Engineering Connection Assessment

P2921 SS-54 Substation Upgrade

Enmax Power Corporation

Date: April 30, 2026

Version: V1

Classification: Public

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The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

NOTE:

The conclusions and recommendations in this report are based on the results presented in *Attachment B: Engineering Connection Assessment: Study Results*, which was prepared by a third party consultant in accordance with the AESO Connection Process.

The AESO has reviewed the *Engineering Connection Assessment: Study Results*, and finds it acceptable for the purpose of assessing the potential impacts of the proposed connection on the performance of the Alberta interconnected electric system.

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1 Introduction

This Alberta Electric System Operator (AESO) Engineering Connection Assessment describes the engineering studies that were completed to assess the impact of the Project (as defined below) on the performance of the Alberta interconnected electric system (AIES). This report also provides the AESO's conclusions and recommendations based on the results of the engineering studies.

Attached to this Engineering Connection Assessment are the results of the engineering studies (see Attachment A) and the scope and methodology used to perform the studies (see Attachment A-1). These attachments provide details regarding the technical criteria, assumptions, and methods for performing these engineering studies, and the results of the engineering studies.

1.1 Project Overview

ENMAX Power Corporation, in its capacity as the legal owner of an electric distribution system (DFO), has submitted a request for system access service to the AESO to serve growing demand for electricity in the Calgary Area.

The DFO's request includes a request for a Rate DTS, *Demand Transmission Service*, contract capacity increase of 60 MW, from 20 MW to 80 MW, at the existing ENMAX Substation No. 54 (SS-54) and a request for transmission development (collectively, the Project). Details on the need for transmission development can be found in the DFO's Distribution Deficiency Report (DDR).

The scheduled in-service date (ISD) for the Project is December 5, 2028.

2 Assessment Scope

2.1 Objectives

The objectives of the AESO Engineering Connection Assessment are as follows:

- Assess the impact of the Project on the performance of the AIES.
- Evaluate Project connection alternatives and identify the AESO's preferred alternative.
- Recommend mitigation measures, if required, to reliably connect the Project to the AIES.
- Identify Project dependencies, including any TFO projects or AESO plans to expand or enhance the transmission system that must be completed prior to connection.

2.2 Existing System

Geographically, the Project is located in the AESO planning area of Calgary (Area 6) which is part of the AESO Calgary planning region. Calgary is surrounded by the planning areas of Airdrie (Area 57), Seebe (Area 44), Strathmore/Blackie (Area 45), and High River (Area 46).

From a transmission system perspective, Calgary consists primarily of a 69 kV, 138 kV, 240 kV and 500 kV transmission system. Calgary is connected to Airdrie through the 138 kV transmission line 631L and 240 kV transmission lines 929L, 925L, 901L, 918L, 906L, and 928L; connected to High River through two 240 kV transmission lines 1037L and 1038L; connected to Strathmore/Blackie through two 240 kV transmission lines 924L and 927L and one 138 kV transmission line 765L; and connected to Seebe through one 138 kV transmission line 860L.

Existing constraints in the Calgary planning region are managed in accordance with the procedures set out in Section 302.1 of the ISO rules*, Real Time Transmission Constraint Management* (TCM Rule).

2.3 Study Area

The Study Area consists of the AESO planning areas of Fort Macleod (Area 53), Stavely (Area 49), High River (Area 46), Lethbridge (Area 54), Strathmore/Blackie (Area 45), and Calgary (Area 6) including the tie lines connecting these planning areas to the rest of the AIES.

All transmission facilities within the Study Area will be studied and monitored for violations of the Reliability Criteria (defined in Section 3.1 of Attachment A-1).

3 Connection Alternatives

3.1 Overview

The AESO, in consultation with the TFO in the Study Area and the DFO, examined 3 transmission alternatives to meet the DFO's request for system access service, as detailed in Section 3.2.

3.2 Connection Alternatives Examined

Below is a description of the developments associated with the transmission alternatives that were examined for the Project.

