L/1072L CRR 205S to Goose Lake 491S and Fidler 312S	Transfer trip 138 kV connections to BC

Detailed results of contingency analysis for all the scenarios to assess the mitigation measures are presented in Appendix E.

6.7.4 Voltage Stability (PV) Analysis

Voltage stability (PV) analysis was performed on all the study scenarios to ensure the PV criteria are met. As discussed in section 4.3.5 Voltage Stability (PV) Analysis Methodology, new base cases were developed by increasing the AB-BC flow by 10% and 5% for Category B and Category C contingency analysis respectively. If there is no voltage collapse in the study scenario following the contingencies, it is assumed that the PV criteria are met for that scenario and there is no need to create PV plots. Table 6.7-9 shows the pre and post contingency voltages on critical buses for the study scenarios. It shows that while bus voltages might be low, there is no voltage collapse for any of the scenarios. The power flow single line diagrams of the system with stressed intertie under Category A and critical Category B conditions are given in Appendix G.

Table 6.7-9: Voltage Stability Results with the Stressed Cases

Study Scenario	Path 1 Flow (MW)	MATL Flow (MW)	Critical Outage	Voltage Collapse	Critical bus	Bus voltage before Contingency	Bus voltage after Contingency
MMA_sc1_PV	1320	300	Genesee 3	No	CBK 500 kV	1.02	0.96
MMA_sc2_PV	1320	300	Genesee 3	No	CBK 500 kV	0.99	0.91
MMA_sc3_PV	1155	300	Genesee 3	No	CBK 500 kV	1.00	0.93
MMA_sc4_PV	810	300	1235L	No	Windy Flats 240 kV	1.02	0.94
MMA_sc5_PV	1320	300	Genesee 3	No	CBK 500 kV	1.01	0.93
MMA_sc6_PV	1320	300	Genesee 3	No	CBK 500 kV	1.00	0.88
MMA_sc7_PV	1155	300	Genesee 3	No	CBK 500 kV	1.01	0.95
MMA_sc8_PV	820	300	1235L	No	Windy Flats 240 kV	1.02	0.96
MMA_sc9_PV	-1050	-325	940L&1036L	No	N. Lethbridge 240 kV	1.01	0.98

6.7.5 Dynamic Stability Analysis

Dynamic performance of the system was simulated for Category A, B, and C5 contingencies. The list of simulated contingencies is provided in Section 4.2.1 and fault clearing times are given in Section 4.3.4. This study showed that there are no dynamic stability issues in any of the studies scenarios. The dynamic plots of voltage, frequency, machine angle, and certain line flows following the contingency are given in Appendix F for Category B and C5 contingencies.

The following contingencies in Alberta are critical with regards to system dynamic performance under high import conditions:

- Intertie outage

- Outage of largest generator (Genesee 3 dispatched at 466 MW net to grid)

System performance under these contingencies is discussed in more detail in the following sections:

6.7.5.1 Controlled Separation

In the need assessment analysis (Section 5.9) it was discussed that due to a direct transfer trip scheme between Path 1 and MATL, an outage of Path 1 will result in tripping of MATL. If Path 1 and MATL are dispatched at their rated capacities, then the AIES will face a loss of 1500 MW of generation. Figure 6-2 shows the system frequency response following such an event and illustrates a resulting UFLS action to trip around 300 MW of firm load when the frequency went lower than 59.1 Hz.

By installing a back to back HVDC converter on MATL, the direct transfer trip between Path 1 and MATL is no longer required. Therefore an outage of Path 1 only imposes a controlled separation with a 1200 MW loss of supply to the AIES. The MATL HVDC would reduce the controlled separation from 1500 MW import to 1200 MW import and reduces the amount of frequency mitigation services required. Figure 6-3 presents the system frequency response following Path 1 outage assuming that MATL HVDC is in service and therefore there is no need for a direct transfer trip. In this simulation it was assumed that 480 MW LSSi is available to be armed and also it was assumed that the total response of AIES load and generation is around 720 MW. This assumed total amount of LSSi and the system response (480MW + 720 MW = 1200 MW) will compensate for the loss of the 1200 MW import from BC and would be sufficient to keep the frequency above 59.5 Hz to prevent firm load shed[22]. System operator action then will dispatch the operating reserves to restore frequency back to 60 Hz.

