Planning Studies Supplemental Report

Provost to Edgerton and Nilrem to Vermilion (PENV) Transmission Reinforcement

March 23, 2018

APEGA
Permit-to-Practice
P-8200

Role	Name	Signature	Date
Prepared	Chris Lipsett, P. Eng. Han Yu, Ph.D., P. Eng.		March 23, 2018 March 23, 2018
Prepared/ Reviewed	Ramaiah Divi, Ph.D., P. Eng. Amir Motamedi, Ph.D., P.Eng.		March 23, 2018 March 23, 2018
Approved	Sami Abdulsalam, Ph.D., P. Eng.		March 23, 2018

Alberta Electric System Operator, Calgary Place, 2500, 330 – 5th Avenue SW Calgary, AB T2P 0L4
Phone: 403-539-2450 Fax: 403-539-2949 www.aeso.ca @theaeso

Executive Summary

In response to the Alberta Utilities Commission (Commission) Decision 22274-D01-2018 (Decision) regarding the AESO's *Provost to Edgerton and Nilrem to Vermilion Needs Identification Document* Application (2016 Application), the AESO has reassessed the need for transmission reinforcement in the PENV area based on the AESO's recent load and generation forecast. This report presents results of the technical studies (2018 Planning Studies) conducted by the AESO to reassess the need for transmission reinforcement in the PENV area.

The purpose of the 2018 Planning Studies was to:

- reassess both load serving and generation based need;
- confirm the generation integration capability in alignment with the AESO's *2017 Long Term Transmission Plan* (2017 LTP), to enable the Government of Alberta's legislated target of 30% energy produced by renewable electricity generation by 2030;[1] and
- validate the AESO's preferred transmission development.

The 2018 Planning Studies include: power flow studies under Category A and Category B contingency conditions for near term and long term study scenarios as well as for selected Category C3 contingency conditions for near term scenarios. Near term study scenarios include 2021 Winter Peak (WP), 2021 Summer Peak (SP) and 2021 Summer Light (SL) study scenarios. The long term study scenarios include 2037 WP, 2037 SP, and 2037 SL.

The load serving capability assessment carried out in the 2016 Application remains valid. In addition, the need reassessment studies demonstrate that lines 749L and 7L50 are either overloaded in the near term in summer peak load conditions under conditions of low cogeneration levels in the Cold Lake area or loaded to 95% and above under multiple generation dispatch scenarios.

The reliability criteria violations along 749L under Category B contingency conditions that occurred (2010-2015) and continue to occur in the near term when the coincident summer peak load of seven substations[2] exceeds 114 MW and these violations are independent of generation dispatch scenarios. In the long term, these violations are exacerbated as the load grows with time. In the long term, low voltage criteria violations and voltage collapse conditions are observed.

The need reassessment was expanded by studying new generation scenarios to include the confirmed and future renewables in the system to compliment the generation capability studies included in the 2016 Application. Presently, the 7L50 path has limited capacity to connect any generation project as overloads under Category A conditions are anticipated to occur due to its limited thermal capacity. From a generation perspective and in the near term, high renewable generation output conditions, particularly along 7L50 or south of PENV lead to transmission congestion along 7L50 (Battle River 757S to Buffalo Creek 526S), 749L (Metiskow 648S to Edgerton 899S) and 7L701 (Battle River 757S to Strome 223S) under several PENV area Category B contingencies in addition to outages of the Eastern Alberta Transmission Line (EATL), 9L20 and 912L.

The overloads on 7L50 and 7L749 reach as high as 126% for the loss of EATL. These overloads (without transmission reinforcement in the PENV area) will require mitigation through generation curtailment which

[1] Described in the *Amended Provost to Egerton and Nilrem to Vermilion Load and Generation Forecast*, submitted under a separate cover

[2] These substations (Killarney Lake 267S, Hayter 277S, Edgerton 899S, Briker 880S, Lloydminster 716S, Hill 751S and Kitscoty 706S) that lie along 749L and 7L749 path.

will exceed the threshold of the current 466 MW Most Severe Single Contingency (MSSC), which represents the most severe single contingency generator or supply loss on the Alberta interconnected electric system (AIES) that may occur as a result of either a generator trip, or the loss of a transmission line that subsequently leads to the simultaneous loss of generation. As more renewable generation is connected to the Central East Sub-region, the AESO anticipates that the PENV area will be subject to congestion under Category A conditions starting in 2022 or earlier and more lines in the PENV area will be congested over time. The Category A overload occurs even when all the renewable generation is located south of the PENV area. These thermal violations show the need for reinforcing the PENV transmission network.

The AESO's findings based on this reassessment show that the preferred transmission development described by the AESO in the 2016 Application (Preferred Transmission Development) continues to be required and remain the AESO's preferred option to meet the need in this area for both load and generation over the planning horizon.

The Preferred Transmission Development is flexible as it allows market participants to connect their projects anywhere along either of the proposed new PENV lines or at their respective terminus substations; it is scalable from 138 kV to 240 kV operation to maximize integration of new generation in the area. For example 300 MW along the Nilrem to Vermillion or 560 MW along the Provost to Edgerton section in steps to meet the growth in the respective areas in a timely manner; it provides a new hub (Drury 2007S substation) in the Vermilion area to enable connection of both load and generation projects in the area. The Drury substation also serves as a strong source substation that connects to the 240 kV network strengthening the supply to Lloydminster area in the east, Bonnyville area in the north and the Edmonton area to the west. In the long term, this Drury substation could be used to enhance the system capability for integration of additional load and generation in the area by terminating existing 144 kV lines 7L130, 7L117 and 7L129 into it in future as need arises.

The AESO also considered the impact of a recently filed connection project NID for *Transmission Enhancements in the Municipal Districts of Provost and Wainwright* (Project 1782)[3] on the Preferred Transmission Development, as this project proposes a 138 kV transmission line from Provost 545S to Hayter 277S substations (P-H line). The P-H line does not eliminate the need for transmission reinforcements in the PENV area, and in fact the 715L (Metiskow 648S to Provost 545S) becomes a bottle-neck under high load and/or generation conditions when the P-H line is included. The P-H line has a negligible effect on renewable integration in the larger PENV area.

As a result of the P-H line (as part of Project 1782), there is an opportunity to further stage the Preferred Transmission Development. The AESO has determined that the Provost to Edgerton (P-E) line (the Edgerton Component of the Preferred Transmission Development) could be built in two stages as described below and shown in Figure 7-1 and Figure 7-2 of this report.:

- **Stage 1**: Build a 240 kV line from Hansman Lake to Killarney Lake tap (energized initially at 138 kV) – the southern portion of the preferred Provost to Edgerton line in the near term. This development helps to create an independent loop from Hansman Lake to Provost and back to Hansman Lake. It will serve loads on the Killarney Lake tap, Hayter and Provost, and supports surplus generation from the Bull Creek Wind facility as well as future wind additions east of the Provost to Killarney tap line segment. As part of Stage 1 development, the 240 kV line from Nilrem to vermilion is to be built and operated initially at 138 kV.

[3] AUC Proceeding 23391.

- **Stage 2:** Build the northern portion of the 240 kV line from Killarney Lake tap to Edgerton, energized initially at 138 kV, subject to meeting the following milestone:
    - The AESO's coincident summer aggregate peak load forecast reaching the existing capacity of the transmission line 749L (Edgerton 899S to the Killarney Lake 267S substation tap-point), which is approximately 83 MW, measured at the Edgerton 898S, Briker 880S, Lloydminster 716S, Hill 751S and Kitscoty 705S substation; or,
    - Construction commencing for generation projects that will connect along the transmission 749L path (from Hansman Lake 650S to Vermilion 710S) and that the AESO anticipates will give rise to congestion under Category A conditions on the transmission line 749L (Edgerton 899S to the Killarney Lake 267S substation tap-point); or
    - The withdrawal or cancellation of FortisAlberta's system access service request for AESO Project 1782.

The Preferred Transmission Development is still required in the near term as it meets the near term need and the need over the 20 year planning horizon based on the current forecast. However, a milestone can be specified for the northern section of the P-E line (the Edgerton Component). The Preferred Transmission Development will be initially energized at 138/144 kV.

This staged development of the Edgerton component will reduce initial capital cost while meeting the need along 7L749 path in an effective manner. The Preferred Transmission Development, when fully energized at 240 kV, would increase the local PENV generation integration capability along both lines up to 860 MW of new generation in the PENV area by providing a strong 240 kV collector system, and thus there has been no change in the PENV area renewable integration capability of the Preferred Transmission Development compared to the 2016 Application.

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

This report is prepared in response to the Alberta Utilities Commission (Commission) Decision 22274-D01-2018, to refer back the AESO's *Needs Identification Document for the Provost to Edgerton and Nilrem to Vermilion Transmission System Reinforcement* Application (2016 Application),[4] in accordance with Subsection 34(3)(b) of the *Electric Utilities Act*. In the Decision, the Commission directed the AESO:

> *…to incorporate its most current load and generation forecasts into its analysis of the need in the PENV area and, if necessary, adjust, its preferred solution to address the updated need. Should the AESO's reassessment of the need in the PENV area result in material changes to the need identified, the Commission expects that the AESO will adapt its preferred alternative accordingly and consider whether project staging based on established milestones is necessary in the circumstances.*[5]

1.1 Summary of Conclusions in the 2016 Application

The PENV area includes the following five AESO Planning Areas as shown in Figure 1-1 and Figure 1-2. These include: Vegreville (Area 56); Lloydminster (Area 13); Wainwright (Area 32); Provost (Area 37); and Alliance/Battle River (Area 36).

The 2016 Application was based on the *AESO 2016 Long-term Outlook* (2016 LTO), which was the latest AESO load forecast available at time of filing. In the 2016 Application, the 2016 Planning Studies[6] described a need for transmission development in the PENV area based on:

1. Load Drivers:
    a. An immediate need for development was described based on the recorded historical PENV area peak load for years 2012 to 2015, which was further supported by the forecasted load growth indicated in the 2016 LTO.
    b. Thermal criteria violations were observed along the existing 7L50 and 749/7L749 paths under summer peak load conditions. Thermal overloads were demonstrated using both the recorded and forecasted peak load levels in the area in the near term (2021), and during certain historical years under Category B (N-1) conditions.
2. Generation Drivers:
    a. Lack of existing transmission capability to integrate renewables in the local PENV area. The Grizzly Bear Creek Wind (Grizzly Wind) wind project and Irma Wind Farm L.P. (Irma Wind) wind project were both subjected to these constraints. Irma Wind was filed with the Commission on May 27, 2016 and had its capacity reduced from 150 MW to 90 MW due to lack of capacity on 7L50. Grizzly Wind was filed with the Commission on August 8, 2017 and originally approved by AUC Decision 21643-D01-2016 and Approval 21643-

[4] Exhibits 22274-X0002 to 22274-X0023.

[5] Decision, para. 66

[6] Exhibits 22274-X0003 to 22274-X0017

D02-2016. Grizzly Wind was unable to connect to Vermilion 710S due to lack of space at the substation. These issues are further elaborated in Section 1.2.

b. It was determined that a new major transmission hub is needed to connect future load and generation projects in the Vermilion area where the proposed Nilrem to Vermilion transmission line will be terminated. Due to routing and siting constraints in and around the existing Vermilion 710S substation, it is not feasible to terminate any new line or project into the Vermilion 710S substation.

   It was also determined that reinforcement is necessary to provide access to the AIES to future generation projects and increase renewable integration capability along the existing 138 kV transmission line 749L (between the existing Hansman Lake 650S and Edgerton 899S substations. As an example, the Bull Creek Project applied to the AESO for 130 MW. It was subsequently downsized to a distribution-sized connection, due to a lack of transmission capacity in the PENV area.

c. Through generation integration capability studies, the AESO has demonstrated that the Preferred Transmission Development continues to meet long-term load serving needs. The generation integration capability along the 7L50 and 749L paths was demonstrated to accommodate up to 410 MW when energized at 138 kV level and up to 860 MW (under Category A (N-0) conditions) when the facilities are energized to 240 kV level.

1.2 Existing Constraints for Connecting New Projects

The transmission capability in the existing PENV area not only limits generation integration capability locally, but also the amount of generation that could be integrated south of PENV in the Hanna Planning Area due to potential Category A (N-0) constraints along the existing 7L50 path and several other Category B (N-1) constraints. Two remedial action schemes RAS #137 and RAS #138 are currently in service in the Central East Sub-region to manage thermal overloads in the area. These RASs are designed to facilitate connecting renewable energy resource (wind or solar projects south of the PENV area. The existing 150 MW Halkirk wind power Project is being operated under RAS #138 and RAS #137 which are required to manage overloads on 7L50 and the Nevis transformer respectively. Both of these RASs result in shedding generation as per their design elements.

The Sharp Hills Project was selected in the Renewable Electricity Program Round 1 (REP1) competition (248.5 MW out of 300 MW applied for) and will be added to the existing RAS #138. With this change, the amount of generation curtailment under this RAS is 400 MW which leaves little room (66 MW) before exceeding the current 466 MW MSSC threshold on the system under a single contingency. This 66 MW curtailment room could be taken up either by a new generation project in the greater Central East Sub-region south of PENV or simply be utilized by a higher conventional generation dispatch level in the study area than that assumed in the planning studies. The potential for severe Category A (N-0) and Category B (N-1) constraints in the PENV area due to limited generation integration capability are not new and has been addressed in detail in prior AUC proceedings [7].

These constraints show that the existing system in the area has limited capability for integrating generation in the area.

[7] Projects 635 - Suncor Hand Hills Wind Energy Project, 637 - BluEarth Hand Hills Wind Project and 1567 - Sharp Hills Wind Farm New Facility Generator Capacity https://www.aeso.ca/grid/projects/

1.3 Reassessment of Need

The AESO has reassessed the need for transmission development in the PENV area based on the AESO's updated load and generation forecast. In contrast to the 2016 Application, which was focused on the need to serve load and assessing the local PENV area generation integration capability, the AESO's 2018 reassessment considered both load and generation need drivers.

Considering the change in the load and generation forecast, the planning studies outlined in this supplemental report used load and generation assumptions reflecting the most recent project specific forecast and recent Renewable Electricity Program (REP) announcements, as described in more detail in Section 2.1 of this report. However, the scenarios were developed similarly to those used in the 2016 Application which was designed to stress the PENV area transmission system. Power flow simulations were performed for the near term (2021) and long term (2037) to identify Reliability Criteria violations (thermal overloads and voltage violations) in the PENV area and confirm the need for the Preferred Transmission Development.

The scope of this reassessment, assumptions and findings are summarized in the following sections.