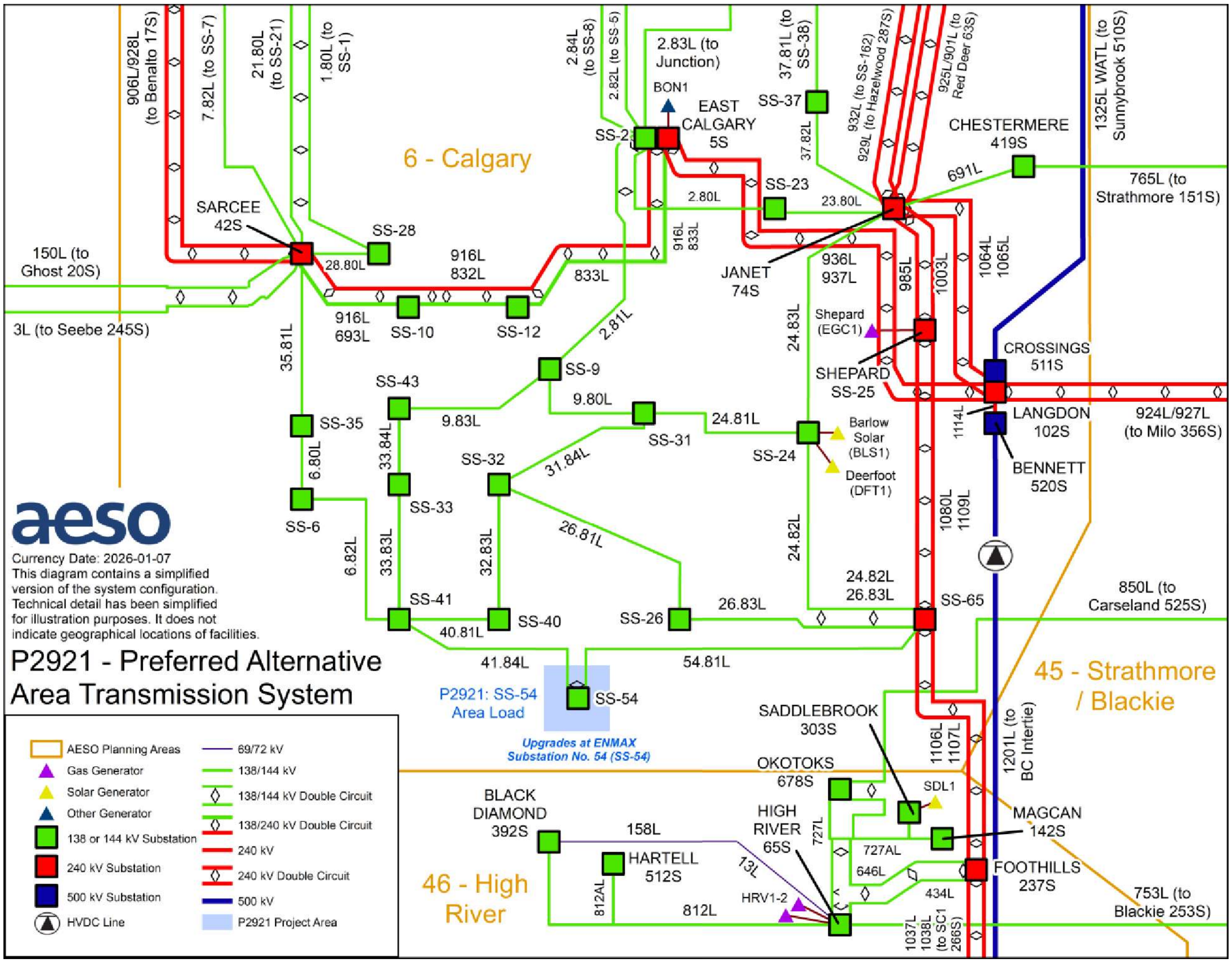
Alternative 1 – Upgrade SS-54 substation

This alternative includes the following developments:

- Upgrade SS-54 substation, including adding one 138/25 kV transformer and one 138 kV circuit breaker; and
- Add or modify associated equipment as required for the above transmission developments.

The DFO has advised that this alternative will require adding approximately 22 km of distribution feeders. The proposed connection configuration is shown in Figure 3-1.