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[22] See section 4.4.4 Frequency Response Guideline.

Figure 6-2: Frequency response with 1500MW total import lost (UFLS action)[23]

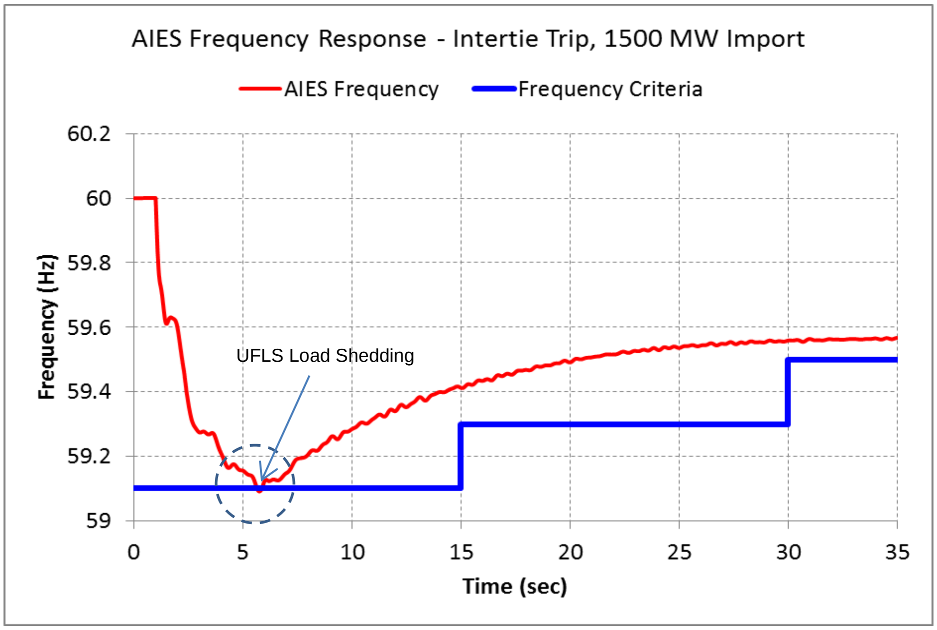
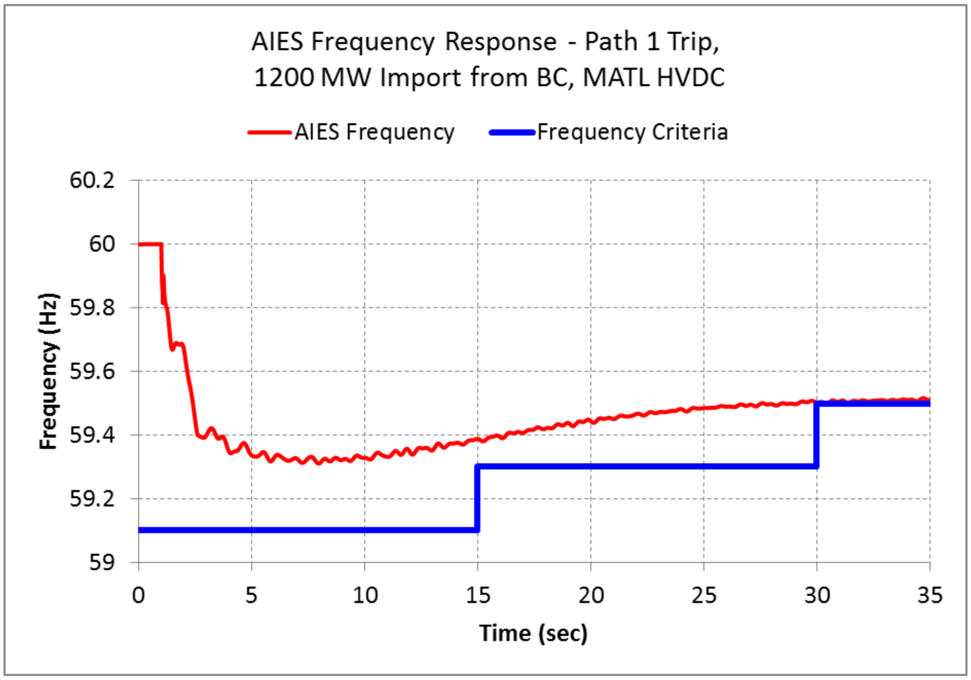