Figure 1-1: Central East Sub-region including PENV Area

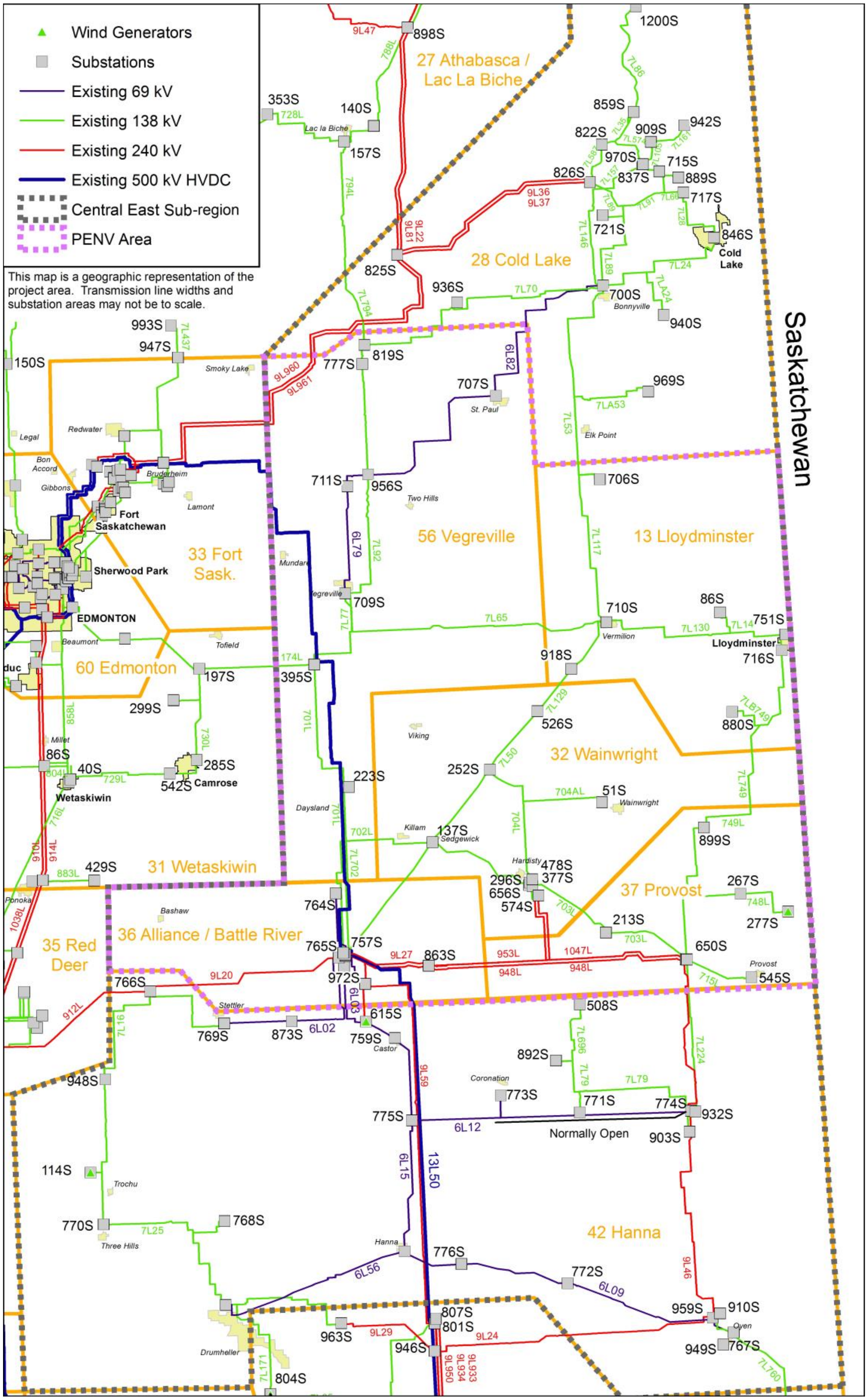
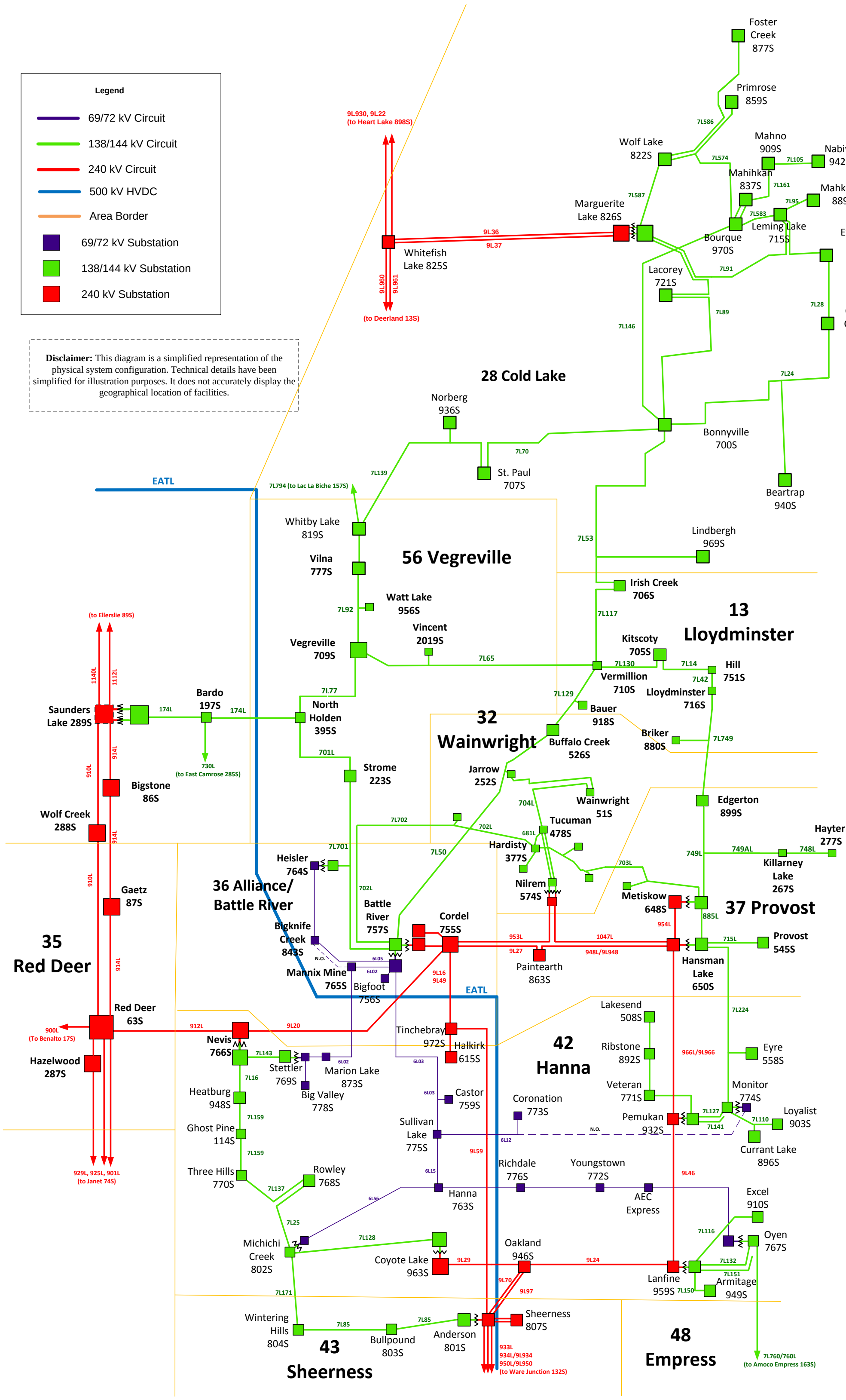


Figure 1-2: Schematic of Transmission System in the Central East Sub-region



1.4 Study Objectives

The study objectives are as follows:

- Assess the need for, and timing of, transmission reinforcement in the PENV area based on project specific load and generation forecast developed based on the 2017 LTO and recent REP announcements.
- Validate whether the Preferred Transmission Development in the 2016 Application is still the preferred transmission development alternative to meet the forecasted load and generation over the current 20 year planning horizon.
- Investigate opportunities for further staging, in addition to those originally imbedded in the 2016 Application filing and identify milestones, if required.

1.5 Study Scope

The following planning studies use a project-specific forecast developed based on 2017 LTO, and were conducted on the PENV area (Study Area) over the 20-year planning horizon.

- Need assessment – power flow simulations were carried out on the existing PENV area transmission system under Category A system conditions (all elements in service), Category B contingency conditions for the near term (2021) and long term (2037) and some selected C3 contingency conditions in the near term.
- System performance was evaluated for the scenarios and system conditions outlined below.

1.5.1 Load Based Analysis – Zero Wind Generation

The purpose of load-based analysis is to ascertain whether the existing system can supply load in a reliable manner, or whether it requires reinforcements over the planning horizon;

1.5.2 Generation Based Analysis – Maximum Wind Generation

This analysis focused on studying the impact of renewable additions in alignment with the AESO 2017 LTP, 2017 LTO, REP1 results and reaching the planned provincial renewable target of 30% by year 2030. This analysis was subdivided into two parts to help demonstrate the drivers for the need and their magnitude;

- Existing system with existing wind generation plus REP1 projects included
- Existing system with all future rounds of REP until 2021: Anticipated Renewable additions prior to the energization of PENV development.

1.5.3 Studies Not Included in the Study Scope

Transfer in/out capability analysis of the Central East Sub-region is beyond the scope of the studies presented in this supplemental report which focuses on local 138 kV/144 kV transmission system adequacy in the PENV area. In any event, consideration of transfer in/out capability of the Central East Sub-region does not affect the local need for transmission reinforcement in the PENV area. Other AESO studies have identified potential transfer out capability issues with increasing net generation development in the Central East Sub-region. As part of its ongoing planning studies, the AESO will continue to monitor and study the Central East Sub-region transfer out capability. When appropriate, the AESO will propose transmission system reinforcement to mitigate the constraints.

In addition, the AESO believes that the conclusions of the voltage stability, short circuit, and transient stability analyses presented in the 2016 Application remain valid. Therefore, these analyses have not been repeated in the Report.

2 Reliability Standards, Criteria, Study Assumptions, and System Model

This section describes the applicable Alberta Reliability Standards, criteria, study assumptions, and system model applied in the 2018 Planning Studies. The load and generation assumptions and system configuration used to create the study cases reflect the most current information available to the AESO. While the AESO makes its assumptions based on the latest available information, it is acknowledged that assumptions are subject to change over time. The AESO addresses the possible impact of changes in assumptions by performing regular system planning studies as part of its long-term transmission plans, conducting system capability studies, and monitoring status of ongoing active system projects. Since there are no material changes to Alberta Reliability Standards and, criteria from the 2016 Application, they are not repeated here and can be found in the 2016 Application.[8] The Transmission Planning (TPL) Standards, which are included in the Alberta Reliability Standards, and the AESO's *Transmission Planning Criteria – Basis and Assumptions*[9] (collectively, the Reliability Criteria) continue to be used to evaluate system performance under Category A system conditions (i.e., all elements in-service) and following Category B contingencies (i.e., single element outage), prior to and following the studied alternatives.

2.1 Load Forecast and Generation Assumptions

The *Amended Provost to Edgerton and Nilrem to Vermilion Transmission Reinforcement Load and Generation Forecasts* (Amended PENV Area Forecast)[10] details the load and generation forecasts used for the 2018 Planning Studies.

As discussed in the Amended PENV Area Forecast, the load forecast for the PENV area still demonstrates a positive load growth outlook, however at a slower pace than originally anticipated as part of the 2016 LTO. These forecasted load levels are reflective of the PENV area coincident peak load levels rather than the Central East Sub-region coincident peak levels utilized in the 2016 Application. The changes are summarized in Table 2-1 below.

Table 2-1: PENV Area Load Forecast: Comparison of 2016 LTO and 2017 LTO

Year	2016 LTO		2017 LTO*		Change from 2016 to 2017 LTO	
	SP (MW)	WP (MW)	SP (MW)	WP (MW)	SP (MW)	WP (MW)
2021	496	578	459	519	-37	-59
2027	523	618	475	529	-48	-89
2037	572	676	515	583	-58	-93

Amended PENV Area Forecast

[8] Exhibit 22274-X0003

[9] Exhibit 22274-X0023

[10] Provided under a separate cover.

2.2 System Development Assumptions

All planned and approved transmission system reinforcements with in-service dates on or before 2021 were considered and modelled accordingly in the 2018 Planning Studies. System developments most relevant to the studies are listed in Table 2-2.

Table 2-2: System Projects Modelled and their Status

Horizon	Development	Status
All-Term	Project 811: Central East Transmission Development as further described below.	Modelled elements with in-service dates on or before 2021; excludes all others
	Project 812: Hanna Area Transmission Development Phase 1	Modelled in the studies
	Project 1113: Hanna Area Transmission Development Phase 2	Not Modelled in the studies
	Project 813 Red Deer Area Transmission Development Phase 1	Modelled in the studies
	Red Deer Area Transmission Development Phase 2 – 166L	Not Modelled in the studies

2.2.1 Central East Transmission Developments not modelled in the Studies

These developments have not changed from what was stated in Section 2.3.1 of the 2016 Planning Studies. As such, they are not reproduced here.

2.3 Voltage Profile Assumptions

The Voltage Profile Assumptions and methodology have not changed from what was stated in Section 2.4 of the 2016 Application. As such, they are not reproduced here.

2.4 HVDC Dispatch Methodology

The 500 kV high voltage direct current (HVDC) Eastern Alberta Transmission Line (EATL) and Western Alberta Transmission Line (WATL) were dispatched in two steps:

Step 1: They were dispatched to a level that minimizes the total real power loss in the AIES. This approach is consistent with the EATL and WATL operating procedures.

Step 2: In order to relieve congestion in the PENV area and the greater Central East Sub-region, the EATL dispatch was maximized to support full 1,000 MW transfer-out capacity south to north in the wind scenarios.

3 Planning Methodology

The methodology used to conduct this reassessment of information related to the 2016 Application is based on a project-specific forecast for the PENV area and included the following:

- Develop credible stressed study scenarios. Summer peak (SP), winter peak (WP) and summer light (SL) load conditions were assessed with various credible generation dispatches to create a variety of scenarios for the PENV planning studies.
- Investigate the system performance under the following system conditions for the near term (2021) and long term (2037). Specifically, conduct need assessment studies for the near term (2021) to identify potential transmission system constraints to serving load and generation under Category A conditions, Category B contingencies and selected Category C3 contingencies,

  (i) Load Stress Scenarios:

  Existing system under zero wind production in the near term

  (ii) Immediate Generation Stress Scenarios:

  Existing system with power production from existing wind facilities and REP1 facilities (all assumed to be in service, in the near term)

  (iii) Near-Term Generation Stressed Scenarios (Pre-PENV):

  Existing system with power production from existing wind facilities, REP1, as well as consideration of the forecasted generation representing the recently announced second and third rounds of the renewable electricity program (REP2 and REP3) (all assumed to be in service, in the near term)

- Investigate staging opportunities.
- Assess the system performance to identify whether the Preferred Transmission Development meets Reliability Criteria to supply both load and generation in the long term (2037).

3.1 Study Scenarios

As further described below, the study scenarios represent combinations of forecast load and generation dispatches that would result in stressed line loadings or low voltages on the local PENV transmission system, under Category A conditions and Category B contingencies.

The study scenarios were developed following similar criteria adopted in the 2016 Application while incorporating the latest load and generation forecast including the REP generation capacities anticipated by the program respective in service years. Using the same approach as was used in the 2016 Application, the Alberta tie lines to British Columbia, Saskatchewan and Montana were dispatched economically in all scenarios.

3.1.1 Load Supply Adequacy Scenarios

The rationale and approach taken to formulate the study scenarios remain the same as outlined in Section 3.1 of the 2016 Planning Studies and are not reiterated here. Accordingly, for load supply adequacy assessment, wind generation in the province was assumed to be zero in combination with one critical generator offline.

Four study scenarios (see Scenarios 1 through 4 in Table 3-1) cover the range of generation dispatches in the Battle River and Cold Lake areas that stress the system in SP and WP load conditions.

3.1.2 Generation Stressed Scenarios

The 2016 Planning Studies did not include a detailed assessment of generation driven need. Instead, generation integration capability was demonstrated to be adequate to meet the generation integration needs in the local PENV area using the Preferred Transmission Development required to meet the load driven needs.

In this reassessment, planning studies illustrate generation driven needs in further detail, considering needs internal and external to the PENV area. Study Scenarios 5 through 11 (Table 3-1) were considered to determine the capability of the existing transmission system for accommodating existing renewables, including REP1 facilities (wind) and future renewable generation capacity that would be developed in the area. Scenarios 5 through 8 represent a combination of high and economic dispatch of PENV and Cold Lake area generation under maximum wind output conditions during SP and WP load conditions. Scenarios 9 through 11 consider additional renewables under REP2 (300 MW) and REP3 (400 MW) for the years 2020 and 2021. These study scenarios are formulated to demonstrate the role of the PENV transmission network, both existing and planned in enabling renewable generation integration in the near term as well as accommodating future projects towards meeting renewable energy targets by 2030.

Locations considered for the near term, prior to PENV are along the Hanna 240 kV looped system at Lanfine 959S and Pemukan 932S substations. To this end, high renewable (wind) generation was assumed in the Study Area and the rest of the province in alignment with the 2017 LTP for renewable integration. High Battle River area generation coupled with economic and low cogeneration dispatched in the Cold Lake area was also considered. Four scenarios (Scenarios 5 through 8) represent existing wind generation with REP1 results, while the last three scenarios cover additional renewable generation for the years 2020 and 2021. Together, these encompass SP, WP and SL conditions.

3.1.3 Long-term Performance

To test the performance in the long term (2037), 11 scenarios similar to the ones for the near term were formulated and used as outlined in the section below. For this reassessment, the scenarios have been adjusted based on the 2017 LTO, as mentioned earlier.

3.1.4 Critically Located Generators Offline

The scenarios considered are almost identical to those used in the 2016 Application. The critical units are Battle River 5 (2021), Battle River 5 Future Replacement (2037) and Primrose. These were used as the most critically located units in this study.

Table 3-1: Summary of Near Term (2021) Study Scenarios

Scenario	Study Year	Load Condition	Wind Generation*	CE Conventional Generation	Cold Lake Cogeneration
01	2021	SP	Zero	High	Low
02	2021	SP		Low	Econ
03	2021	WP		High	Econ
04	2021	WP		Low	Econ
05	2021	SP	Existing Wind plus REP1	High	Low
06	2021	SP		Low	Econ
07	2021	WP		High	Low
08	2021	WP		Low	Econ
09	2021	SP	Existing Wind, REP1 and future rounds of REP	High	Low
10	2021	WP		High	Econ
11	2021	SL		High	Low

*Wind generation condition for the entire system; wind generation is dispatched to 92% of the installed capacity

The scenarios will follow the notation shown in Table 3-2 below. Scenarios that include outages of the critically located generator will be noted by adding the generator interconnecting substation number to the scenario name, e.g., 03_2021_SP_859S will represent a scenario with the Primrose unit connecting through substation 859S assumed out of service. The 2037 scenarios will follow the same notation as the near term scenarios. Seven scenarios (1-4 and 8-11) similar to the ones for the near term were formulated and used. The scenarios 5-8 are not applicable to the long term because existing generation will be included as part of future generation. For the sake of brevity, the long term scenarios are not re listed here.