Figure 3-1: Connection Alternative 1



Alternative 2 – Upgrade SS-26 substation

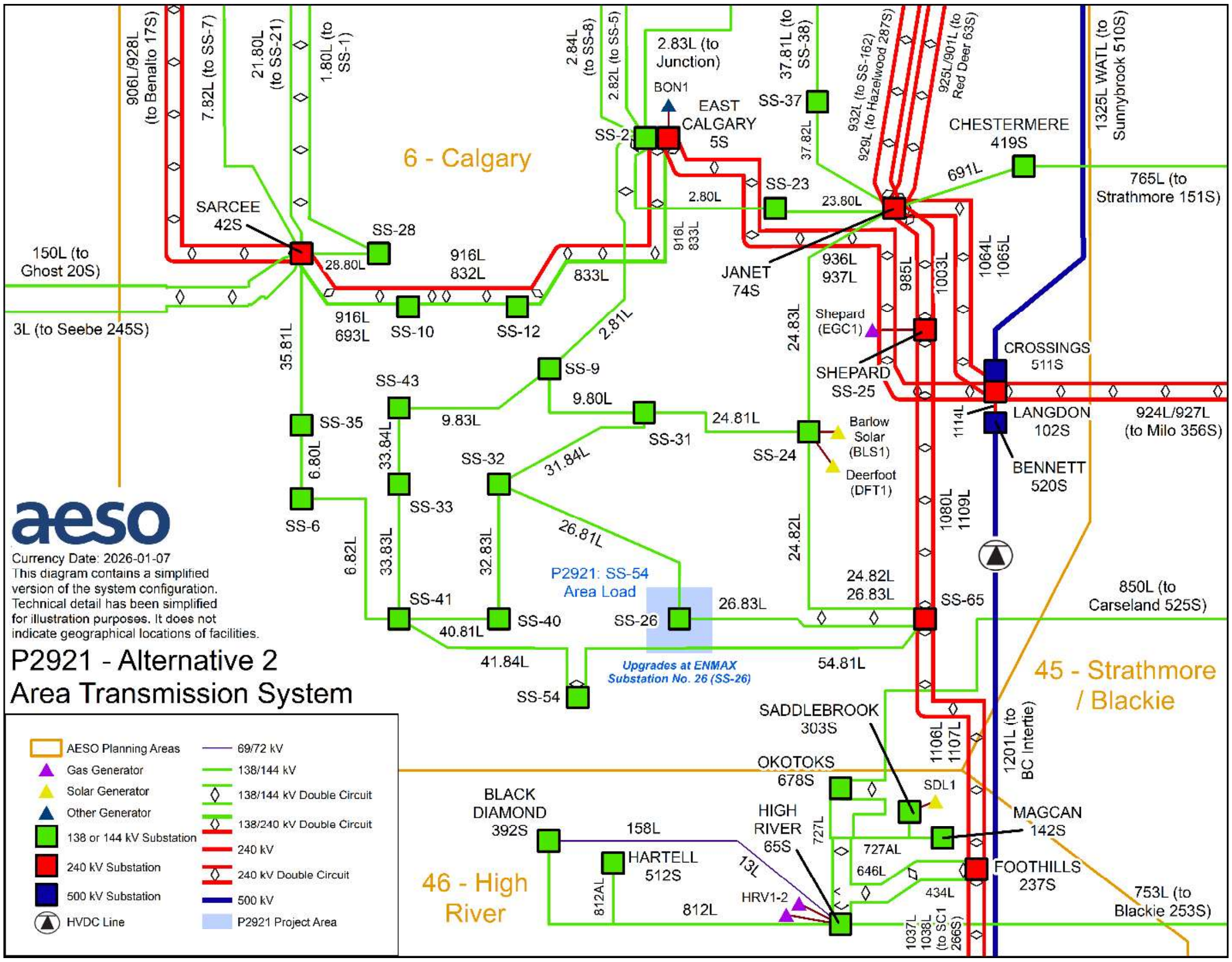
This alternative includes the following developments:

- Upgrade SS-26 substation, including adding one 138/25 kV transformer and one 138 kV circuit breaker; and
- Add or modify associated equipment as required for the above transmission developments.

The TFO has advised that this alternative will require substation fence expansion. The DFO has advised that this alternative will require adding approximately 23.6 km of distribution feeders.

The proposed connection configuration is shown in Figure 3-2.