Figure 6-3: Frequency response with 1200MW total import lost (No UFLS action), MATL DC

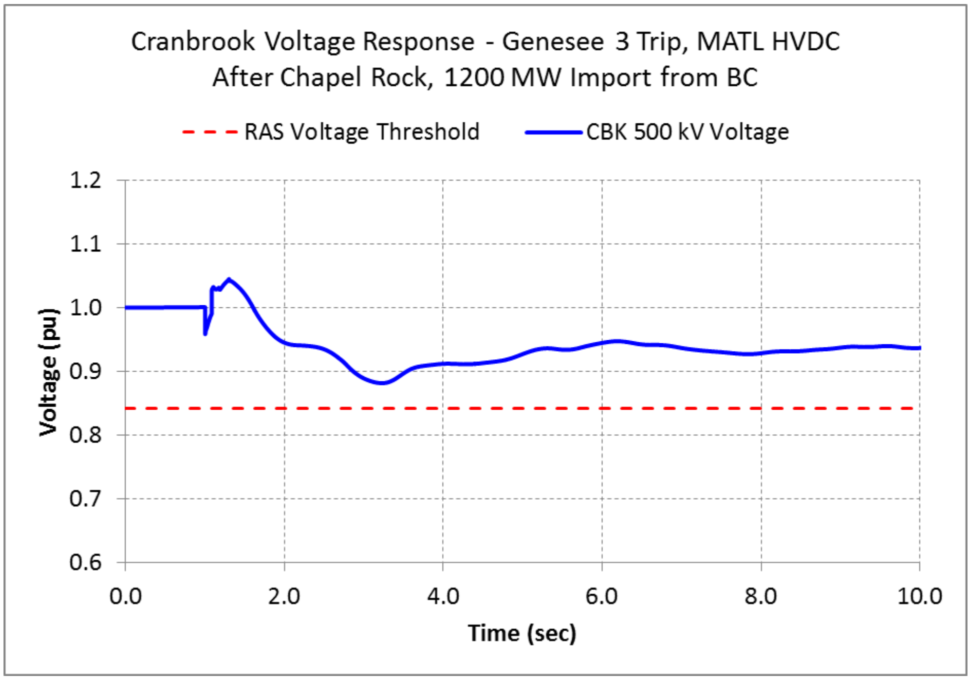


[23] Case Y17C04 was used for this analysis.