Table 3-2: Notation for Study Scenarios

Scenario	Study Year
1	01_2021_SP
2	01_2021_SP
3	03_2021_WP
4	04_2021_WP
5	05_2021_ExWind_SP
6	06_2021_ExWind_SP
7	07_2021_ExWind_WP
8	08_2021_ExWind_WP
9	09_2021_FtrWind_SP
10	10_2021_FtrWind_WP
11	11_2021_FtrWind_SL

3.2 Power Flow Analysis

Power flow analyses were conducted under steady state conditions for Category A conditions and Category B and selected Category C3 contingencies. The Category B and Category C3 contingencies were selected to identify thermal overloads and voltage criteria violations on the 72 kV and above transmission system in the PENV area. These analyses were performed for the need assessment prior to any new transmission development in the area to identify Alberta Reliability Standards violations and limiting elements.

Each of the alternative reinforcements considered to address identified violations was analyzed and compared on the same basis. Each of scenarios listed in Table 3-1 was included in the power flow analyses. The observed per cent thermal loading values shown in the result tables are as measured by current (amps) although the ratings are specified in terms of MVA.

4 Need Assessment

4.1 Need Prior to 2021

The AESO evaluated the PENV area performance over the past seven years to determine if the need for system reinforcement arises prior to 2021. The PENV area's recorded coincident summer and winter peak load from 2010 to 2017 is presented in Table 2-1.

Historically, the 138 kV transmission line 749L has been observed to carry high flows in real time as it transfers power from the southern part of the PENV Study Area to supply loads along the 749L and 7L749L transmission line. These loads are served through the following point-of-delivery substations: Killarney Lake 267S, Hayter 277S, Edgerton 899S, Briker 880S, Lloydminster 716S, Kitscoty 705S, and Hill 751S, as shown in Figure 4-1.

To assess the 749L performance under the historical recorded load, the coincident summer peak (SP) and winter peak (WP) MW and MVA loads of these seven substations were extracted from historical recorded data and are presented in Table 4-1.

Table 4-1: Historical Coincident Peak Load Along the 749L/7L749 Path to Vermilion Substation

Year	Total Load (MVA)*		Total Load (MW)*		749L Line Rating (MVA)		Estimated Loading Post-contingency (%) **	
	SP	WP	SP	WP	SP	WP	SP	WP
2010	125.2	133.3	113.0	126.1	121	149	103	89
2011	124.0	134.8	113.5	135.5	121	149	102	90
2012	130.8	141.9	120.1	130.9	121	149	108	95
2013	130.9	141.3	122.4	134.2	121	149	108	95
2014	128.4	141.7	118.0	130.4	121	149	106	95
2015	130.8	137.3	119.3	120.3	121	149	108	92
2016	115.6	123.7	109.4	118.3	121	149	95	83
2017	114.1	118.9	103.2	108.0	121	149	94	80

*****Loads of seven substations along the 749L/7L749 path: Kitscoty 705S, Hill 751S, Lloydminster 716S, Briker 880S, Edgerton 889S, Killarney Lake 267S, and Hayter 227S.

** For outage of 7L130

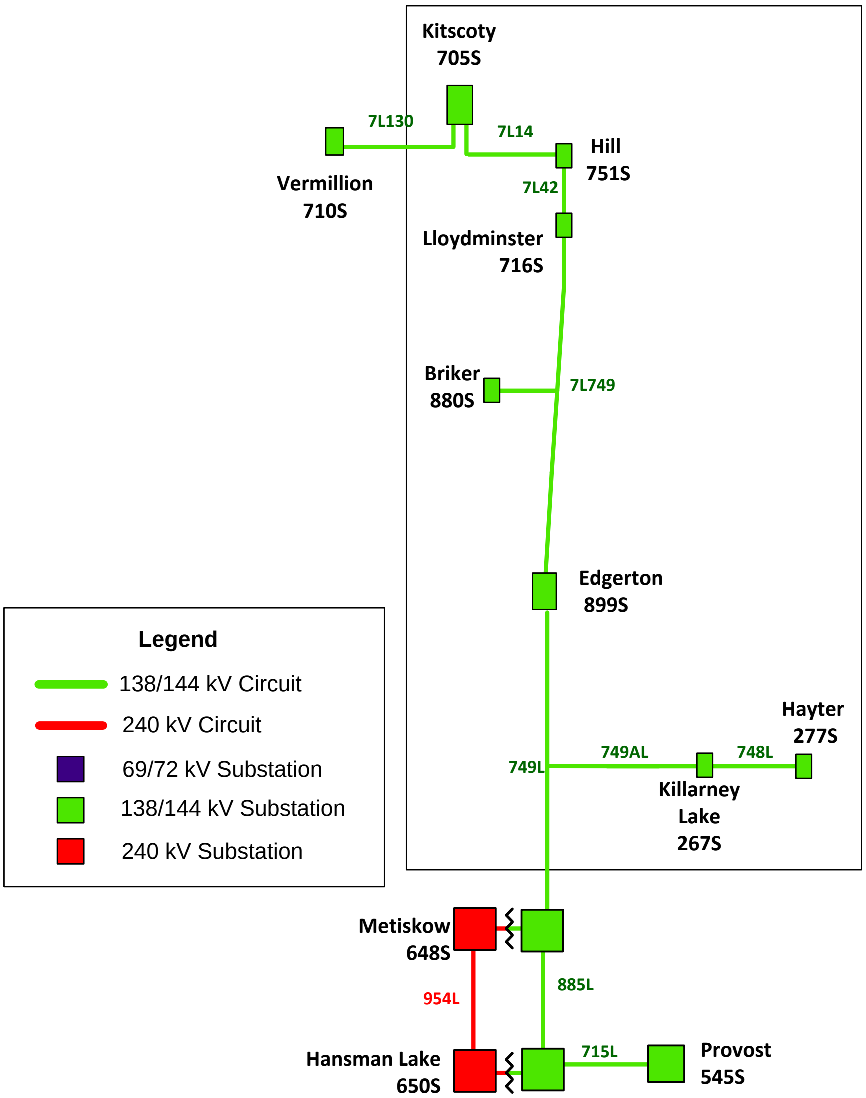
As was indicated in Table 2-1 in Section 2 of this report, the PENV area summer peak load increased from 371 MW in 2010 to a peak value of 426 MW in 2015 and dropped to 423 MW by 2017.

From the load data represented in Table 4-1 above, the following could be concluded:

- The summer peak load growth pattern along 749L is similar to that of PENV area. It may be noted that the load along 749L is about 33% of the PENV area peak load. Furthermore, there is a good correlation between summer peaks of PENV area and 749L path load. However, the load dropped by nearly 16.7 MW along 749L over the past two years while only 3 MW load dropped in the entire PENV area. This load could recover as it did historically between 2011-2012 and 2012-2013.
- When 7L130 goes out of service, 749L would be overloaded to 102% to 108% of its continuous summer thermal rating in 6 out of 8 recent past years.

- Due to the drop (approximately 16.8 MW) of summer peak load along 749L in 2016 and 2017, the post-7L130 outage loading on 749L reaches just below the maximum continuous 100% rating at 95% and 94% respectively.
- The system performance was reliable during winter season due to the transmission lines have higher winter rating.

Figure 4-1: 749L Vermilion-Hansman Lake Line Path



Pre-contingency operational measures were used to manage potential thermal violations along the existing 7L749/749L path all the way north towards Vermilion 710S substation along 7L130 transmission line(currently de-rated) as well. Based on historical performance coupled with the fact that operators continue to use of operational measures to manage thermal violations in the PENV area including 749L Path indicates the system is still weak and prone to over loads should the load forecast picks up in the area as anticipated under 2018 forecast. Thermal criteria violations are observed once the loads along the 7L749/749L exceed its continuous thermal rating of 121 MVA. Even with the recent decline in load, the loading on 749L under Category B (N-1) conditions is still quite high at 95% to 98% of continuous summer rating, which indicates the need for immediate transmission development in the area from a purely load supply perspective. Thus, the 749L path will be subject to thermal overloads independent of generation dispatch.

4.2 Load Based Need Assessment – Near Term (2021)

Using the updated load and generation forecast, the AESO conducted power flow analyses on the existing system to identify Reliability Criteria violations in the PENV area. The need assessment was carried out for the system in the near term.

Using the study scenarios described in Table 3-1, the need assessment studies were conducted to identify Reliability Criteria violations in the PENV area under Category A conditions and Category B contingencies. The study scenarios with zero wind (Scenarios 1-4) and generation based conditions associated (N-G)[11] conditions were utilized for this purpose as these scenarios stress the PENV area system.

The sections below summarize the need assessment results for the 2021 study year. The maximum observed loading for each monitored system element and the worst observed loading violations for each major contingency are reported. Detailed need assessment results and single line diagrams (SLDs) are provided in Appendix A.

4.2.1 Existing System

4.2.1.1 Category A Analysis

The near term (2021) steady-state performance of the transmission system in the Study Area shows no thermal or voltage violations under Category A conditions.

4.2.1.2 Category B Analysis

The power flow study results under Category B contingencies are provided in Table 4-2 for thermal performance and Table 4-3 for voltage performance. These tables show that 749L and 7L50 would experience thermal overloads as high as 107% and 105% respectively in the near term with the existing system. Additionally, these transmission lines are loaded to 95% and above under several scenarios as indicated in Table 4-2. There are also low voltage violations observed along the 7L749 path. The full list of observed thermal loading and voltage violations for all scenarios is provided in Appendix A.

[11] N-G denotes a scenario with a critically located generating unit out of service

Table 4-2: Summary of Category B Thermal Loadings (2021)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
749L (648s Metiskow - 267s Killarney Lake Tap)	7L129	01_2021_SP	138	120.9	119.9	95.7
		01_2021_SP_859S	138	120.9	125.2	**100.0**
	7L130	01_2021_SP	138	120.9	132.8	**106.1**
		01_2021_SP_757S_G5	138	120.9	132.8	**106.1**
		01_2021_SP_859S	138	120.9	132.8	**106.1**
		02_2021_SP_757S_G5	138	120.9	127.0	**102.4**
		02_2021_SP_859S	138	120.9	127.0	**102.4**
		03_2021_WP	138	148.9	143.3	97.2
		03_2021_WP_757S_G5	138	148.9	143.3	97.2
		03_2021_WP_859S	138	148.9	143.3	97.2
		04_2021_WP	138	148.9	143.3	97.2
		04_2021_WP_757S_G5	138	148.9	143.3	97.2
		04_2021_WP_859S	138	148.9	143.3	97.2
		02_2021_SP	138	120.9	127.0	**102.4**
	7L14	01_2021_SP	138	120.9	129.1	**103.1**
		01_2021_SP_757S_G5	138	120.9	129.1	**103.1**
		01_2021_SP_859S	138	120.9	129.2	**103.1**
		02_2021_SP_757S_G5	138	120.9	122.4	98.6
		02_2021_SP_859S	138	120.9	122.4	98.6
		02_2021_SP	138	120.9	122.4	98.6
	7L50	01_2021_SP	138	120.9	128.5	**102.7**
		01_2021_SP_757S_G5	138	120.9	120.9	96.6
		01_2021_SP_859S	138	120.9	133.8	**107.1**
		03_2021_WP_859S	138	148.9	147.3	96.3
7L50 (526s Buffalo Creek - 252s Jarrow Tap)	749L	01_2021_SP	138	109.3	110.7	98.3
		01_2021_SP_859S	138	109.3	117.3	**105.0**
	7L749	01_2021_SP_859S	138	109.3	111.1	98.3
7L749 (899s Edgerton - 267s Killarney Tap)	7L130	03_2021_WP	138	96.0	92.5	97.3
		03_2021_WP_757S_G5	138	96.0	92.5	97.4
		03_2021_WP_859S	138	96.0	92.5	97.3
		04_2021_WP	138	96.0	92.5	97.3
		04_2021_WP_757S_G5	138	96.0	92.5	97.3
		04_2021_WP_859S	138	96.0	92.5	97.3
	7L50	03_2021_WP_859S	138	96.0	94.3	97.7

Table 4-3: Summary of Category B Voltage Violations (2021)

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
749L	716s Lloydminster (138kV)	04_2021_WP_859S	1.123	0.942	0.933
	751s Hill (138kV)	04_2021_WP_859S	1.123	0.942	0.935
	880s Briker (138kV)	04_2021_WP_859S	1.123	0.942	0.924
7L130	705s Kitscoty (138kV)	04_2021_WP	1.123	0.942	0.924
	716s Lloydminster (138kV)	04_2021_WP	1.123	0.942	0.927
	751s Hill (138kV)	04_2021_WP	1.123	0.942	0.926
	880s Briker (138kV)	04_2021_WP	1.123	0.942	0.934

4.3 Generation Based Need Assessment – Near Term (2021)

This section presents the summary of need assessment studies for the scenarios with renewables generating additions. This analysis is further divided into two parts;

i. Immediate Generation Stress Scenarios; this assessment summarizes Reliability Criteria violations for the scenario of all existing wind and renewable projects selected in REP1.

ii. Near-Term Generation Stressed Scenario; this assessment summarizes reliability assessment results with additional renewable generation projects expected with REP2 (300 MW of procurement) and REP3 (400 MW of procurement), by 2021.

For clarity, Table 4-4 summarizes wind modeled in the near-term scenarios.

Table 4-4: Summary of Renewable Generation (Wind) used in Near-term Study Scenarios (2021)

Description	Central East Sub-region Renewables (MW)				Total wind in Alberta (MW)
	Existing Wind	REP-1 projects	REP-2 & 3 projects	Total wind in Central East Sub-region	
Existing wind plus REP-1 projects Study scenarios 5-8, Year 2019	262	248.5	0	510.5	2065
Existing wind plus REP-1, REP-2 and 3 projects Study scenarios 9-11, Year 2021	262	248.5	200*	710.5	2865

* Conservatively assuming only 200 MW out of total REP renewable generation procurements over 2020 and 2021 will be integrated in Central east region.

4.3.1 Immediate Generation Stress Scenario

In these scenarios, the awarded REP1 wind generation projects are modelled as per their respective approved capacities and locations (refer to Table 4-4). Although this is a 2021 assessment, the condition of existing wind plus REP1 wind projects represent the year 2019. The system performance with REP2

(300 MW of procurement) and REP3 (400 MW of procurement) projects are addressed below, to show the bottlenecks that are observed by 2021.

4.3.1.1 Category A Analysis

Neither overloads nor voltage violations were observed under system normal conditions for high generation conditions (Scenarios 5, 6, 7 and 8 and associated N-G scenarios).

4.3.1.2 Category B Analysis

Table 4-5 summarizes thermal loading in the PENV area that exceeded 95% of line ratings. Table 4-6 summarizes voltage violations in the PENV area. The full set of Category B results are provided in Appendix A.

Table 4-5 Summary of Thermal Loading in the PENV Area

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
701L (395s North Holden - 223s Strome)	EATL	05_2021_SP_ExWind_859S	138.0	119.0	121.3	99.1
7L129 (526s Buffalo Creek - 918s Bauer Tap)	EATL	05_2021_SP_ExWind_859S	138.0	109.2	105.6	96.0
7L50 (526s Buffalo Creek - 252s Jarrow Tap)	749L	05_2021_SP_ExWind	138.0	109.3	112.1	**101.1**
		05_2021_SP_ExWind_859S	138.0	109.3	120.6	**109.6**
	766S901T	05_2021_SP_ExWind_859S	138.0	109.3	110.5	99.5
	7L749	05_2021_SP_ExWind	138.0	109.3	106.7	95.2
		05_2021_SP_ExWind_859S	138.0	109.3	115.3	**103.6**
	912L	05_2021_SP_ExWind_859S	138.0	109.3	110.2	99.2
	EATL	05_2021_SP_ExWind	138.0	109.3	117.4	**105.2**
		05_2021_SP_ExWind_859S	138.0	109.3	124.0	**111.9**
7L701 (223s Strome - 764s Heisler Tap)	EATL	05_2021_SP_ExWind	138.0	139.1	143.4	97.0
		05_2021_SP_ExWind_859S	138.0	139.1	148.9	**100.9**
7L701 (757s Battle River - 764s Heisler Tap)	EATL	05_2021_SP_ExWind_859S	138.0	139.0	143.6	97.3
7L749 (899s Edgerton - Tap 267s Killarney)	7L129	07_2021_WP_ExWind_859S	138.0	96.0	93.6	96.7
	7L130	07_2021_WP_ExWind	138.0	96.0	92.6	97.6
		07_2021_WP_ExWind_757S_G5	138.0	96.0	92.6	97.7
		07_2021_WP_ExWind_859S	138.0	96.0	92.6	97.6
		08_2021_WP_ExWind	138.0	96.0	92.6	97.9
		08_2021_WP_ExWind_757S_G5	138.0	96.0	92.6	97.8
		08_2021_WP_ExWind_859S	138.0	96.0	92.6	97.9
	7L50	05_2021_SP_ExWind_859S	138.0	96.0	93.2	96.7
		07_2021_WP_ExWind	138.0	96.0	96.2	99.9
		07_2021_WP_ExWind_859S	138.0	96.0	102.8	**107.2**
	EATL	07_2021_WP_ExWind_859S	138.0	96.0	95.3	99.2
7L749 (899s Edgerton - Tap 880s Briker)	7L50	07_2021_WP_ExWind_859S	138.0	96.0	94.3	99.8

Table 4-6: Voltage Criteria Violations

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
749L	705s Kitscoty (138 kV)	07_2021_WP_ExWind_859S	1.123	0.942	0.942
	716s Lloydminster (138 kV)	07_2021_WP_ExWind_859S	1.123	0.942	0.930
	751s Hill (138 kV)	07_2021_WP_ExWind_859S	1.123	0.942	0.932
	880s Briker (138 kV)	07_2021_WP_ExWind_859S	1.123	0.942	0.921
7L130	705s Kitscoty (138 kV)	08_2021_WP_ExWind	1.123	0.942	0.915
	716s Lloydminster (138 kV)	08_2021_WP_ExWind	1.123	0.942	0.917
	751s Hill (138 kV)	08_2021_WP_ExWind	1.123	0.942	0.916
	880s Briker (138 kV)	08_2021_WP_ExWind	1.123	0.942	0.926

4.3.2 Near-Term Generation Stressed Scenarios

Under study scenarios 9 through 11 it is assumed that approximately 400 MW of additional renewable generation will be in service per year in 2020 and 2021. These projects are assumed to be distributed as per the locational pattern used for REP1 in alignment with the market interest and the proven wind (and solar) rich resource potential in the Central East sub region, southeast and southwest areas of Alberta. Distribution is expected to continue in this pattern in the future in order to utilize the existing transmission system capacity efficiently in the Southeast and Southwest Alberta regions.