Figure 3-2: Connection Alternative 2



Alternative 3 – Upgrade SS-24 substation

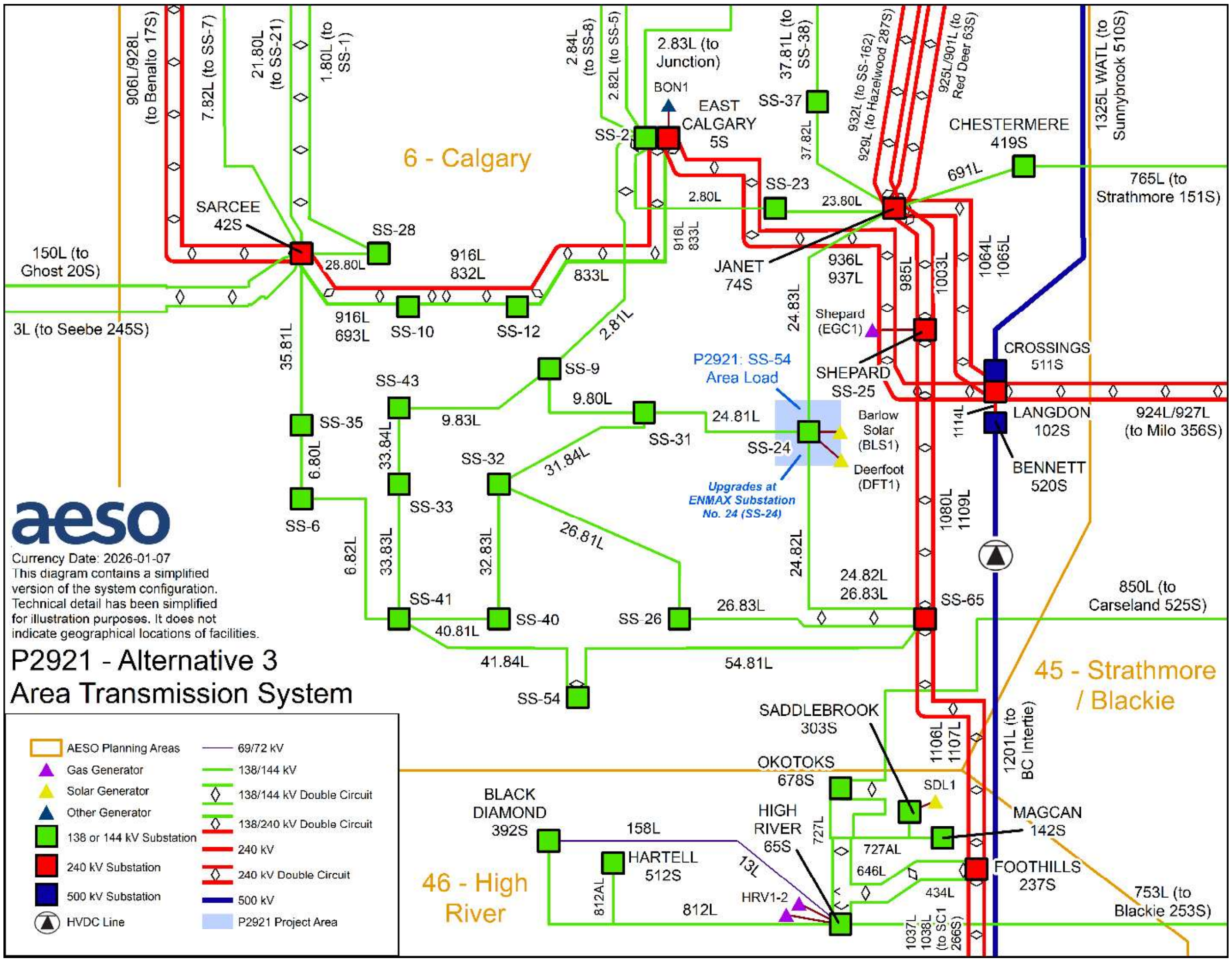
This alternative includes the following developments:

- Upgrade SS-24 substation, including adding one 138/25 kV transformer and one 138 kV circuit breaker; and
- Add or modify associated equipment as required for the above transmission developments.

The TFO has advised that this alternative will require substation fence expansion to provide additional space for the new transformer. The DFO has advised the total feeder length required for this alternative would be in the range of16-22 km.

The proposed connection configuration is shown in Figure 3-3.

Figure 3-3: Connection Alternative 3



3.3 Connection Alternatives Selected for Further Study

Alternative 1 is considered technically feasible and was selected for further study.

3.4 Connection Alternatives Not Selected for Further Study

The TFO has advised that Alternatives 2 and 3 will require substation fence expansion to provide additional space for the new transformer, unlike Alternative 1. The TFO also advised adding a second transformer, in Alternative 1, eliminates the single point of failure, increases substation reliability, and provides flexibility for maintenance planning and operations of SS-54 substation. The DFO[1] has advised that Alternative 2 and Alternative 3 will result in the violation of the DFOs planning criteria as well as involving increased scope, hence increased cost, compared to Alternative 1.

[1] See Appendix D of Needs Identification Document.

4 Assessment Approach

4.1 Standards, Criteria and Assumptions

A detailed description of the standards, criteria, and assumptions that were used for the connection assessment is provided in Attachment A (see Attachment A-1).

4.2 Studies Performed

At the time of study, the scheduled ISD for the Project was July 1, 2028. As a result, studies were performed using scenarios for 2028 Summer Peak (SP) Low Generation (LG), and 2028 Winter Peak (WP) Low Generation (LG). After completion of the studies, the ISD of the Project was changed from July 1, 2028 to December 5, 2028. The AESO determined that the ISD change would not have material impact on the connection alternative, the mitigation measures and the conclusions for the scenario studies conducted.

Short-circuit studies were performed using the 2028 WP LG and 2033 WP scenarios.

Error! Not a valid bookmark self-reference. lists the study scenarios. Post-Project scenarios reflect the requested Rate DTS contract capacity increase of 60 MW at the SS-54 substation.