6.7.5.2 Genesee 3 Outage

A RAS is currently in service at the Cranbrook substation to trip the AB-BC intertie if the Cranbrook 500 kV bus voltage goes below 0.842 pu for more than 0.5 seconds. An outage of a fully dispatched Genesee 3 generator under high import conditions is the most critical outage in Alberta that causes a voltage drop at the Cranbrook bus. As shown in Figure 5-1 in the need assessment section, an outage of a fully dispatched Genesee 3 generator under 1200 MW import before the Chapel Rock connection will cause a prolonged low voltage at Cranbrook resulting in the intertie trip. Following the Chapel Rock connection and given the close proximity of Chapel Rock substation to the AB-BC border, the reactive power support at Chapel Rock will improve the voltage profile under steady state and transient conditions. Figure 6-4 shows the bus voltage at Cranbrook after the Chapel Rock connection for a Genesee 3 outage event under 1200 MW import from BC. Comparison of the plot in Figure 6-4 with the plot in Figure 5-1 reveals that before the Chapel Rock connection it is challenging to keep the voltage at 1.0 pu in steady state conditions while after the Chapel Rock connection there is no issue to have Cranbrook at 1.0 pu voltage under the studied scenarios. Also the plot shows that before Chapel Rock, a Genesee 3 outage will result in the intertie trip due to voltage sag at Cranbrook while after the Chapel Rock connection the Cranbrook voltage will recover after the transient.

Figure 6-4: Cranbrook voltage following Genesee 3 outage with Chapel Rock and MATL HVDC[24]



Dynamic plots for assessment of mitigation measure are presented in Appendix F.

6.7.6 Summary of System Analysis with Mitigation Measures

Figure 6-5 and Figure 6-6 show the system capability before and after implementing all the recommended mitigation measures listed in Table 6.4-1. The AIES and BCH CBK area systems meet all the performance criteria including facility ratings, voltage performance, dynamic stability, and frequency response at BC to AB flows up to the levels identified in Figure 6-5 and Figure 6-6.

As presented in Figure 6-5 and Figure 6-6 there are a few hours in the study year in which the anticipated import is beyond the capacity of the system. These results indicate that with the mitigation measures implemented, there still would be criteria violations if certain scenarios such as simultaneous full wind and full import from BC and Montana are considered. However since such scenarios are not occurring in near term, no mitigation plans are considered to resolve issues identified under those scenarios at this stage. Table 6.7-10 presents the percentage of the hours in which the import would potentially need to be curtailed to prevent criteria violations.

[24] Case Y17C04 was used for this analysis.

Figure 6-5: Impact of Mitigation Measures[25] on Summer Import Capability

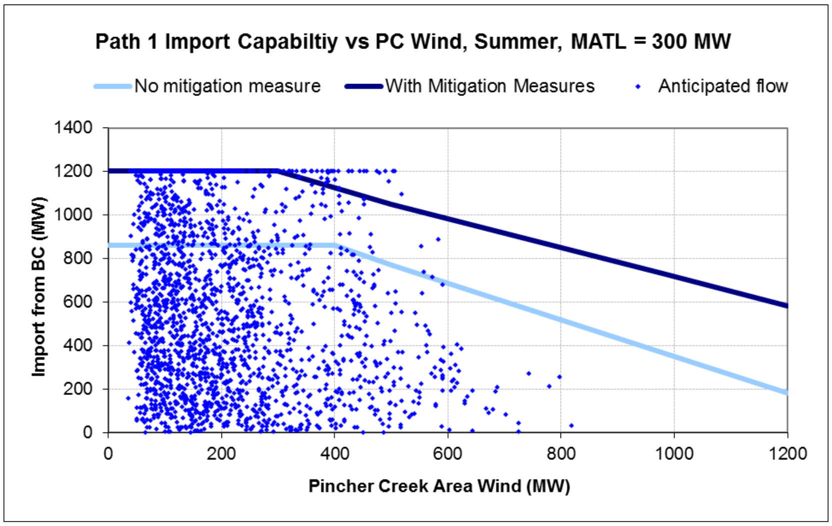
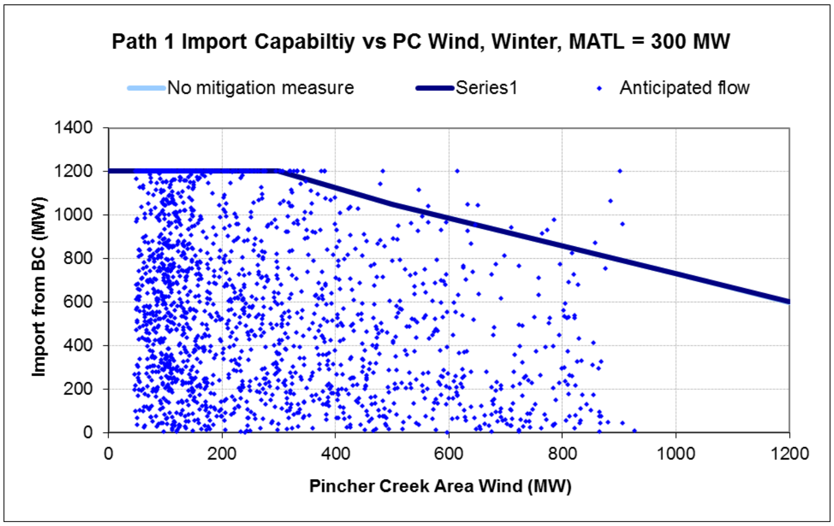