- Pemukan: 200 MW (Hanna area system integration)
- Southeast: 300 MW (Bowmanton – Cassils –Bowmanton -Whitla (CBW) path)
- Southwest: 300 MW (North Lethbridge, Windy Flats)

4.3.2.1 Category A Analysis

No Reliability Criteria violations were observed under system normal conditions in the Study Area. However the Category A (N-0) loading along the 7L50 path reaches 92%.

4.3.2.2 Category B Analysis

A large number of thermal overloads exceeding 100% of continuous seasonal ratings were observed, a selection of those observed are presented in Table 4-7. For the sake of condensing the results the N-G cases have been omitted from the table. It is to be noted that when Primrose is out of service (N-G) condition, observed thermal criteria violations are exacerbated. Table 4-8 contains voltage violations. Details regarding all thermal loading and voltage violations in all studied scenarios are provided in Appendix A.

Table 4-7: Selected Thermal Overloads in the Near Term (2021)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
174L (197s Bardo - 395s North Holden)	766S901T	10_2021_WP_FtrWind	138	90.1	98.8	**112.9**
	912L	10_2021_WP_FtrWind	138	90.1	98.5	**112.4**
	EATL	10_2021_WP_FtrWind	138	90.1	88.8	**100.5**
701L (395s North Holden - 223s Strome)	766S901T	09_2021_SP_FtrWind	138	119.0	133.3	**110.6**

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
		10_2021_WP_FtrWind	138	146.0	160.9	**111.4**
	912L	09_2021_SP_FtrWind	138	119.0	133.1	**110.4**
		10_2021_WP_FtrWind	138	146.0	160.8	**111.2**
	EATL	09_2021_SP_FtrWind	138	119.0	138.5	**113.6**
		10_2021_WP_FtrWind	138	146.0	157.9	**107.2**
704L (478s Tucuman - 51s Wainwright Tap)	749L	10_2021_WP_FtrWind	138	79.0	85.7	**106.3**
	7L749	10_2021_WP_FtrWind	138	79.0	81.5	**100.9**
	EATL	10_2021_WP_FtrWind	138	79.0	85.5	**105.9**
766s 901T 240/144kV (766s Nevis)	9L20	09_2021_SP_FtrWind	240	100.0	102.9	**102.9**
		10_2021_WP_FtrWind	240	100.0	122.9	**122.9**
7L129 (526s Buffalo Creek - 918s Bauer Tap)	749L	09_2021_SP_FtrWind	138	109.2	111.2	**101.8**
	EATL	09_2021_SP_FtrWind	138	109.2	111.7	**101.8**
7L50 (526s Buffalo Creek - 252s Jarrow Tap)	749L	09_2021_SP_FtrWind	138	109.3	129.6	**117.8**
		10_2021_WP_FtrWind	138	139.0	147.2	**107.6**
	766S901T	09_2021_SP_FtrWind	138	109.3	124.7	**113.3**
		10_2021_WP_FtrWind	138	139.0	142.6	**104.0**
	7L42	09_2021_SP_FtrWind	138	109.3	112.2	**100.2**
	7L701 \ 701L	09_2021_SP_FtrWind	138	109.3	113.7	**102.0**
	7L749	09_2021_SP_FtrWind	138	109.3	124.5	**111.9**
		10_2021_WP_FtrWind	138	139.0	143.0	**102.1**
	912L	09_2021_SP_FtrWind	138	109.3	124.4	**113.0**
		10_2021_WP_FtrWind	138	139.0	142.3	**103.7**
	9L20	09_2021_SP_FtrWind	138	109.3	117.8	**106.5**
	EATL	09_2021_SP_FtrWind	138	109.3	130.3	**117.7**
		10_2021_WP_FtrWind	138	139.0	143.4	**103.2**
7L701 (223s Strome - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind	138	139.1	160.6	**110.6**
		10_2021_WP_FtrWind	138	169.0	187.9	**107.9**
	912L	09_2021_SP_FtrWind	138	139.1	160.4	**110.4**
		10_2021_WP_FtrWind	138	169.0	187.9	**107.7**
	9L20	09_2021_SP_FtrWind	138	139.1	146.2	**100.2**
	EATL	09_2021_SP_FtrWind	138	139.1	167.8	**113.5**
		10_2021_WP_FtrWind	138	169.0	186.1	**104.4**
7L701 (757s Battle River - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind	138	139.0	157.4	**106.3**
	912L	09_2021_SP_FtrWind	138	139.0	155.4	**105.0**
	9L20	09_2021_SP_FtrWind	138	139.0	151.8	**102.5**
	EATL	09_2021_SP_FtrWind	138	139.0	161.8	**109.5**
7L749 (899s Edgerton - Tap 267s Killarney)	766S901T	10_2021_WP_FtrWind	138	96.0	102.3	**107.1**
	7L129	10_2021_WP_FtrWind	138	96.0	110.3	**114.7**

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
	7L50	09_2021_SP_FtrWind	138	96.0	102.4	**106.0**
		10_2021_WP_FtrWind	138	96.0	119.1	**125.2**
	912L	10_2021_WP_FtrWind	138	96.0	102.1	**106.8**
	9L20	10_2021_WP_FtrWind	138	96.0	99.3	**103.5**
	EATL	10_2021_WP_FtrWind	138	96.0	108.4	**113.7**
7L749 (899s Edgerton - Tap 880s Briker)	7L129	10_2021_WP_FtrWind	138	96.0	102.1	**107.4**
	7L50	10_2021_WP_FtrWind	138	96.0	109.4	**117.5**
	EATL	10_2021_WP_FtrWind	138	96.0	99.0	**106.0**
912L (766s Nevis - 63s Red Deer)	EATL	09_2021_SP_FtrWind	240	488.0	538.2	**108.0**
9L20 (755s Cordell - 766s Nevis)	EATL	10_2021_WP_FtrWind	240	498.0	531.5	**105.8**

Table 4-8: Voltage Violations in the Near Term (2021)

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
749L	705s Kitscoty (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.891
	710s Vermilion (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.941
	716s Lloydminster (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.872
	751s Hill (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.874
	880s Briker (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.861
	899s Edgerton (138kV)	10_2021_WP_FtrWind_859S	1.101	0.898	0.854
	918s Bauer (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.940
7L130	705s Kitscoty (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.921
	716s Lloydminster (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.924
	751s Hill (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.923
	880s Briker (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.932
7L50	880s Briker (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.938
EATL	880s Briker (138kV)	10_2021_WP_FtrWind_859S	1.123	0.942	0.942

4.4 Generation Curtailment Required to Maintain System Reliability

Transmission system constraints (Thermal violation primarily) demonstrated in Section 4.3 will be managed in the interim and prior to future transmission enhancements in the PENV area via RAS utilization and in accordance with Section 302.1 of the ISO rules, *Real Time Constraint Management* (TCM Rule). The RASs that are being used to mitigate certain existing constraints in the Study Area, are listed below:

1. Battle River 7L50 and 7L701 Thermal Protection Scheme (TPS)
2. RAS #134: 174L–395S North Holden overload mitigation scheme
3. RAS #138: 7L50–526S Buffalo Creek overload mitigation scheme
4. RAS #139: 901T–766S Nevis overload mitigation scheme

5. HVDC RAS: EATL RAS for 912L and 9L20 contingencies

The assessment that follows focuses on RAS #138 to alleviate numerous overloads on 7L50 as it relates directly to the limited transmission system capability in the PENV area.

4.4.1 RAS #138: 7L50–526S Buffalo Creek Overload Mitigation Scheme

Transmission line loading on 7L50 is measured at the Buffalo Creek 526S end and operation of the RAS generation curtailment stops when loading on 7L50 drops to 95%. Whenever the loading on 7L50 line gets overloaded, 704L will be opened at Jarrow and generation curtailment via telemetry signals at the existing Halkirk wind farm will start and will continue until the loading on 7L50 to 95% of its rated capacity.

When is considered that new wind farms are curtailed as per in-service date (ISD), then the last wind farm that becomes operational will be curtailed first in sequence followed by the second-last and so on until generation curtailment is adequate to bring the load on 7L50 to 95% of its rating. This process has been used below to estimate the amount of renewable (wind) generation curtailed in the Central East Sub-region. The sequence of curtailment is described below

During either under normal or emergency conditions (i.e., whenever the loading on 7L50 exceeds 95%):

Step 1: Open 704L

Step 2: Curtail Generation along the Hanna 240 kV system (modeled at Pemukan 932S)

Step 3: Curtail Sharp Hills Generation (REP1 awarded)

Step 4: Curtail Halkirk Generation (existing)

Check status after each step, and if the loading on 7L50 drops to 95% or below, then stop.

If 7L50 is still above 95% after Step 4, then more generation will be curtailed to ensure reliable operation before further adjustment are made operational to substitute curtailed generation as well as prepare for subsequent contingency. For the purpose of estimating the amount of additional generation to be curtailed, Battle River 4 and Battle River 5 will be considered as needed. In practice, these coal units are runback for RAS #138. Therefore, detailed studies will have to be carried out to determine effective units and their respective contributions for reduction of overload on 7L50.

Since the focus of this study is the 7L50 RAS, it should be noted that the overloads on 7L50 are well over 110% for the condition with all future renewables in service by 2021. In the near term, 7L50 gets overloaded well over 95% under several contingencies of EATL, 9L20; 912L, 749Land the 766S901T transformer)) in both SP and WP load conditions (see Table 4-7).

Table 4-9: Generation Curtailment and Loading on 7L50 - Scenario 09_2021_SP_FtrWind_859S

Steps used per RAS Order	Event	RAS Action	Initial Gen. Output	Total RAS Generation Curtailed (MW)	Curtailment Exceeding 466 MW Threshold	7L50 @ Buffalo Creek below 95%?	7L50 Loading
	N-0			0			92%
	EATL Outage			0			126%
1	EATL Outage	704L Opening		0			108%
2	EATL Outage	Curtail Pemukan Wind Generation	184	184	No	No	105%
3	EATL Outage	Curtail Sharp Hills 1	114.3	298.3	No	No	104%

Steps used per RAS Order	Event	RAS Action	Initial Gen. Output	Total RAS Generation Curtailed (MW)	Curtailment Exceeding 466 MW Threshold	7L50 @ Buffalo Creek below 95%?	7L50 Loading
		Generation					
4	EATL Outage	Curtail Sharp Hills 2	114.3	412.6	No	No	102%
5	EATL Outage	Curtail Halkirk 2	67.6	480.2	14.2 MW	No	100%
6	EATL Outage	Curtail Halkirk 1	70.4	550.6	84.6 MW	No	98%
7	EATL Outage	Curtail Battle River 4 (proxy)	144.3*	594.8	128.8 MW	Yes	95%

Note: In order to show the amount of generation to be shed, BR#4 was used as a proxy for other renewable generators. It was run back 45MW to clear the RAS #138.

The amount of generation that must be curtailed for reliable operation following the Category B (N-1) contingency varies from one contingency to another. The generation curtailment process is illustrated on one "worst" overload on 7L50 that was observed during SP under high wind conditions with the Primrose unit out of service. Generation curtailments for other contingencies are also presented below for the existing wind conditions for the scenario: 09_2021_SP_FtrWind_859S.

Table 4-10: Generation Curtailment required to alleviate Constraints on 7L50 for Different Contingencies :Scenario 09_2021_SP_FtrWind_859S

Name of Contingency	Loading on 7L50 (%)	Generation to be Curtailed (MW)
N-0	92	0
749L	128	570.6
7L701	111	184
912L	121	298.3
9L20	115	184
EATL	126	594.8

4.5 Sensitivity Study

A sensitivity study was carried out to find the break point (overloads on the PENV area lines) under Category A (N-0) conditions as number of renewables projects continue to increase in the system to meet 5,000 MW target level by 2030. Accordingly, another 400 MW of renewable generation was added to 2021 levels to formulate 2022 study cases in the Central East Sub-region as shown in Table 4-11. In order to balance the generation, the corresponding equivalent amount of conventional generation in Fort McMurray and Wabamun areas was scaled down. The locational assumptions for renewables follow a similar pattern to what was observed for REP1.

Table 4-11: 400 MW Wind Generation Capacity Added to make 2022 Wind Cases

Location of Renewable Generation added to 2022	Wind Capacity (MW)
Tinchebray 972S	100
Windy Flats 138S	150
Jenner 972S	150

4.5.1 Category A Analysis

Power flow simulations with the above assumptions of renewable resource locations show that 7L50 gets overloaded under Category A (N-0) conditions as shown in Table 4-12. In spite of maximum utilization of EATL, the 7L50 transmission line gets congested under system normal conditions – which further indicate lack of transmission capacity in the PENV area.

Table 4-12: Overloads on 7L50 under Category A (N-0) Conditions in 2022

Element	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
7L50 (526S Buffalo Creek - Jarrow Tap)	09_2022_SP_FtrWind_859S	138	109.3	120.2	**106.7**
	09_2022_SP_FtrWind	138	109.3	110.4	98.2

4.5.2 Category B Analysis

The thermal overloads on 7L50 and 7L749 for a few critical contingencies (for demonstration purposes) are presented below. At least five contingencies stress 7L50 well over 140% of its current rated capacity. 7L749 is equally got overloaded for the loss of 7L50.

Table 4-13: Thermal Overloads on 7L50 and 7L49

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
7L50 (526S Buffalo Creek - Jarrow Tap)	749L	09_2022_SP_FtrWind_859S	138	109.3	160.5	**146.8**
	766S901T	09_2022_SP_FtrWind_859S	138	109.3	155.4	**144.6**
	7L749	09_2022_SP_FtrWind_859S	138	109.3	156.3	**141.1**
	912L	09_2022_SP_FtrWind_859S	138	109.3	155.1	**144.2**
	EATL	09_2022_SP_FtrWind_859S	138	109.3	154.9	**143.6**
7L749 (899s Edgerton - Tap 267s Killarney)	7L50	10_2022_WP_FtrWind_859S	138	96.0	131.7	**140.2**

4.6 Summary of Near-Term Conclusions

The PENV area system currently has limited capacity to serve its local load, integrate local generation or accommodate planned future renewable generation in the greater Central East Sub-region south of PENV. Local load serving reliability violations were demonstrated under load-stressed scenarios along both the 7L50 and 749L transmission paths in the very near term.

From Table 4-2, it is clear that even under a lower PENV area load forecast, thermal violations are still anticipated along the two main transmission lines in the PENV area: 749L and 7L50 as a result of the loss of the other main supply line in PENV. Voltage violations are also observed as demonstrated in Table 4-3 along the 7L749/749L path due to the load concentration along that lengthy path stretching between Metiskow 648S in the South and Vermilion 710S substation in the north. As the load continues to grow beyond the near term, the observed violations will be exacerbated overtime. Moreover, either even small

Load DTS increase along any of the three paths into the PENV area or small changes in generation dispatch in the Battle River area will lead to significantly higher overloads than demonstrated in Table 4-2.

The demonstrated overloads and voltage violations continue to indicate the need for transmission development in the PENV area despite the fact that peak load for the near term is expected to be below what has historically occurred along the 749L path over the past few years (2012 to 2015). Historical load levels of those years will lead to significantly higher overloads as demonstrated in the 2016 Planning Studies.

As demonstrated in Section 4.3 and from generation integration capability perspective and as more generation is integrated in the Central East Sub-region, heavy overloads are expected inside the PENV area under a large number of contingencies. Thermal criteria violations reaching up to 126% under contingency conditions and up to 92% under system normal operating conditions are expected by 2021, before the planned PENV reinforcement is in place.

Significant generation curtailments, to manage system reliability under either Category B (N-1) or Category A (N-0) conditions, are expected in the Central East Sub-region (both existing and future) before the planned PENV transmission reinforcement is in place, Section 4.4. These curtailments which will rapidly grow with increase in future generation additions to approach and even exceed the current MSSC threshold of 466 MW (see Table 4-9 and Table 4-10). Once the MSSC is exceeded, potential Category A (N-0) reduction to either the WECC Path 1 (AB-BC) or WECC Path 83 (AB-MATL intertie) available transfer capability (ATC) or local central region generation would be required to ensure reliable operation beyond the current MSSC threshold level of 466 MW. By 2021, it will be necessary to curtail about 592 MW of generation to manage overloads on 7L50 under a single contingency, which will exceed the current MSSC threshold.