Table 4-1: Connection Study Scenarios

Scenario No.	Year/Season	System Generation Dispatch Conditions	Scenario Name	SS-54 Load (MW)
Pre-Project				
1	2028 Summer Peak (SP)	Low Generation (LG)	2028 SP LG Pre-Project	20
2	2028 Winter Peak (WP)	LG	2028 WP LG Pre-Project	20
Post-Project				
3	2028 SP	LG	2028 SP LG Post-Project	80
4	2028 WP	LG	2028 WP LG Post-Project	80
5	2033 WP	All generators in Study Area In-Service	2033 WP Post-Project	80

The AESO Planning Region load forecasts used for the connection studies were based on the *AESO's 2023 Long-Term Outlook (2023 LTO)*. While the AESO has updated its regional forecasts since the connection studies were performed, the use of the current AESO forecast, the *2024 Long-Term Outlook* (*2024* LTO), would not materially alter the connection study results or affect the conclusions and recommendations in this report.

4.2.1 Power Flow Studies

The purpose of the power flow studies is to identify and quantify any thermal and voltage criteria violations in the Study Area.

In addition, power flow studies are also used to identify point of delivery (POD) low voltage bus voltage deviations beyond the limits listed in Table 3-1 of Attachment A-1.[2]

Power flow studies were performed for 2028 SP LG and WP LG pre-Project scenarios, and post-Project scenarios.

4.2.2 Voltage Studies

The purpose of the voltage stability studies is to determine the ability of the transmission system to maintain voltage stability at the busses in the Study Area.

Voltage stability studies were performed for the 2028 WP LG post-Project scenario.

4.2.3 Short-Circuit Current Level Studies

The purpose of short-circuit current level studies is to determine the expected system short-circuit current levels in the vicinity of the Project.

Short circuit studies were performed for the 2028 WP LG pre-Project scenario and for 2028 WP LG and 2033 WP post-Project scenarios.

4.3 Mitigation Measure Development and Evaluation

As explained in Section 6 of Attachment A, mitigation measures were developed to address system performance issues that were identified in the post-Project scenarios. Studies performed to assess the effectiveness of mitigation measures are briefly outlined below.

4.3.1 Post-Mitigation Studies

Power flow and voltage studies were performed to assess the impact of the Project on the performance of the AIES following implementation of the AESO's proposed mitigation measures.

[2] The AESO's desired post-contingency voltage deviations for low voltage busses represent guidelines rather than criteria. A POD bus voltage deviation that exceeds the desired limits shown in Table 3-1 of Attachment A-1 does not represent a Reliability Criteria violation. Mitigation measures would not be developed to specifically address POD bus voltage deviations that exceed the desired values in Table 3-1 of Attachment A-1.

5 Interpretation of Results

5.1 Results Overview

This section provides an assessment of the impact of the Project on the performance of the AIES. The Reliability Criteria violations observed during the connection assessment studies, and the proposed mitigation measures are summarized in Table 5-1.

- Section 5.2 includes an overview of the pre-Project studies results.
- Section 5.3 includes an overview of the post-Project studies results.
- Section 5.4 includes a description of the proposed mitigation measures to address observed Reliability Criteria violations.

Detailed study results are provided in Attachment A.

Table 5-1: Summary of Category B Reliability Criteria Violations, Project Impact and Mitigation Measures

Scenario	Type of Reliability Criteria Violation		Contingency (System Element Lost)	Details of Violation	Project Impact	Pre-Project Mitigation Measures	Post-Project Mitigation Measures
	Pre-Project	Post-Project					
2028 SP LG	Thermal - below emergency rating	Thermal - below emergency rating	1109L (SS-65 - SS-25)	1080L (SS-65 - SS-25)	Marginally decreased	Real-time operational practices (RTOP)	RTOP
	Thermal - below emergency rating	Thermal - below emergency rating	1080L (SS-65 - SS-25)	1109L (SS-65 - SS-25)	Marginally decreased	RTOP	RTOP

Notes:

- Marginally decreased refers to a percent loading difference (post-Project percent loading minus pre-Project percent loading) between 0% and -3%.

5.2 Pre-Project Study Results

5.2.1 Category A Conditions

No Reliability Criteria violations were observed under the Category A conditions (i.e., all elements in service) for any of the pre-Project scenarios.

The short-circuit fault levels were found to be within the typical capabilities of the nearby facilities.

5.2.2 Category B Conditions

The pre-Project power flow studies identified thermal criteria violations under Category B conditions (i.e., loss of a single system element).

No voltage deviations were observed that were beyond the limits listed in Table 3-1 of Appendix A – A1: Engineering Connection Assessment Scope (hereafter referred to as point of delivery (POD) bus voltage deviations) under Category B conditions.

5.3 Post-Project Study Results

5.3.1 Category A Conditions

No Reliability Criteria violations were observed under Category A conditions for any post-Project scenarios. Post-Project short-circuit fault levels were not significantly higher than pre-Project levels.

The long-term short circuit levels were found to be within the designed capabilities of the nearby facilities.

5.3.2 Category B Conditions

Post-Project power flow studies identified the same system performance issues under Category B conditions, as pre-Project.