Figure 6-6: Impact of Mitigation Measures[26] on Winter Import Capability



[25] As listed in Table 6.4-1

[26] As listed in Table 6.4-1

Table 6.7-10: Impact of Mitigation Measure in Reducing Congestion

Scenario	Congestion in Summer (% of time)	Congestion in Winter (% of time)
Without Mitigation Measures	28.8%	1.5%
With Mitigation Measures (year 2022)	4.0%	1.5%

The AESO will continue to monitor the wind development in the Pincher Creek area and further enhancements will be considered if forecast data shows that the system has reached its capacity to accommodate 1200MW import under high wind scenario. In addition to the mitigation measures and reinforcements recommended in this report with OOM cost estimate of approximately $180 M, the following reinforcements[27] will be also be required to accommodate simultaneous 1200 MW import from BC and 1000 MW wind in the Pincher Creek area:

- Re-conductor the Goose Lake to Windy Flats lines with high temperature conductors: Cost estimate: $37M
- Resolve the issue on 1235L from Chapel Rock to Bennett (around 200 km): Cost estimate: $261M
- Resolve issue on Bennett 1200MVA transformer: Cost estimate: $16M
- Resolve the voltage issues at Cranbrook and southern Alberta (the optimum location for voltage support will be determined later): cost estimate: TBD

The OOM cost estimate for the above reinforcements is $314M for the AIES.

[27] As per AESO practice, detailed RAS designed will be done at a later stage of project development and hence RASes are not included here.

7 Summary and Conclusions

In the near-term the development of the FATD-East transmission plan will help address the overload on the Langdon to Janet 240 kV lines (936L/937L). Similarly the Chapel Rock substation and the 240 kV lines from Chapel Rock to Castle Rock Ridge in the Pincher Creek area will also address some other existing issues related to the intertie restoration. With planned transmission projects in service, and assumed availability of 480 MW of LSSi, the AESO's intertie restoration mandate is achieved because TTC at full path rating is possible under certain scenarios and system assumptions such as winter peak load. However to accommodate intertie flows up to their WECC path ratings as in-merit energy, the AESO is recommending all of the following enhancements to be considered in the near to medium term:

- Implement DTLR on the Goose Lake to Windy Flats 240 kV lines (955L, 956L, 1048L, 1049L)
- Implement a RAS to trip Path 1 following an outage of the Chapel Rock to Bennett line (1235L) under high wind and high import scenarios.
- Resolve the overload issue on the 500 kV line from Chapel Rock to BC border. Re-conductoring or re-building the line are two possible solutions.
- Reduce frequency mitigation and operating reserves requirements to perform and recover from a controlled separation. The recommended technical solution would be to install a back-to-back HVDC converter somewhere along the MATL line. This would be required in addition to the assumed availability of 480 MW LSSi.