From a generation capability and integration perspective, the PENV area requires reinforcement to enhance its capability to integrate generation locally in the PENV area as well as allow for higher renewable generation to efficiently utilize the Hanna transmission system south of PENV as a collector system. Enhancing the transmission capability in the PENV area will enable the generation in the Central East Sub-region to be consumed locally within the PENV area without Category A (N-0) and un-manageable Category B (N-1) constraints before any surplus generation is transferred to neighboring load centers outside the Central East Sub-region.

The system performance as demonstrated in the near-term analysis sections above illustrate a clear need for immediate transmission system reinforcements in the PENV area. The PENV area transmission capability is not adequate to meet the load serving requirements in the area, the generation integration outside the PENV area as well as lack of transmission wires capacity locally to integrate generation in the PENV area itself.

4.7 Need Assessment Results – Long Term (2037)

4.7.1 Load Based Need

4.7.1.1 Category A Analysis

No Reliability Criteria violations were observed.

4.7.1.2 Category B Analysis

The following section presents the thermal violations and voltage violations observed under Category B contingencies. During WP load conditions, voltage collapse was observed for the loss of 749L. This happens because all remaining five substation loads (Kitscoty, Hill, Lloydminster, Briker and Edgerton) will have to be fed radially from Vermilion 710S substation along 7L130, 7L749 and 749AL tap and do not have proper VAr support. This voltage collapse could occur sooner than 2037 if load along the 7L749 path grows to 90 MW which is possible by a single load POD addition along that path in the future.

Table 4-14: Thermal Overloads in the PENV Area in the Long Term (2037)

Element	Contingency	Scenario	Rating (MVA)	Flow (MVA)	Loading (%)
757S 912T 240 kV/144 kV (757S Battle River)	766S901T	03_2037_WP_859S	224	225.9	**100.9**
	953L	03_2037_WP_859S	224	226.2	**101.0**
	9L20	01_2037_SP_859S	224	234.2	**104.5**
704L (478S Tucuman – 51S Wainwright Tap)	757S912T	01_2037_SP_859S	75	79.1	**104.5**
	9L80	01_2037_SP_859S	75	79.1	**104.5**
7L749 (899S Edgerton - Tap 267S Killarney)	7L130	04_2037_WP	96	101.7	**105.7**
	7L50	03_2037_WP_859S	96	98.9	**102.1**
749L (648S Metiskow – 267S Killarney Lake Tap)	7L129	01_2037_SP_859S	120.9	132.3	**105.8**
	7L130	01_2037_SP_757S_G 5	120.9	125.8	**101.0**
	7L50	01_2037_SP_859S	120.9	141.5	**113.5**
7L50 (526S Buffalo Creek – 252S Jarrow Tap)	7L749	01_2037_SP_859S	109.3	117.0	**104.7**

Table 4-15: Voltage Violations in the Long Term (2037)

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V Observed (p.u.)
7L130	880s Briker (138kV)	04_2037_WP	1.123	0.942	0.940
	705s Kitscoty (138kV)	04_2037_WP	1.123	0.942	0.931
	751s Hill (138kV)	04_2037_WP_859S	1.123	0.942	0.933
	716s Lloydminster (138kV)	04_2037_WP_859S	1.123	0.942	0.933
7L701 \ 701L	223S Strome (138kV)	03_2037_WP_859S	1.123	0.942	0.932
749L	N/A	03_2037_WP_859S	N/A	N/A	Collapse

4.7.1.3 Conclusion

- Due to load growth of about 56 MW and 64 MW in the summer and winter peaks respectively from 2021 to 2037, the overloads on 749L and 7L50 are higher than in the near term plus a few more other lines get overloaded. The voltage performance is further degraded compared to the near term besides exhibiting voltage collapse under certain contingency conditions.
- These violations indicate the PENV system will continue to lack transmission capability to reliably serve load with the existing system.

4.7.2 Generation Based Need

In the long term, the total amount of renewable generation in the system is forecasted to be approximately 7,500 MW (New wind generation: 5,000 MW; solar power projects: 1,000 MW and existing wind: 1,465 MW). Power flow cases showed that a number of lines would be overloaded under system normal conditions based on the forecasted renewable additions in the long term. Most of the renewable projects are in the southern part of system. The surplus generation from the south will move through Central East Sub-region to other load centers in Edmonton area, Northeast and Cold Lake areas. Some of these Category A (N-0) overloads are presented in Table 4-16 and also shown in Figure 4-2.

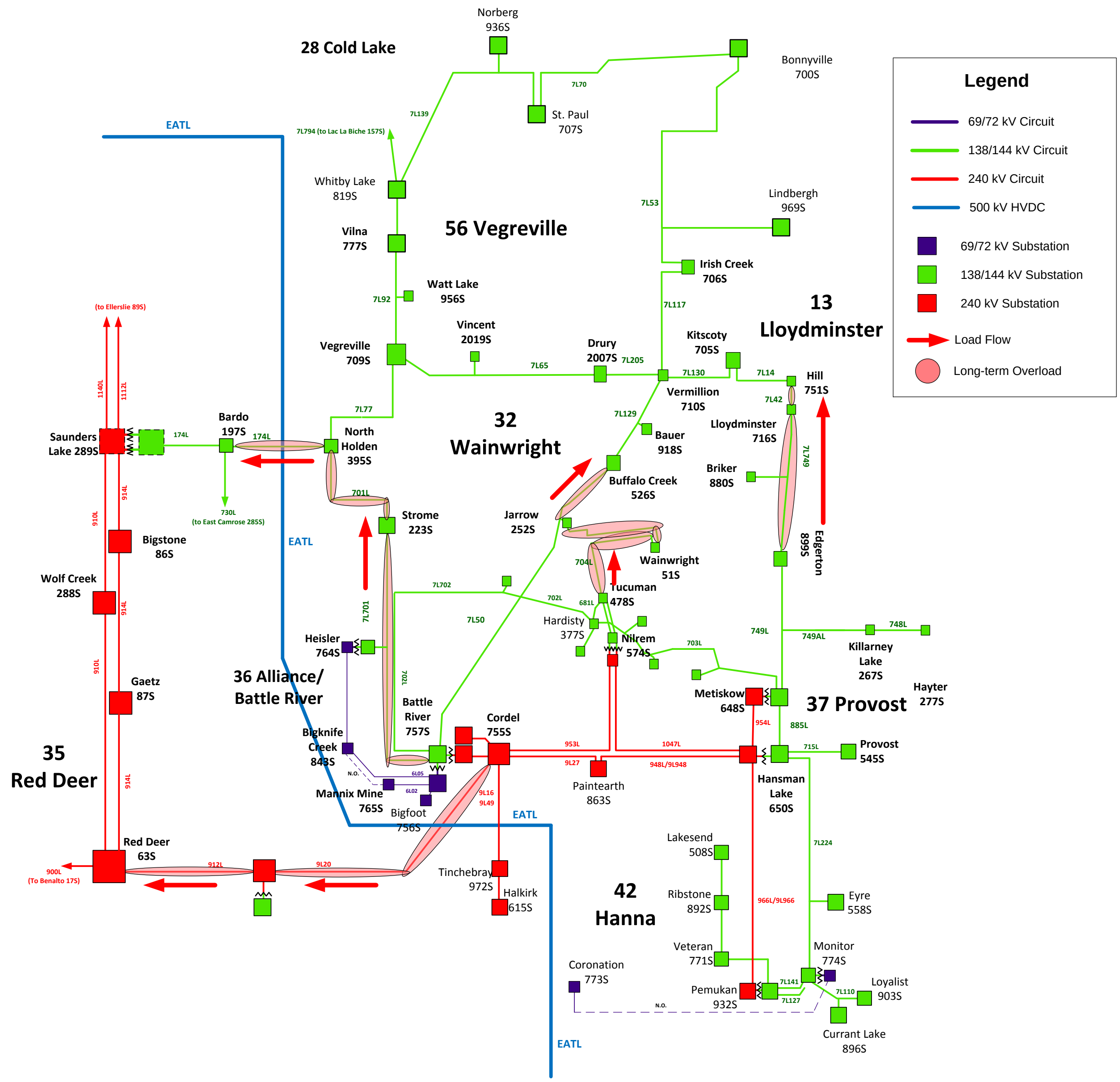
Since the existing system has no capacity to accommodate such large volume of generation under normal conditions, no Category B contingency analysis was carried out because these overloads will get worse and thus additional studies would add no material value to understanding the system performance.

Table 4-16: Thermal Overloads under Category A (N-0) System Conditions (2037)

Element	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
174L (197s Bardo - 395s North Holden)	11_2037_SL	138	85	98.1	**112.3**
	09_2037_SP	138	85	99.9	**124.1**
701L (221s Strome - 395s North Holden)	11_2037_SL	138	119	156.6	**128.0**
	09_2037_SP	138	119	162.8	**140.9**
701L/7L701 (221s Strome - Heisler Tap)	11_2037_SL	138	139	163.3	**112.5**
	09_2037_SP	138	139	196.3	**137.9**
7L701 (757s Battle River - Heisler Tap)	11_2037_SL	138	139	160.5	**109.0**
	09_2037_SP	138	139	195.4	**132.8**
704L (51s Wainwright - 478s Tucuman)	11_2037_SL	138	75	91.7	**118.4**
	09_2037_SP	138	75	107.4	**138.5**
	10_2037_WP	138	79	101.1	**121.1**
704L (51s Wainwright - 252s Jarrow)	11_2037_SL	138	75	78.2	**102.1**
	09_2037_SP	138	75	82.6	**111.2**
749L/7L749 (899s Edgerton - Briker Tap)	11_2037_SL	138	96	127.9	**128.6**
	09_2037_SP	138	96	142.9	**143.2**
	10_2037_WP	138	96	135.6	**131.4**
7L749 (710s Lloydminster- Briker Tap)	11_2037_SL	138	109	123.2	**106.9**
	09_2037_SP	138	109	128.9	**119.2**
7L42 (710s Lloydminster - 751s Hill)	11_2037_SL	138	94.9	102.5	**102.4**
	09_2037_SP	138	94.9	101.4	**107.9**
7L50 (526s Buffalo Creek - Jarrow Tap)	11_2037_SL	138	109	128.4	**113.7**
	09_2037_SP	138	109	150.1	**139.1**
912L/9L912 (63s Red Deer - 766s Nevis)	11_2037_SL	240	488	719.6	**147.8**
	09_2037_SP	240	488	755.0	**154.8**
	10_2037_WP	240	623	675.6	**106.9**
9L20 (755s Cordell - 766s Nevis)	11_2037_SL	240	488	663.4	**130.8**
	09_2037_SP	240	488	733.2	**141.0**
	10_2037_WP	240	498	657.4	**123.5**

Element	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
757s912T (757s Battle River 240/144 kV transformer	09_2037_SP	240/138	224	281.1	**118.5**
	10_2037_WP	240/138	224	267.1	**111.4**

Figure 4-2: Category A (N-0) Overloads with Renewable Generations in 2037



4.8 Impact of proposed new 138 kV line from Provost 545S to Hayter 277S (Project 1782)

The *Transmission Enhancements in the Municipal Districts of Provost and Wainwright Needs Identification Document* was filed with the AUC on February 13, 2018. The Preferred Transmission Development includes a 138 kV transmission line between the Provost and Hayter substations (Provost to Hayter line). Even with this Provost to Hayter line in service by May 1, 2020, the 749L line will be loaded to 99% close to its rated thermal rating for the loss of 715L as shown in Table 4-17 and Figure 4-3.

Figure 4-3: Proposed 138 kV line from Provost to Hayter Substations

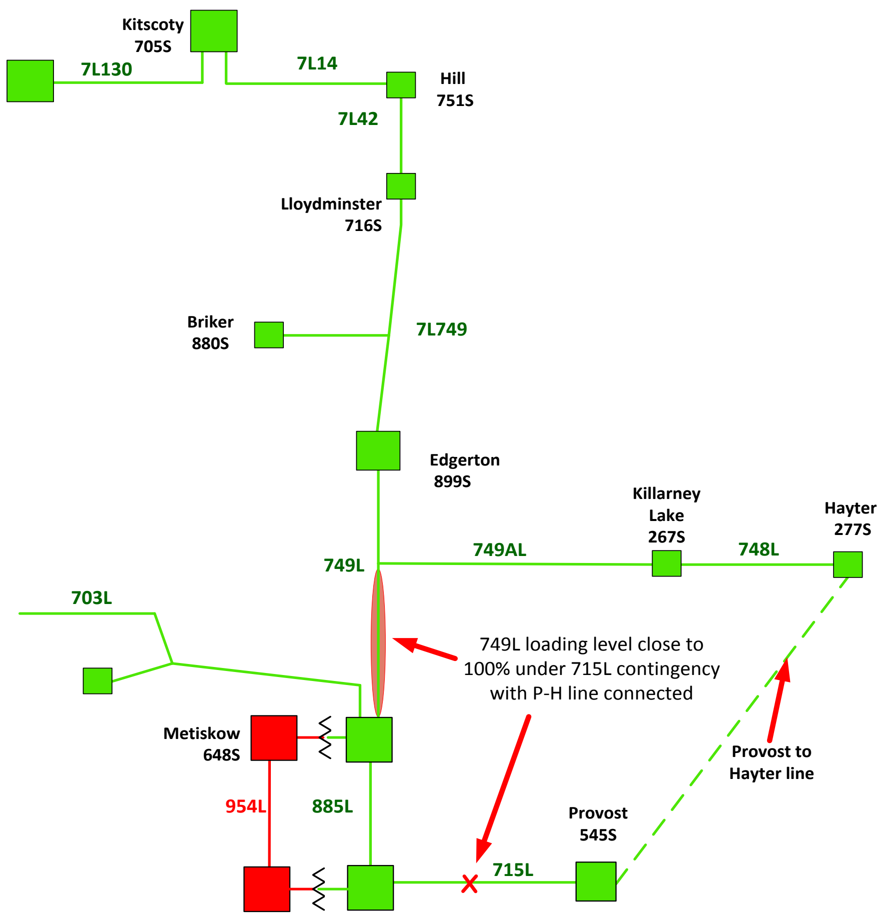


Table 4-17: Impact of Provost to Hayter line on 749L Reliability

Element	Contingency	Scenario	Rating (MVA)	Flow (MVA)	Loading (%)
749L (Metiskow to Killarney Lake Tap)	715L	01_2021_SP_757S_G5	121	116.2	92.9
	885L	01_2021_SP_859S	121	117.1	95.0
	715L	01_2021_SP	121	120.0	95.9
	715L	01_2021_SP_859S	121	123.5	98.7
	885L	01_2021_SP	121	113.9	92.3

A sensitivity study showed that 749L would be overloaded if load along the 749L path grows by a mere 3 MW, or 10 MW in the PENV area.

The addition of this line does not alter any Reliability Criteria violations under high wind scenarios in the near term. The violations reported in Section 4.3 still continue to exist with minute change in their magnitudes compared to the situation without this line. The wind generation capability at Edgerton is not affected by the proposed Provost to Hayter transmission line.

4.8.1 Conclusion

This Provost to Hayter line will not eliminate the need for transmission reinforcement along the 749L path. If the summer peak load increases by 3 MW, then 749L will experience overload for the loss of the 715L from Hansman Lake to Provost Substations. Whether the Provost to Hayter line is in service or not, the need for reinforcing the 749L path still exists to serve load and provide access to renewable generation in the area.

4.9 Outage Scheduling (N-1-1) concerns in the PENV area

As indicated in the 2016 Application, the PENV area is subject to significant operational challenges and scheduling maintenance outages in the area is currently very challenging[12]. To further demonstrate this, the AESO studied key conditions under which the PENV area gets subjected to significant Reliability Criteria violations in the Lloydminster (Area 13) and Vegreville (Area 56) areas even with proposed transmission line from Provost 545S to Hayter 277S in service (Project 1782).

- The 2021 summer peak (SP) and Winter Peak (WP) load condition was chosen to show thermal violations and voltage violations under N-1-1 conditions respectively. This is proven by historical area operational performance where requiring the formation of radials in the area to mitigate line overloads has led to multiple load loss incidents.
- During 2021 SP load conditions, when 7L77 is on outage, severe overloads exceeding emergency ratings on 7L50 will be possible. Accordingly, outages will not be possible to schedule without loss of load especially under subsequent forced outage conditions. During such instances, operators may have to rely on load shedding. Similarly, when the Battle River 757S substation breaker 709 is taken out for maintenance, then loss of 7L749 will overload 704L up to 140% and the loss of Metiskow 240 kV/138 kV tie transformer will overload 715L. During 2021 SP load conditions when 715L is out of service for maintenance, then loss of the Metiskow 240 kV/138 kV tie transformer causes voltage collapse in the Lloydminster area.
- Several Category C3 (N-1-1) contingencies cause voltage collapse in the Vegreville area and Lloydminster areas during winter peak load conditions as shown in Appendix A. For example, outage of the Whitby Lake breaker followed by loss of 7L77 results in voltage collapse in the Vegreville area. Such events pose serious challenges in real time operations and put the system reliability at major risk.