No voltage criteria violations POD bus voltage deviations were observed under Category B conditions.

The voltage stability margin was met for all studied conditions.

5.4 Mitigation Measures

Both before and after the connection of the Project, all of the observed Category B thermal criteria violations can be managed by using real-time operational practices.

6 Project Dependencies

The Project does not require the completion of any other AESO plans to expand or enhance the transmission system prior to connection.

7 Conclusions and Recommendations

Based on the study results, Alternative 1 is technically viable. The connection assessment identified pre-Project and post-Project system performance issues under Category B conditions. All of the thermal criteria violations observed under Category B conditions can be mitigated through real-time operational practices.

The AESO recommends proceeding with the Project using Alternative 1 as the preferred alternative to respond to the DFO's request for system access service. Alternative 1 involves upgrading the existing SS-54 substation, including adding one 138/25 kV transformer and one 138 kV circuit breaker. The transformer should have a minimum rating of 44.5 MVA to meet the DFO's requested DTS.

Attachment A:
Engineering Connection Assessment Results

Engineering Connection Assessment: Study Results

P2921 Enmax SS-54 Area Load

Enmax Power Corporation (EPC)

Date: January 22, 2026

Version: V1

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1 Introduction

This report presents the results of the engineering studies that were completed by ENMAX Power Corporation (EPC) (the Studies Consultant) to assess the impact of the Project (as defined in Attachment A1: AESO Engineering Assessment Scope) on the performance of the Alberta interconnected electric system (AIES). The studies were performed in accordance with Attachment A1: AESO Engineering Connection Assessment: Study Scope, which was prepared by AESO.

The power system network analysis tool that was used for the studies in this connection assessment was PSS/E version 34.

2 Pre-Project Study Results

This section describes the results of the pre-Project power flow studies.

2.1 Power Flow Studies

Power flow diagrams illustrating the pre-Project power flow studies results for Category A and Category B conditions are provided in Attachment A2.

2.1.1 Scenario 1: 2028 SP LG Pre Project

Category A Conditions

No Reliability Criteria (as defined in Section 3.1 of Attachment A1) violations were observed under Category A conditions.

Category B Conditions

Thermal Criteria Violations

Thermal criteria violations were observed under certain Category B conditions as shown in Table 2-1.

Table 2-1: Thermal Criteria Violations under Category B Conditions for Scenario 1

Contingency (System Element Lost)	Violation Location Details	Thermal Ratings[a] (MVA)		Pre-Project Results	
		Normal Rating	Emergency Rating	Power Flow[b] (MVA)	% Loading[c]
1080L (SS-65 to SS-25)	1109L (SS-65 to SS-25)	487	584	503.1	103.3
1109L (SS-65 to SS-25)	1080L (SS-65 to SS-25)	487	584	502.8	103.2

Notes:

[a] The facility ratings shown in Attachment A1 have been adjusted from a [72/144] kV voltage base to a [69/138] kV voltage base, as is used by the power system network analysis tool.

[b] Power flow (MVA) is current expressed as MVA (i.e., $S = \sqrt{3} \times V_{base} \times I_{actual}$)

[c] Reported as a percentage of the power flow (in MVA, i.e., $S = \sqrt{3} \times V_{base} \times I_{actual}$) relative to the transmission line's Normal Rating (also in MVA), as shown in Attachment A1.

Voltage Criteria Violations

No voltage criteria violations were observed under Category B conditions.

POD Bus Voltage Deviations

No voltage deviations beyond the limits listed in Table 3-1 of Attachment A1 (hereafter referred to as point of delivery (POD) bus voltage deviations) were observed.

2.1.2 Scenario 2: 2028 WP LG Pre Project

Category A Conditions

No Reliability Criteria (as defined in Section 3.1 of Attachment A1) violations were observed under Category A conditions.

Category B Conditions

No Reliability Criteria violations were observed under Category B conditions.

Thermal Criteria Violations

No thermal criteria violations were observed under Category B conditions.

Voltage Criteria Violations

No voltage criteria violations were observed under Category B conditions.

POD Bus Voltage Deviations

No POD bus voltage deviations were observed.

3 Post-Project Study Results

This section describes the results of the post-Project power flow studies and voltage stability studies.

As described in Section 2 of Attachment A1, the post-Project studies were performed using Alternative 1

3.1 Power Flow Studies

Power flow diagrams illustrating the post-Project power flow studies results for Category A and Category B conditions are included in Attachment A3.

3.1.1 Scenario 3: 2028 SP LG Post Project

Category A Conditions

No Reliability Criteria violations were observed under Category A conditions.

Category B Conditions

Thermal criteria violations were observed under certain Category B conditions as shown in Table 3-1.