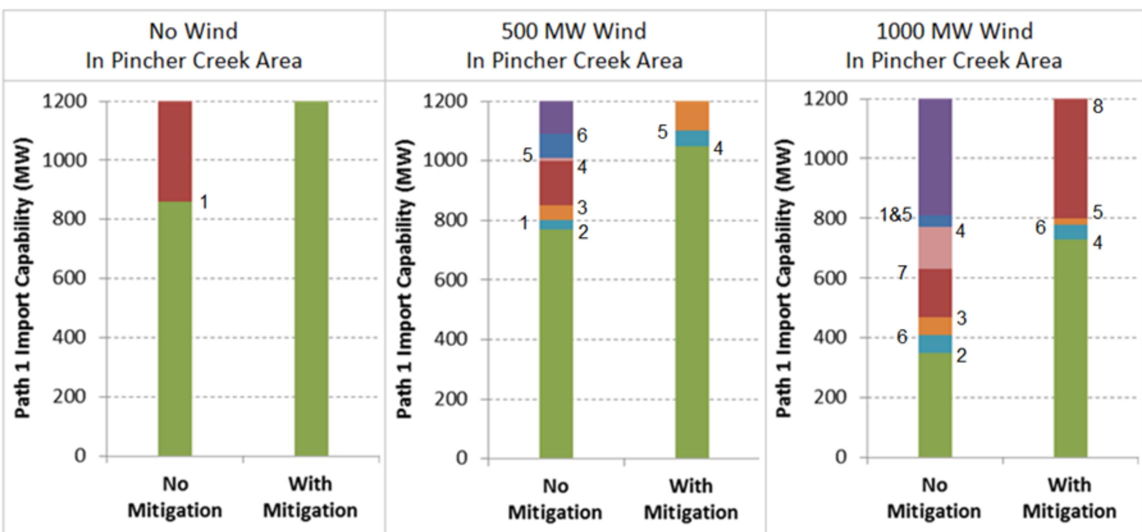
BCH has indicated that it plans to continue with the existing operation practice of opening the 138kV ties to resolve the overload on the Natal to Pocaterra 138 kV transmission path.

A high level assessment of the AESO's forecast data shows that after the implementation of the above enhancements, the AIES would be able to accommodate the anticipated import (up to 1200 MW) up to year 2022. Off frequency mitigation measure will be required at higher import and export transfer levels. For import condition it has been assessed that 480 MW LSSi would be required to be armed under high import conditions. Operational studies would be required to establish more specific amounts of frequency mitigation.

With the recommended mitigation measures implemented, it is anticipated that the AIES will be capable of congestion free operation 96% of the time or greater based on forecast wind capacity additions in near to medium term. However even with mitigation measures there would still be criteria violations if more stressed scenarios such as full wind and full import from BC are considered. AESO will continue to monitor the wind development in the Pincher Creek area and further enhancements will be considered if forecast data shows that the system has reached its capacity to accommodate 1200MW import from BC under a high wind scenario.