Power flow simulations were repeated for the same Category C3 (N-1-1) contingencies post implementation of the PENV preferred solution These PENV lines help eliminate overloads, open more

[12] 22274-X0162_ AESO rebuttal Evidence_0169.Pdf;

window for scheduling outages and reduce overall load shedding exposure during outage conditions and improve voltage performance; thereby, vastly improving the system operation in real time. It is safe to conclude that the preferred solution not only resolves Reliability Criteria violations under emergency conditions, but also aids in the ability to performing maintenance on facilities in the PENV area in a timely manner.

5 The AESO Preferred Transmission Development Alternative

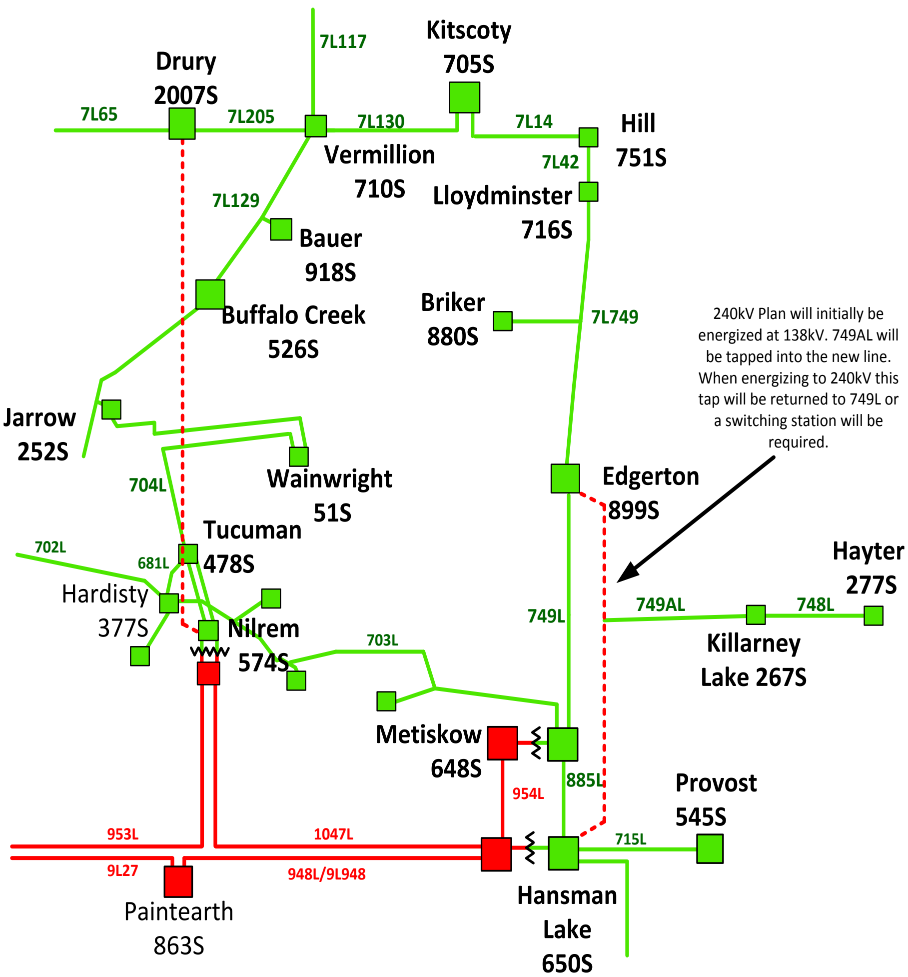
The Preferred Transmission Development described in the 2016 Application remains the AESO's preferred option to meet the need identified above.

5.1 Preferred Alternative

For quick reference, the Preferred Transmission Development as proposed in the 2016 Application is illustrated in Figure 5-1 and summarized below:

- Add a 240 kV single circuit from the existing 240 kV/138 kV Nilrem 574S substation to a new 144 kV Drury 2007S substation. Operate this line initially at 144 kV; Drury 2007S substation will be expandable to 240 kV/144 kV.
- Add a 240 kV single circuit from the existing Hansman Lake 650S substation to Edgerton 899S substation. Operate this line initially at 138 kV.
- Connect 7L65 line in/out to Drury 2007S; rename section of line between Drury 2007S and Vermilion 710S substation to 7L205.
- Add an alternate 749AL tap to the new circuit between Hansman Lake 650S and Edgerton 899S substations. Leave the existing tap facilities in place to facilitate maintenance and future connections to 79L if required

Figure 5-1: Schematic Diagram of Preferred 240 kV Development (240 kV Operated at 138 kV)



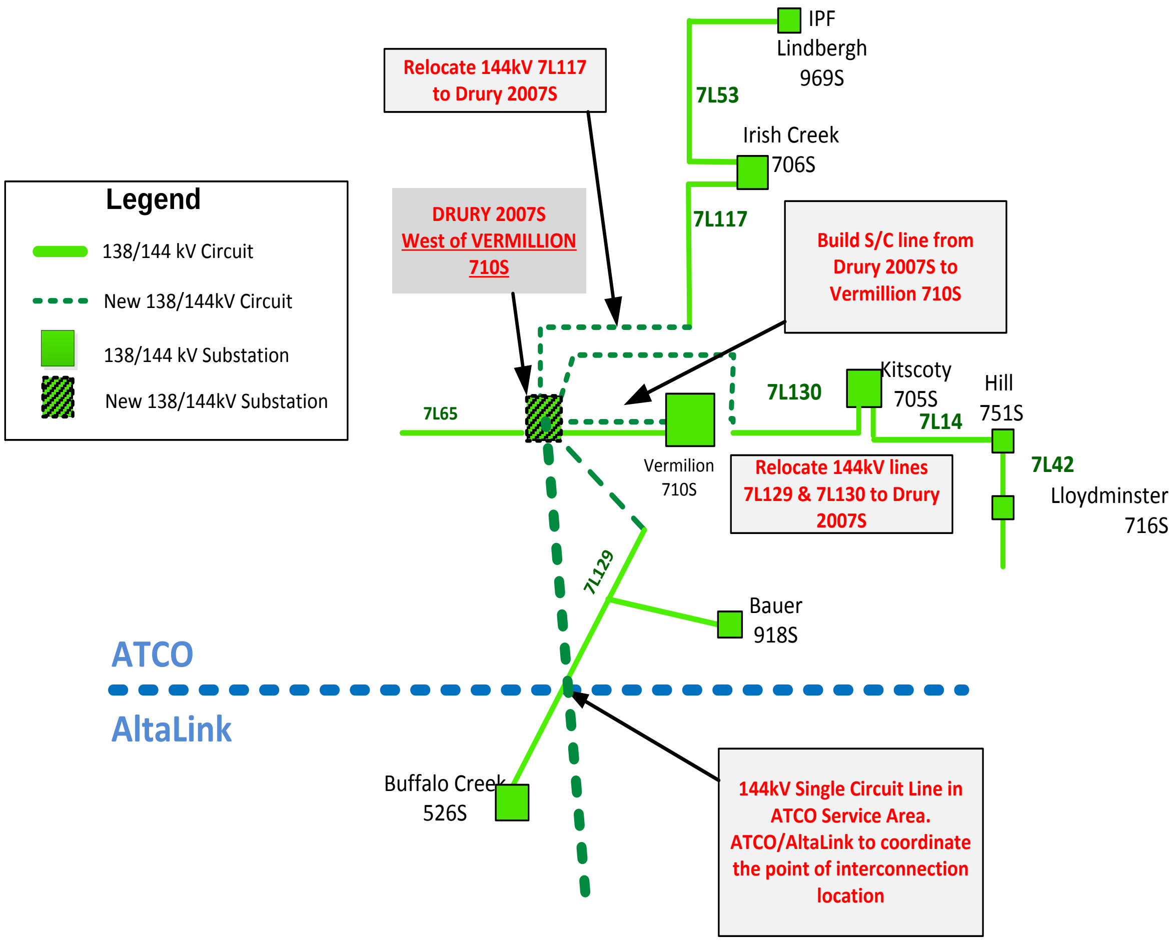
5.2 Inherent Flexibility/Staging

The Preferred Transmission Development is flexible, insofar as:

- Each one of the planned Provost-Edgerton and Nilrem-Vermilion lines could be independently energized one at a time from 138 kV to 240 kV operation as and when need arises for integrating large sized projects that exceed the thermal capability of 138 kV operation.
- Enhancements to generation integration capability (particularly along the 7L50 path and at the Drury northern hub) is further possible by terminating existing 144 kV lines in the Vermilion area to the Drury substation, Figure 5-2.
- As stated in the 2016 Application (see PDF page 23 of PENV Transmission Reinforcement Report), the Drury substation is required because the Vermilion 710S has no space to terminate any new transmission facilities into it. By developing Drury substation in a staged manner (initially as an in-and-out 144 kV switching station, with provision for future expandability) and with the addition of infrastructure to convert it to a 240 kV level, the Central East Sub-region will be provided with a strong source station connected to the 240 kV backbone network providing supply reinforcement to

Lloydminster to the east, Bonnyville to the north and the Edmonton area to the west. Furthermore, existing 144 kV lines 7L130, 7L117 and 7L129 could in the future be modified to terminate at this substation to enhance the system capability for integration of additional load and generation in the area (see Figure 5-2).

Figure 5-2: Reconfiguration of 138 kV/144kV Lines into Drury Substation



6 Technical Assessment of the Preferred Transmission System Alternative

Based on the need for development as demonstrated in the previous section and the reliability performance assessments summarized in Section 4, the AESO re-assessed the Preferred Transmission Development to confirm whether it still meets the need described in Section 4.

This section also examines the opportunity for further staging of the Preferred Transmission Development in the PENV area.

The performance assessment of the Preferred Transmission Development followed the same approach adopted in assessing the system need (in Section 4) for three broad system conditions:

(i) Load based need with zero wind production (Scenarios 1 to 4)

(ii) Load plus Existing wind with REP1 (Scenarios 5 to 8)

(iii) Load plus Existing wind with REP1 plus future rounds of REP (Scenarios 9 to 11)

To investigate further opportunities for staging in addition to those already considered in the 2016 Planning Studies (refer to Section 5), the system performance was tested with a single Provost to Edgerton (PE) line (see Figure 6-1) or Nilrem to Vermilion (NV) (Drury) line (see Figure 6-2), and then with both of these lines (PENV) in service, all of these 240 kV facilities operating initially at 138 kV/144 kV level and with the initial 138 kV termination shown in Figure 5-1.

The results indicated whether any potential for staging of developments exists and determine the required milestones to enable such staging. The staged solution was tested to ensure it meets both near term and long term needs and the results are summarized in Sections 6.1 through 6.4.

Figure 6-1: Single Hansman Lake – Edgerton Line (P-E Line)

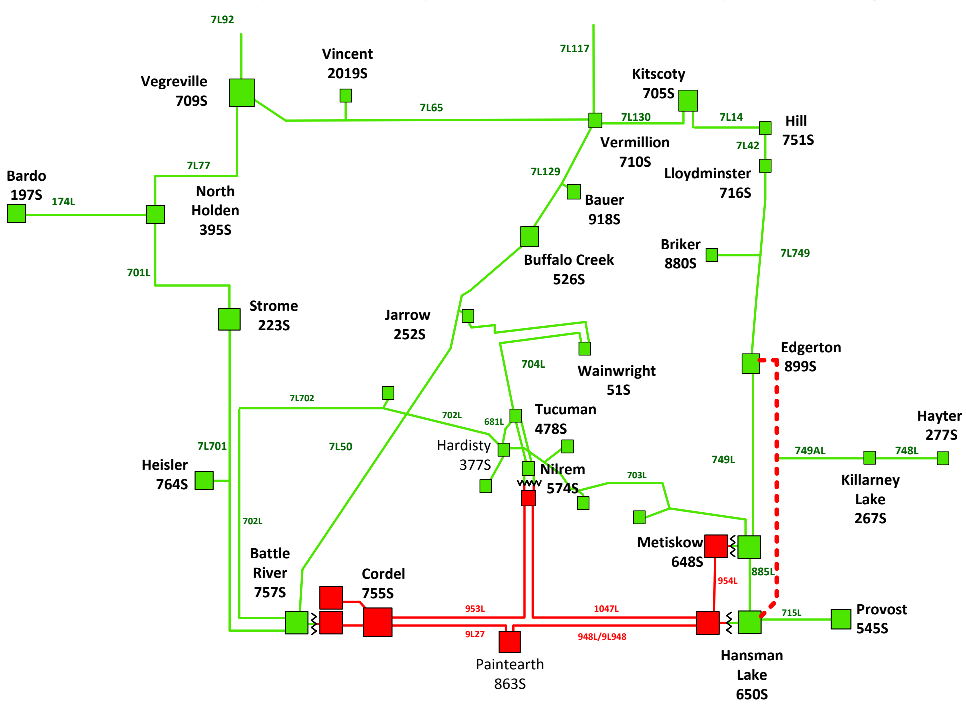
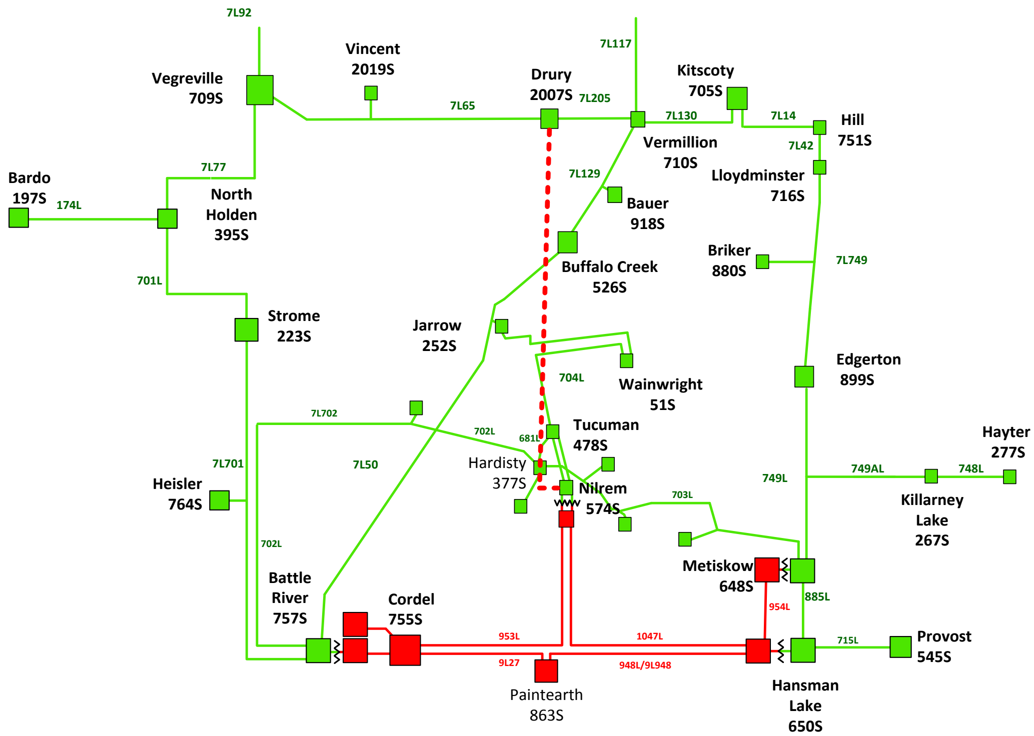


Figure 6-2: Single Nilrem – Drury Line (NV)



6.1 Load Stressed Scenarios - Near Term

6.1.1 Existing System with One New Line (Hansman Lake to Edgerton)

With the Hansman Lake to Edgerton transmission line (P-E Line) in service, there are no Reliability Criteria violations under system normal and Category B conditions for load stressed study scenarios.

Table 6-1: Category B Thermal Loadings above 95% for Provost Area to Edgerton Line

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
7L749 (899s Edgerton - Tap 880s Briker)	7L50	05_2021_WP_859S	138	96.0	97.8	99.1

6.1.2 Existing System with One New Line (Nilrem to Drury Line)

Category A Analysis

No Reliability Criteria violations were observed under Category A conditions.

Category B Analysis

Category B thermal loadings above 95% of line ratings are displayed in Table 6-2. Category B voltage violations are shown in Table 6-3.

Table 6-2: Category B Thermal Loadings for Nilrem Drury Line

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
749L (648s Metiskow - 267s Killarney Lake Tap)	7L130	01_2021_SP	138	120.9	127.0	**102.4**
	7L14	01_2021_SP	138	120.9	122.4	98.6
7L749 (899s Edgerton - Tap 267s Killarney)	7L130	03_2021_WP	138	96	92.5	97.3

Table 6-3: Category B Voltage Violations for the Nilrem Drury Line

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
7L130	880s Briker (138kV)	03_2021_WP_757S_G5	1.123	0.942	0.935
	705s Kitscoty (138kV)	03_2021_WP_757S_G5	1.123	0.942	0.925
	751s Hill (138kV)	03_2021_WP_757S_G5	1.123	0.942	0.927
	716s Lloydminster (138kV)	03_2021_WP_757S_G5	1.123	0.942	0.928

For load stressed study scenarios, the Nilrem to Vermilion line by itself will resolve thermal and voltage criteria violations along the 7L50 path (as demonstrated in Section 4). However, it will not be able to mitigate thermal overload and voltage violations along the 749L path. The P-E Line is required to resolve both thermal and voltage criteria violations along 749L path as thermal constraints along 749L are driven primarily by local load along its own path.