Table 3-1: Thermal Criteria Violations under Category B Conditions for Scenario 3

Contingency (System Element Lost)	Details of Violation (Violation Observed On)	Normal Rating (MVA)	Emergency Rating (MVA)	Pre-Project Results		Post-Project Results		% Loading Difference (Post-Pre)*
				Observed Power Flow (MVA)	% Loading	Observed Power Flow (MVA)	% Loading	
1080L (SS-65 to SS-25)	1109L (SS-65 to SS-25)	487	584	503.1	103.3	491.5	100.9	-2.4
1109L (SS-65 to SS-25)	1080L (SS-65 to SS-25)	487	584	502.8	103.2	491.2	100.9	-2.4

Notes:

*Negative Difference means post project loading was lower than pre project

Voltage Criteria Violations

No voltage criteria violations were observed under Category B conditions.

POD Bus Voltage Deviations

No POD bus voltage deviations were observed.

3.1.2 Scenario 4: 2028 WP LG Post Project

Category A Conditions

No Reliability Criteria violations were observed under Category A conditions.

Category B Conditions

No Reliability Criteria violations were observed under Category B conditions.

Voltage Criteria Violations

No voltage criteria violations were observed under Category B conditions.

POD Bus Voltage Deviations

No POD bus voltage deviations were observed.

3.2 Voltage Stability Studies

3.2.1 Scenario 4: 2028 WP LG Post Project

Voltage stability analysis was performed for the 2028 WP LG Post Project scenario (Scenario 4). The reference load level for the Study Area is 1820 MW. For Category B contingencies, the minimum incremental load transfer is 5% of the reference load, or 91 MW (0.05 x 1820 MW = 91 MW), in order to meet the voltage stability criteria.

Table 3-2 provides the voltage stability study results under Category A condition and for the five worst contingencies under Category B conditions. The voltage stability diagrams are provided in Attachment A4.

Table 3-2: Voltage Stability Study Results under Category B Conditions for Scenario 4

Contingency (System Element Lost)	From (Bus#)	To (Bus#)	Maximum Incremental Transfer (MW)	Maximum Incremental Transfer (%)	Meets Criteria ?
N-0	System Normal		881	48	Yes
54.81L	547	570	751	41	Yes
924L	159	540053	801	44	Yes
927L	159	540070	801	44	Yes
906L	155	161	811	45	Yes
928L	155	161	811	45	Yes

4 Short Circuit Studies

4.1 Pre-Project Results

Pre-Project short-circuit current levels for Scenario 2 (2028 WP LG Pre Project) are provided in Table 4-1[1].

Table 4-1: Pre-Project Short-Circuit Current Levels for Scenario 2

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (pu)	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (pu)
SS-65 (240 kV)	240.0	1.05	20.44	0.002793+ j0.012357	20.91	0.002270+ j0.011695
SS-54	138.0	1.01	14.22	0.006238+ j0.029754	9.14	0.023535+ j0.077772
SS-65 (138kV)	138.0	1.01	24.26	0.003873+ j0.017376	23.14	0.002435+ j0.020356
SS-26	138.0	1.00	18.82	0.005144+ j0.022338	14.45	0.006600+ j0.043301
SS-41	138.0	1.01	19.10	0.006008+ j0.021885	13.90	0.010657+ j0.047029

4.2 Post-Project Results

4.2.1 Scenario 4: 2028 WP LG Post Project

Post-Project short-circuit current levels for Scenario 4 (2028 WP LG Post-Project) are provided in Table 4-2.

[1] Short-circuit current studies were based on modeling information provided to the AESO by third parties. The authenticity of the modeling information has not been validated. Fault levels could change as a result of system developments, new customer connections, or additional generation in the area. It is recommended that these changes be monitored and fault levels reviewed to ensure that the fault levels are within equipment operating limits. The information provided in this study should not be used as the sole source of information for electrical equipment specifications or for the design of safety-grounding systems.

Table 4-2: Post-Project Short-Circuit Current Levels for Scenario 4

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (pu)	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (pu)
SS-65 (240 kV)	240.0	1.04	20.49	0.002821+ j0.012271	20.96	0.002250+ j0.011633
SS-54	138.0	1.00	14.30	0.006585+ j0.029191	9.10	0.023547+ j0.077855
SS-65 (138kV)	138.0	1.01	24.29	0.003999+ j0.017325	23.10	0.002466+ j0.020502
SS-26	138.0	1.00	18.84	0.005260+ j0.022271	14.44	0.006617+ j0.043397
SS-41	138.0	1.01	19.13	0.006119+ j0.021718	13.88	0.010661+ j0.047068

4.2.2 Scenario 5: 2033 WP Post-Project

Post-Project short-circuit current levels for Scenario 5 (2033 WP Post-Project) are provided in Table 4-3.