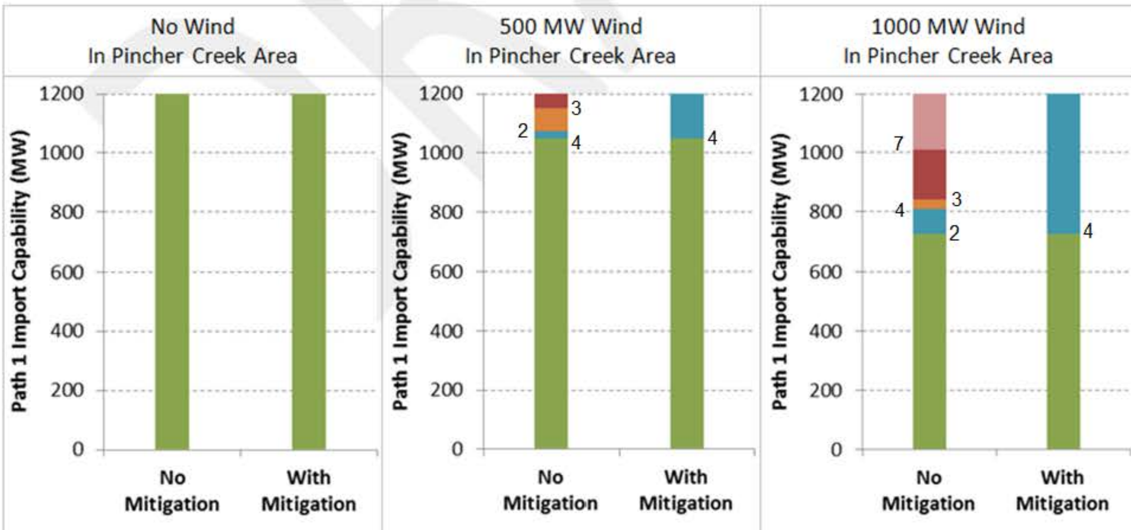
Diagrams in Table 6.7-1 and Table 6.7-2 show how the recommended mitigation measures increase the import capability under varying levels of wind generation in the Pincher Creek area in summer and winter respectively. The green bar shows the maximum import capability and other bars show different criteria violations as the import level increases. Since no mitigation measure is recommended for the most limiting element for import in winter (Bennett Transformer) the import capability remains unchanged with and without mitigation measures in winter. However the diagrams in Table 6.7-1 and Table 6.7-2 indicate that some of the issues at higher import levels can be resolved by the mitigation measures. For example with 1000 MW wind in the Pincher Creek area in winter, there would be 4 limiting elements if the import goes beyond around 730 MW without mitigation measure. However with mitigation measure in place, there is only one issue for imports higher than 730 MW which is the overload on the Bennett transformer.

Table 6.7-1: Impact of Mitigation Measure on Path 1 Import Capability in Summer



1: 1201L overload – Genesee 3 outage
2: 1049L overload – 1235L outage
3: 955L overload – 1235L outage
4: Bennett Tx overload – Genesee 3 outage
5: 1235L overload – Genesee 3 outage
6: 1049L overload – 1048L outage
7: 1072L overload – 1235L outage
8: Intertie Trip (CBK low voltage) – Genesee 3 outage

Table 6.7-2: Impact of Mitigation Measure on Path 1 Import Capability in Winter



1: 1201L overload – Genesee 3 outage
2: 1049L overload – 1235L outage
3: 955L overload – 1235L outage
4: Bennett Tx overload – Genesee 3 outage
5: 1235L overload – Genesee 3 outage
6: 1049L overload – 1048L outage
7: 1072L overload – 1235L outage
8: Intertie Trip (CBK low voltage) – Genesee 3 outage

8 References

[1] Study Scope for the SOL study

[2] Stage 1 of AESO's intertie report

[3] Stage 2 of intertie restoration studies

[4] AESO Study Scope for the joint study

[5] BC Hydro Study Scope for the joint study

[6] BC Hydro Engineering Study Report for the joint study

[7] ABB report on MATL HVDC capability

[8] South regional long term plan

[9] Transmission Regulation, Section 16

[10] Transmission Regulation, Section 15

[11] Transmission Regulation, Section 17

9 Appendices

Appendix A:

Need Assessment

Power Flow Single Line Diagrams

Appendix B:

Need Assessment

Detailed Contingency Analysis Results

Appendix C:
Need Assessment
Dynamic Stability Plots

Appendix D:

Mitigation Measure Assessment

Power Flow Single Line Diagrams

Appendix E:

Mitigation Measure Assessment

Detailed Contingency Analysis Results

Appendix F:

Mitigation Measure Assessment

Dynamic Stability Plots

Appendix G:

Mitigation Measure Assessment

Voltage Stability Power Flow Single Line Diagrams