6.1.3 Existing System with Two New Lines (Full PENV)

With both PENV Lines in service, there are no thermal or voltage violations in the near term Load Stressed scenarios.

6.2 Generation Stress Scenario – Immediate Need

In this section, the performance of each line individually as well as combined is summarized under Generation-Stressed scenarios immediately following energization of REP1 projects.

6.2.1 Existing System with One New Line (Hansman Lake to Edgerton)

Category A (N-0)

No Reliability Criteria violations were observed under Category A conditions.

Category B (N-1) Contingency

The observed thermal overloads are summarized in Table 6-4. No voltage violations were observed. It is clear that under generation stressed scenarios, the P-E line alone will not be able to mitigate the identified thermal overloads.

Table 6-4: Thermal Loading with PE Line Only – Near Term (2021)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
701L (395s North Holden - 223s Strome)	EATL	05_2021_SP_ExWind_859S	138	119.0	118.8	97.9
7L50 (526s Buffalo Creek - 252s Jarrow Tap)	766S901T	05_2021_SP_ExWind_859S	138	109.3	106.5	95.8
	7L749	05_2021_SP_ExWind	138	109.3	106.5	95.3
		05_2021_SP_ExWind_859S	138	109.3	115.1	**103.8**
	912L	05_2021_SP_ExWind_859S	138	109.3	106.3	95.6
	EATL	05_2021_SP_ExWind	138	109.3	113.0	101.1
		05_2021_SP_ExWind_859S	138	109.3	119.5	107.7
7L701 (223s Strome - 764s Heisler Tap)	EATL	05_2021_SP_ExWind	138	139.1	142.4	96.7
		05_2021_SP_ExWind_859S	138	139.1	147.8	**100.5**
7L701 (757s Battle River - 764s Heisler Tap)	EATL	05_2021_SP_ExWind_859S	138	139.0	142.5	96.9
7L749 (899s Edgerton - Tap 880s Briker)	7L129	07_2021_WP_ExWind_859S	138	96.0	96.0	97.1
	7L50	07_2021_WP_ExWind_859S	138	96.0	105.9	**108.0**
		05_2021_SP_ExWind_859S	138	96.0	96.0	97.8
	EATL	07_2021_WP_ExWind_859S	138	96.0	99.1	**101.2**

6.2.2 Existing System with One New Line (Nilrem to Drury Line)

Category A Analysis

No Reliability Criteria violations were observed under Category A conditions.

Category B Analysis

The Nilrem to Drury line effectively mitigates thermal overloads under Category B contingency conditions. The local voltage violations (Table 6-5 and Table 6-6) along 749L can't be resolved by this line as mentioned earlier even in the load serving analysis as well. Local thermal overloads due to loads along the 7L749/749L (Table 4-1) are not resolvable by the Nilrem to Drury line alone.

Table 6-5: Loading above 95% with Nilrem to Vermilion Line – Near Term (2021)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
7L701 (223s Strome - 764s Heisler Tap)	EATL	05_2021_SP_ExWind_859S	138	139.1	140.3	95.1
7L749 (899s Edgerton - Tap 267s Killarney)	7L130	08_2021_WP_ExWind	138	96.0	92.6	97.8

Table 6-6: Voltage Violations with Nilrem to Vermilion Line – Near Term (2021)

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
7L130	880s Briker (138kV)	08_2021_WP_ExWind_757S_G5	1.123	0.942	0.927
		08_2021_WP_ExWind_757S_G5	1.123	0.942	0.927
	705s Kitscoty (138kV)	08_2021_WP_ExWind_757S_G5	1.123	0.942	0.916

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
	751s Hill (138kV)	08_2021_WP_ExWind_757S_G5	1.123	0.942	0.918
	716s Lloydminster (138kV)	08_2021_WP_ExWind_757S_G5	1.123	0.942	0.919

6.2.3 Existing System with Two New Lines (Full PENV)

The results of contingency analysis presented in above tables showed that full PENV system will alleviate all Reliability Criteria violations originally observed in the need assessment section under all studied scenarios.

6.3 Generation Stressed Scenarios – 2021

In this section, the performance of each line individually as well as combined is summarized under Generation-Stressed scenarios by 2021 when REP1, REP2 (300 MW of procurement) and REP3 (400 MW of procurement) projects are expected to be energized.

6.3.1 Existing System with One New Line (Hansman Lake Provost to Edgerton)

Category A Analysis

No Reliability Criteria violations were observed under Category A conditions.

Category B Analysis

The observed thermal overloads are summarized in Table 6-7 below. No voltage violations were observed. It is clear that under the 2021 generation stressed scenarios, the P-E line alone will not be able to mitigate the identified thermal overloads. With only the P-E line, the PENV transmission system will be subject to a number of overloads as high as 134% and thus won't meet reliability criteria. Furthermore, generation curtailments exceeding 466 MW will occur to manage Category B (N-1) contingencies in the area and maintain system reliability particularly to manage overloads along the 7L50 138 kV line. Hence this line alone is not adequate to enable connection of renewable generation in the area as anticipated to result from the REP2 (300 MW of procurement) and REP3 (400 MW of procurement) competitions.

Table 6-7: Category B Thermal Violations over 105% – Near Term (2021)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
174L (197s Bardo - 395s North Holden)	766S901T	10_2021_WP_FtrWind_859S	138.0	90.1	92.1	**107.8**
	912L	10_2021_WP_FtrWind	138.0	90.1	94.6	**109.9**
701L (395s North Holden - 223s Strome)	766S901T	10_2021_WP_FtrWind_859S	138.0	146.0	161.1	**113.2**
	912L	10_2021_WP_FtrWind_859S	138.0	146.0	161.1	**113.1**
	EATL	09_2021_SP_FtrWind_859S	138.0	119.0	139.3	**115.5**
704L (478s Tucuman - 51s Wainwright Tap)	EATL	10_2021_WP_FtrWind_859S	138.0	79.0	86.5	**107.2**
	7L749	10_2021_WP_FtrWind_859S	138.0	79.0	86.5	**107.3**
766s 901T 240/144kV (766s Nevis)	9L20	10_2021_WP_FtrWind_859S	240.0	100.0	123.1	**123.1**

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
7L129 (526s Buffalo Creek - 918s Bauer Tap)	7L749	09_2021_SP_FtrWind_859S	138.0	109.2	118.5	**106.4**
	EATL	09_2021_SP_FtrWind_859S	138.0	109.2	116.1	**105.4**
7L50 (526s Buffalo Creek - 252s Jarrow Tap)	EATL	09_2021_SP_FtrWind_859S	138.0	109.3	134.7	**121.4**
	766S901T	09_2021_SP_FtrWind_859S	138.0	109.3	129.3	**117.2**
	7L42	09_2021_SP_FtrWind_859S	138.0	109.3	124.4	**111.0**
	7L701 \ 701L	09_2021_SP_FtrWind_859S	138.0	109.3	119.8	**107.2**
	7L749	09_2021_SP_FtrWind_859S	138.0	109.3	136.6	**122.6**
	912L	09_2021_SP_FtrWind_859S	138.0	109.3	129.0	**116.9**
	9L20	09_2021_SP_FtrWind_859S	138.0	109.3	122.7	**110.5**
7L701 (223s Strome - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind_859S	138.0	139.1	162.3	**112.2**
	912L	09_2021_SP_FtrWind_859S	138.0	139.1	162.1	**112.0**
	EATL	09_2021_SP_FtrWind_859S	138.0	139.1	170.3	**115.6**
7L701 (757s Battle River - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind_859S	138.0	139.0	155.5	**107.5**
	912L	09_2021_SP_FtrWind_859S	138.0	139.0	153.7	**106.3**
	EATL	09_2021_SP_FtrWind_859S	138.0	139.0	164.0	**111.4**
7L749 (899s Edgerton - Tap 267s Killarney)	EATL	10_2021_WP_FtrWind	138.0	96.0	113.5	**116.7**
	912L	10_2021_WP_FtrWind_859S	138.0	96.0	110.6	**113.9**
	704L	10_2021_WP_FtrWind_859S	138.0	96.0	103.4	**105.4**
	9L20	10_2021_WP_FtrWind_859S	138.0	96.0	107.5	**110.3**
	766S901T	10_2021_WP_FtrWind_859S	138.0	96.0	110.8	**114.2**
	7L105	10_2021_WP_FtrWind_859S	138.0	96.0	102.8	**105.3**
	7L129	10_2021_WP_FtrWind_859S	138.0	96.0	121.1	**123.7**
	7L161	10_2021_WP_FtrWind_859S	138.0	96.0	102.8	**105.3**
	7L50	10_2021_WP_FtrWind_859S	138.0	96.0	130.6	**134.8**
912L (766s Nevis - 63s Red Deer)	EATL	09_2021_SP_FtrWind	240.0	488.0	537.2	**107.8**
9L20 (755s Cordell - 766s Nevis)	EATL	10_2021_WP_FtrWind_859S	240.0	498.0	530.8	**105.8**

6.3.2 Existing System with One New Line (Nilrem to Drury Line)

This section presents results for the case if only Nilrem to vermilion goes into service.

Category A (N-0) Analysis

No Reliability Criteria violations were observed under Category A conditions.

Category B Analysis

Both thermal and voltage criteria violations were observed under this alternative. It is worth pointing out that voltage violations lie along the 749L path and this line as seen before will not help resolve the local issue. Moreover, the thermal overloads are in the western part of PENV area (e.g., 174L and 7L701) plus 240 kV outlet path 912L as summarized in Table 6-8 below.

Table 6-8: Thermal overloads above 105% with the Nilrem to Vermilion Line – Near Term (2021)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
174L (197s Bardo - 395s North Holden)	766S901T	10_2021_WP_FtrWind	138.0	90.1	100.6	**115.8**
	912L	10_2021_WP_FtrWind	138.0	90.1	100.3	**115.4**
	EATL	10_2021_WP_FtrWind	138.0	90.1	93.7	**106.9**
701L (395s North Holden - 223s Strome)	766S901T	10_2021_WP_FtrWind_859S	138.0	146.0	151.5	**105.3**
	912L	10_2021_WP_FtrWind_859S	138.0	146.0	151.5	**105.2**
	EATL	09_2021_SP_FtrWind_859S	138.0	119.0	131.1	**108.1**
766s 901T 240/144kV (766s Nevis)	9L20	10_2021_WP_FtrWind	240.0	100.0	120.1	**120.1**
7L701 (223s Strome - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind_859S	138.0	139.1	152.6	**105.1**
	EATL	09_2021_SP_FtrWind_859S	138.0	139.1	161.4	**109.2**
7L701 (757s Battle River - 764s Heisler Tap)	EATL	09_2021_SP_FtrWind_859S	138.0	139.0	155.8	**105.5**
912L (766s Nevis - 63s Red Deer)	EATL	09_2021_SP_FtrWind	240.0	488.0	525.0	**105.2**

Table 6-9: Voltage Violations with Nilrem to Vermilion Line – Near Term (2021)

Contingency	Substation	Scenario	V max (p.u.)	V min (p.u.)	V observed (p.u.)
7L130	880s Briker (138 kV)	10_2021_WP_FtrWind_757S_G5	1.123	0.942	0.933
	705s Kitscoty (138 kV)	10_2021_WP_FtrWind_757S_G5	1.123	0.942	0.922
	751s Hill (138 kV)	10_2021_WP_FtrWind_757S_G5	1.123	0.942	0.924
	716s Lloydminster (138 kV)	10_2021_WP_FtrWind_757S_G5	1.123	0.942	0.925

6.3.3 Existing System with Two New Lines (Full PENV)

Category A Analysis

There are no Reliability Criteria violations under category A conditions.

Category B Analysis

Only thermal overloads associated with transfer out capability issues were observed and summarized in Table 6-10. All observed overloads due to internal PENV area 138 kV transmission outages are addressed by the PENV preferred transmission development. The overloads listed in Table 6-10 are directly associated with outages of transmission elements transferring surplus power out of the Central

East Sub-region. The identified overloads will be addressed by future Central East transmission reinforcement development and could be managed without exceeding the current MSSC level.

Table 6-10: Thermal Violations with both PENV Lines – Near Term (2021)

Element	Contingency	Scenario	Base (kV)	Rating (M VA)	Flow (MVA)	Loading (%)
174L (197s Bardo - 395s North Holden)	766S901T	10_2021_WP_FtrWind	138.0	90.1	101.2	116.4
	912L	10_2021_WP_FtrWind	138.0	90.1	101.0	116.1
	EATL	10_2021_WP_FtrWind	138.0	90.1	94.6	107.8
701L (395s North Holden - 223s Strome)	EATL	09_2021_SP_FtrWind_859S	138.0	119.0	130.7	107.9
766s 901T 240/144kV (766s Nevis)	9L20	10_2021_WP_FtrWind_859S	240.0	100.0	120.1	120.1
7L701 (223s Strome - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind_859S	138.0	139.1	152.4	105.1
	EATL	09_2021_SP_FtrWind_859S	138.0	139.1	161.2	109.2
7L701 (757s Battle River - 764s Heisler Tap)	EATL	09_2021_SP_FtrWind_859S	138.0	139.0	155.6	105.4
912L (766s Nevis - 63s Red Deer)	EATL	09_2021_SP_FtrWind	240.0	488.0	524.5	105.1

6.3.4 Conclusion

The two proposed PENV lines resolve all local transmission reliability concerns in the PENV area. Thermal overloads related to limited transmission system transfer out capability from the Central East Sub-region remain which are manageable by RAS. These are the overloads observed on 7L701, 174L, 912L and Nevis transformer. The overloads on 174L and 7L701 can be addressed temporarily by transfer tripping 174L. The existing RAS #137 can be used to mitigate overloads on the Nevis transformer until such time as it is upgraded to a higher capacity. The overload on 912L and on 174L will be addressed through a future transfer out project as described in Section 3.0 of the 2017 LTP.

For clarity, the PENV lines do not require any 7L50 RAS or generation curtailments to alleviate overloads in the PENV area. Thus PENV lines successfully and efficiently addressed the need to reliably serve the area load as well as enable integration of new generation in the Study Area.

6.4 Long Term Performance

The long term system performance for both load serving and future renewable resource was carried out with both PENV area preferred transmission development lines in service. To supply load, it was recognized that the lines would be energized to the 138 kV/144 kV level.

6.4.1 Preferred Alternative – Load Stressed Scenarios

The Preferred Transmission Development meets the reliability requirement in the long term as no Reliability Criteria violations were detected for supplying load.

Table 6-11 Category B Loading Above 95% for Preferred Alternative (2037)

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
757S Battle River 240/138 kV XFMR	766S901T	01_2037_SP_859S	240/138	224.0	216.1	96.5
	953L	03_2037_WP_859S	240/138	224.0	219.2	97.9
	9L20	01_2037_SP_859S	240/138	224.0	215.6	96.2

6.4.2 PENV Generation Capability Assessment

In order to integrate renewable generation in the local PENV area up to 860 MW as described in the 2016 application, three 138 kV/144 kV lines (174L, 7L92 and 7L53) will have to be operated as normally open with both PENV lines energized to the 240 kV level. Under Category B (N-1) contingencies within PENV area, thermal overloads could be managed by RAS with maximum curtailments below 400 MW (see section 7 and 9 of 2016 Application, PENV Transmission Reinforcement report).

6.5 Summary

The above study results demonstrate that:

- No voltage violations were observed in the near and long term under either Category A or Category B conditions. This indicates that the system can serve the forecast load over the planning horizon.
- Neither proposed line alone would be adequate to reliably supply forecasted load or provide access to new generation in the Study Area; both lines are required together to meet the load and generation driven needs in the PENV area in the near term.
- The Preferred Transmission Development energized to 138 kV/144 kV level is required and sufficient to satisfy reliability requirements for serving forested load and enable integration of new generation in the Study Area within PENV and externally south of PENV in the Hanna Planning Area.
- The Preferred Transmission Development meets the thermal criteria in the near to long-term for serving forecasted generation. Also, the Preferred Transmission Development would enable integration of anticipated renewable generation in the near term in a reliable manner. The results indicate that all anticipated in-merit generation would be dispatched under both system normal conditions and with no RAS exceeding the MSSC threshold in the Central East Sub-region in the near term up to the forecasted renewable capacity additions in the Central East Sub-region.
- The Preferred Transmission Development when converted to 240 kV operation can integrate 860 MW of new generation in the PENV area; thus there is no change in generation integration capability from the level reported in the 2016 Application.
- The observed overloads as reported in Section 6.3.3 and Section 6.4 will be addressed through the Central East transfer out project as described in the 2017 LTP.

7 Further Staging of Preferred Alternative & Milestones

Based on the recent filing of AESO's connection needs identification document for *Transmission Enhancements in the Municipal Districts of Provost and Wainwright* (Project 1782), the AESO explored opportunities for staging the Hansman Lake to Edgerton line. As note above, Project 1782 does not remove the need for the P-E line. However, upon review of study results for 2021 (post-Project 1782 in service); the AESO now considers it appropriate to develop the P-E line in two stages, as follows:

- **Stage 1:** Build a 240 kV line from Hansman Lake to vicinity of Killarney Lake tap – the southern portion of the preferred Hansman Lake to Edgerton line in the near term. This development helps to create an independent loop from Hansman Lake to Provost and back to Hansman Lake. It will serve loads on the Killarney Lake tap, and at Hayter and Provost, and supports any net generation from the Bull Creek Wind facility. Build a 240 kV line from Nilrem 574S to Drury (2007S, new substation). Energize these two 240 kV lines initially to 138 kV operating level.
- **Stage 2:** Build the northern portion of the 240 kV line from Killarney Lake tap to Edgerton subject to meeting the milestones descried in Section 7.1. It will also be energized to 138 kV initially.

Figure 7-1: Stage 1 of PENV Preferred Development

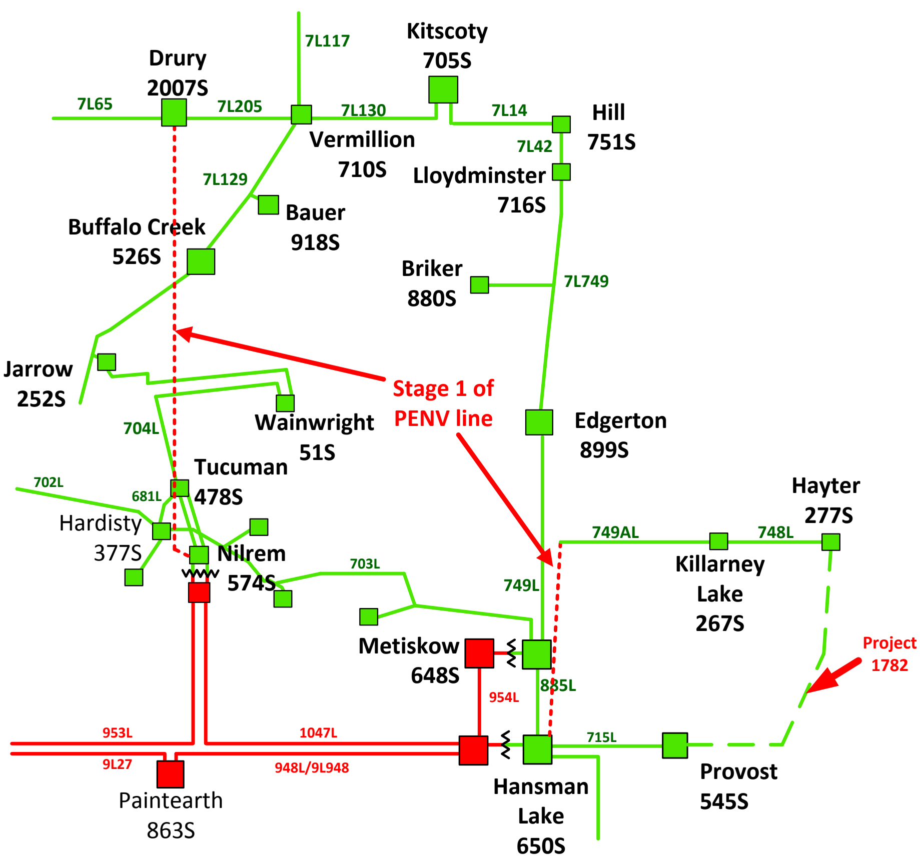
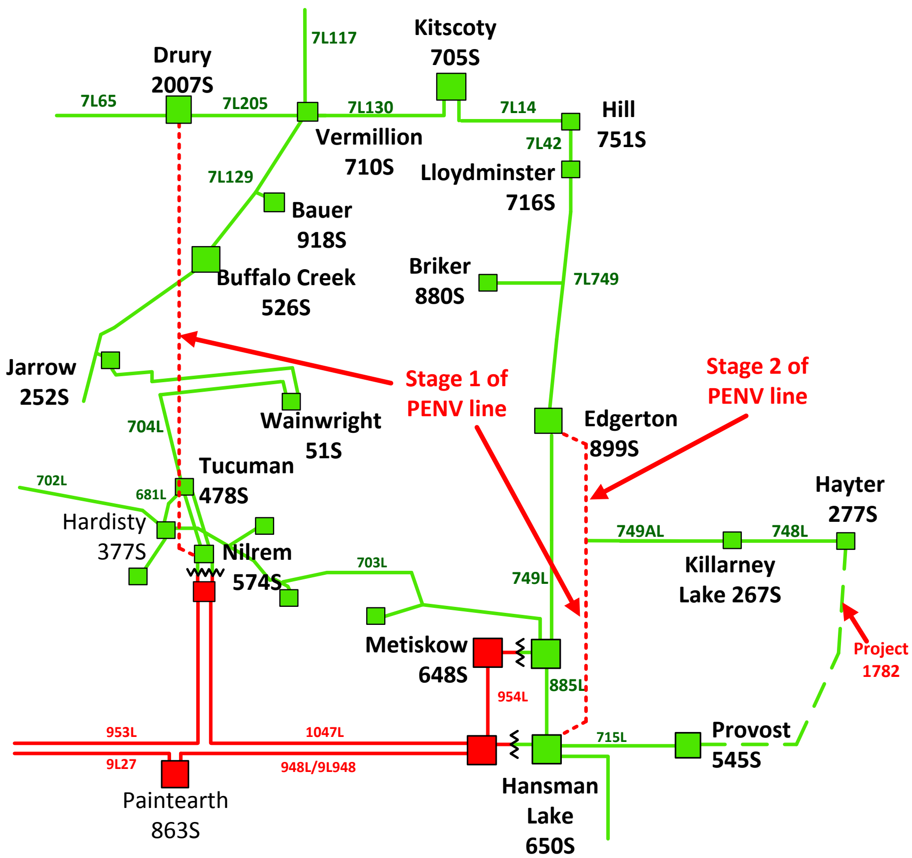


Figure 7-2: Stage 1 and Stage 2 of PENV Preferred Development



7.1 Milestones

Construction of the northern segment (Killarney Lake Tap to Edgerton) of the Hansman Lake to Edgerton line would commence following any of the following milestones being met:

- The AESO's coincident summer aggregate peak load forecast reaching the existing capacity of the transmission line 749L (Edgerton 899S to the Killarney Lake 267S substation tap-point), which is approximately 83 MW, measured at the Edgerton 898S, Briker 880S, Lloydminster 716S, Hill 751S and Kitscoty 705S substation; or,
- Construction commencing for generation projects that will connect along the transmission 749L path (from Hansman Lake 650S to Vermilion 710S) and that the AESO anticipates will give rise to congestion under Category A conditions on the transmission line 749L (Edgerton 899S to the Killarney Lake 267S substation tap-point); or
- The withdrawal or cancellation of FortisAlberta's system access service request for AESO Project 1782.

7.2 Stage 1 – Near-term Performance

In this section, the near-term performance of "Stage 1" as described in Section 7 above has been evaluated against all study scenarios including both load and generation stressed scenarios.

7.2.1 Category A Analysis

There are no thermal of voltage violations under Category A conditions.

7.2.2 Category B Analysis

No voltage violations were observed under Category B Conditions, thermal violations are listed in Table 7-1.

Table 7-1: Thermal Violations with Stage 1

Element	Contingency	Scenario	Base (kV)	Rating (MVA)	Flow (MVA)	Loading (%)
7L701 (757s Battle River - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind_859S	138.0	139	146.8	101.2
	912L	09_2021_SP_FtrWind_859S	138.0	139	145.2	100.1
	EATL	09_2021_SP_FtrWind_859S	138.0	139	156.0	105.7
766s 901T 240/144kV (766s Nevis)	9L20	10_2021_WP_FtrWind_859S	240.0	100	120.2	120.2
9L20 (755s Cordell - 766s Nevis)	EATL	10_2021_WP_FtrWind_859S	240.0	498	515.4	102.5
912L (766s Nevis - 63s Red Deer)	EATL	09_2021_SP_FtrWind	240.0	488.0	524.9	105.2
174L (197s Bardo - 395s North Holden)	766S901T	10_2021_WP_FtrWind	138.0	90.1	100.7	115.9
	912L	10_2021_WP_FtrWind	138.0	90.1	100.5	115.5
	EATL	10_2021_WP_FtrWind	138.0	90.1	93.9	107.1
701L (395s North Holden - 223s Strome)	766S901T	10_2021_WP_FtrWind_859S	138.0	146.04	151.4	105.2
	912L	10_2021_WP_FtrWind_859S	138.0	146.04	151.4	105.1
	EATL	09_2021_SP_FtrWind_859S	138.0	119.03	131.1	108.2
7L701 (223s Strome - 764s Heisler Tap)	766S901T	09_2021_SP_FtrWind_859S	138.0	139.11	152.9	105.4
	912L	09_2021_SP_FtrWind_859S	138.0	139.11	152.8	105.3
	EATL	09_2021_SP_FtrWind_859S	138.0	139.11	161.7	109.5

These thermal overloads are related to transfer out capability limitations and are almost similar to those reported in Section 4.3.2.2 with both lines in service and will be managed by RAS. The planned Central East transfer out reinforcement will address those thermal overloads in the longer term.

7.2.3 Conclusion

Stage 1 is sufficient to meet both load and generation in the near term and thus staging of the Preferred Alternative is a prudent solution.

7.3 System Losses Evaluation

System losses were estimated for the existing system, with PENV Stage 1 and Stage 2 in in the near term (2021). Losses were estimated for summer peak, summer light and winter peak load under Category A conditions. The average system losses were calculated by taking the numerical average of system losses in all of study scenarios. The average system losses and the average losses in the PENV study area are summarized in Table 7-2

Table 7-2: Summary of the System Average Losses in the Near Term (2021)

System Topology	System Losses (MW)	Study Area Losses (MW)	PENV Area Losses (MW)
Existing System	375.4	59.4	29.8
System with PENV Stage 1	369.8	54.3	25.4
System with PENV Stages 1 and 2	368.8	53.0	24.3

With Stage 1 in service, the losses in the system would be reduced by 5.6 MW in the near term and there is marginal reduction of 1 MW loss when Stage 2 goes into service. A similar pattern of reduction in losses occur in both PENV and Central East Sub-regions of the system

7.4 Capability of Stage 1 Development in the Near Term (2021)

The AESO created two scenarios to demonstrate the capability of the proposed PENV initial development in the near term if all renewables show up either in the PENV area or the Central East Sub-region.

Scenario A:

Approximately 640 MW of new renewable projects were modeled in the PENV area as shown in Table 7-3 below. In this scenario, no new projects were included in the Central East Sub-region:

Scenario B:

600 MW of new renewable projects were considered in the Central Eat sub-region with no new renewable projects in the PENV Area.

In both of the above scenarios, existing wind generation is included in the system simulations.

Table 7-3: Wind distribution for Capability Study

PENV Area		Central East Sub-region	
Substation	Project Size (MW)	Location	Project Size (MW)
Drury	120	Tinchebray	200
Edgerton	200	Pemukan	200
Buffalo creek	120	Lanfine	200
Hansman Lake	200		
Total	640		600

The system performance was simulated for Category A (N-0) conditions with EATL being dispatched to 1,000 MW south to north. There were no over loads in the PENV area and this indicates that PENV Stage 1 could facilitate integration of about 600 MW of renewables entirely either in the PENV area or south of PENV area along the 240 kV loop in the Hanna area. Stage 2 would be required when the wind projects on the 144 kV network in the PNEV area exceeds 410 MW or a large project in excess of 200 MW gets developed near Edgerton 899S substation.

8 Project Interdependencies

The facilities described in the *Transmission Enhancements in the Municipal Districts of Provost and Wainwright* (Project 1782) NID are planned to be in-service by May 01, 2020. The AESO developed staging of its Preferred Transmission Development taking into account this Project 1782. Except for this project, there are no other AESO transmission reinforcement plans inside or outside of the Study Area that impact the need, the timing, or the transmission development alternatives considered in this Report. There are no AESO transmission plans that directly depend on the transmission development alternatives considered in this Report.

9 Conclusion

In response to Commission Decision 22274-D01-2018 regarding the AESO's 2016 Application, the AESO has reassessed the need for transmission reinforcement in the PENV area based on the AESO's recent load and generation forecast. This report presented the results of 2018 Planning Studies conducted by the AESO to reassess the need for transmission reinforcement in the PENV area.

The AESO's findings based on this reassessment show that the preferred transmission development described by the AESO in the 2016 Application (Preferred Transmission Development) continues to be required and remain the AESO's preferred option to meet the need in this area for both load and generation over the planning horizon. The entire Preferred Transmission Development is required to satisfy the load and generation forecast over the planning horizon.

As a result of the recent filing of AESO Project 1782, the Preferred Transmission Development can be staged. Specifically, the component of transmission line 749L from the Edgerton substation to the Killarney Lake tap can be subject to the milestone described in Section 7 above. The remainder of the Preferred Transmission Development, however, continues to be required by 2021 in order to avoid Reliability Criteria violations due to the forecasted load and generation growth.

Table 9-1 and Table 9-2 demonstrate a summary of the need drivers as covered in the 2016 and 2018 applications from Load and Generation based need drivers respectively.

The performance of the PENV preferred transmission reinforcement was demonstrated in the 2018 Application as well as in the 2016 application to address all identified needs related to the local PENV and Central East Sub-region from load and generation integration perspective.

Table 9-1: Comparison of Load Need Drivers between the 2016 Application and this Reassessment

Load Driven Needs		
Issue	2016 Application	2018 Application
Local Reliability Criteria violations along 749L Path prior to 2021	• Demonstrated overloads during summer peak in 2013 to 2015, inclusive (3 out of past 7 years) • The PENV area's load serving capability is 400 MW during summer peak load which was exceeded over 4 years (2013 to 2016) • See section 4.3 of exhibit 22274-X0003- PENV study report	• Extended the analysis of historical performance of 749L to cover 2016 and 2017 years • Concurs with 2016 Application conclusions
Load Forecast needs along 7L50 and 7L749	• 2016 LTO showed overloads as high as 118% on both 749L and 7L50 in the near term (2021)See Exhibit 22274-X0003, 2016 Planning Studies Section 4.1	• Project Specific PENV Area Forecast reflects drop in forecast compared to 2016 LTO • Both 749L and 7L50 lines still experience overloads however, less severe compared to 2016 Application analysis
Outage Scheduling (N-1-1 Performance)	• The PENV area will be subject to voltage collapse and thermal overloads. • PENV development helps to mitigate voltage collapse for certain C3 contingencies and eliminate overloads. • See Exhibits 22274-x0165 and 22274-X0003 PENV Study report	• The PENV area will be subject to voltage collapse and thermal overloads even with Provost 545S to Hayter 277S (Project P1782) line in service • PENV preferred Alterative mitigates these Reliability Criteria violations and substantially improves the maintainability of facilities

Table 9-2: Comparison of Generation Need Drivers between the original 2016 Application and this Reassessment

Generation Driven Needs		
Issue	2016 Application	2018 Application
Lack of Transmission Capacity (wires Capacity) in the PENV area for generation integration of generation (renewables)	• Two projects Mainstream Irma and BluEarth Bull creek projects had to reduce their project sizes due to lack of transmission capacity along 7L50 and in the Provost area • See exhibit 22274-X0163	• The PENV area still requires reinforcement to enable renewable generation integration locally along the 7L50 and 749L/7L749 paths
Market Interest in PENV area and Greater Central east region	• Evidence of high renewable generation interest was provided demonstrating that 25 applications for a total of 2,411 MW of wind and solar applications in the Central East Sub-region • PENV area had 210 MW of applications (as of March 2016) • See exhibit 22274-X0164	• Market interest has increased. 2,730 MW of renewables in the Central East Sub-region with 555 MW in the PENV area (as of March 2018) • High market interest and competitive renewable generation development reaffirmed as reflected in the REP1 competition
Renewable Electricity Program 2030 Target	• 2016 Application was filed before the Renewable Electricity Program was developed and approved.	• REP1 results announced; includes 248.5 MW Sharp Hills Wind project in Hanna region, just south of PENV area • Supplemental generation assessment studies were included in this re assessment to complement • 2018 Application is aligned with the AESO 2017 LTP to enable Alberta Renewable Electricity Program targets by 2030
Generation Integration Capability	• Studied independent of Generation forecast, particularly immediately outside (south) of the PENV area • Determined up to 860 MW could be integrated (locally in PENV) with lines energized at 240 kV with lines to Cold Lake and Wetaskiwin operated normally opened	• Supplemental generation assessment studies were included in this re assessment to complement the generation integration capability studies done in 2016 Application • Reconfirmed generation integration capability estimate provided in 2016 Application • Demonstrated PENV transmission development role (elimination of anticipated Category A (N-0) and unmanageable Category B (N-1) generation congestion levels) for integrating renewables south of the PENV study area in alignment with the AESO 2017 LTP
Need for Drury Substation	• Access to the existing Vermilion substation is not feasible requiring new 138 kV/240 kV access point east of Vermilion • ATCO provided evidence that it is not feasible to expand the Vermilion substation to terminate new line(s) or connect any new generation. • See Exhibit 22274-X0022.	• Need for the Drury substation is re-affirmed • Additional 138 kV terminations into Drury to enhance the PENV area wind integration capability along the central 7L50 path will be triggered when need arises (staging)