Table 4-3: Post-Project Short-Circuit Current Levels for Scenario 5

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (pu)	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (pu)
SS-65 (240 kV)	240.0	1.05	22.00	0.002483+ j0.011415	22.06	0.002224+ j0.011536
SS-54	138.0	1.00	14.55	0.006311+ j0.028558	9.14	0.023550+ j0.077898
SS-65 (138kV)	138.0	1.02	25.20	0.003735+ j0.016682	23.58	0.002491+ j0.020612
SS-26	138.0	1.01	19.34	0.004994+ j0.021615	14.60	0.006625+ j0.043448
SS-41	138.0	1.01	19.58	0.005870+ j0.021036	13.97	0.010656+ j0.047069

5 Mitigation Measure Development and Evaluation

The Studies Consultant, in consultation with the AESO, developed mitigation measures to address the system performance issues that were identified in the post-Project scenarios. Existing remedial action schemes (RASs) are described in Section 1.2.2 of Attachment A1.

As part of this Project, mitigation measures will not be specifically developed for the POD bus voltage deviations observed under certain Category B conditions during pre-Project and post-Project scenarios.[2]

5.1 Pre-Project

Pre-Project mitigation measures are summarized in Table 5-1.

Table 5-1: Pre-Project Mitigation Measures

Mitigation Measure	Location of Observed Violation	Contingency
Real time operational practices [a]	1080L (SS-25 to SS-65)	1109L (SS-25 to SS-65)
	1109L (SS-25 to SS-65)	1080L (SS-25 to SS-65)

Notes:

[a] In addition, the 240kV line rating increases for 1080L and 1109L as per the AESO's 2025 Long Term Plan may help mitigate the congestion in the future.

5.2 Post-Project

Post-Project mitigation measures are summarized in Table 5-2.

Table 5-2: Post-Project Mitigation Measures

Mitigation Measure	Location of Observed Violation	Contingency
Real time operational practices [a]	1080L (SS-25 to SS-65)	1109L (SS-25 to SS-65)
	1109L (SS-25 to SS-65)	1080L (SS-25 to SS-65)

Notes:

[a] In addition, the 240kV line rating increases for 1080L and 1109L as per the AESO's 2025 Long Term Plan may help mitigate the congestion in the future.

[2] The AESO's desired post-contingency voltage deviations for low voltage busses represent guidelines rather than criteria. A POD bus voltage deviation that exceeds the desired limits shown in Table 3-1 of Attachment A1 does not represent a Reliability Criteria violation.

Attachment A1: Engineering Connection Assessment: Study Scope

aeso

Engineering Connection Assessment: Study Scope

P2921 Enmax SS-54 Area Load

Enmax Power Corporation

Date:	January 16, 2026
Version:	V1
Classification:	Public

Company Name	Name and Credentials	Date	Signature
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1 Introduction

This Study Scope provides an overview of the engineering studies to be completed by Enmax Power Corporation (the Studies Consultant) to assess the impact of the Project (as defined in section 1.1) on the performance of the Alberta interconnected electric system (AIES). Technical criteria, assumptions and methods for performing these engineering studies are provided in this document.

1.1 Project Overview

ENMAX Power Corporation, in its capacity as the legal owner of an electric distribution system (DFO), has submitted a request for system access service to the Alberta Electric System Operator (AESO) to increase the contract capacity of one of their substations in the Calgary Area.

The DFO's request includes a request for a Rate DTS, Demand Transmission Service, contract capacity increase of 60 MW, from 20 MW to 80 MW, for the system access service provided at the existing ENMAX Substation No. 54 (SS-54) and a request for transmission development (collectively, the Project). Specifically, the DFO requested an enhancement to the existing SS-54 substation. Details on the need for the enhancement can be found in the DFO's Distribution Deficiency Report (DDR).

The Project in-service date (ISD) used for the purpose of the studies is August 2028.

Load components of the Project are listed in Table 1-1.

Table 1-1: Project Load and Generation Details

Project Component		Description
Load	Existing Rate DTS, *Demand Transmission Service,* contract capacity	20 MW at SS-54
	Requested Rate DTS	An increase of 60 MW at SS-54 to 80 MW
	Type	Residential, commercial, and, industrial (except oilsands).
	Motors (number and size)	N/A
	Power factor	0.9 pf
	Future load expansion plans	No

Note:

MARP and MC are defined in the AESO's *Consolidated Authoritative Document Glossary*, which can be found on the AESO's website.

1.2 Existing System Overview

1.2.1 Study Area

Geographically, the Project is located in the AESO planning area of Calgary (Area 6).

The Study Area consists of the AESO planning area of Calgary (Area 6), including the tie lines connecting these planning areas to the rest of the AIES.

The existing transmission system in the Study Area is shown in Figure 1-1.

1.2.2 Existing Constraints

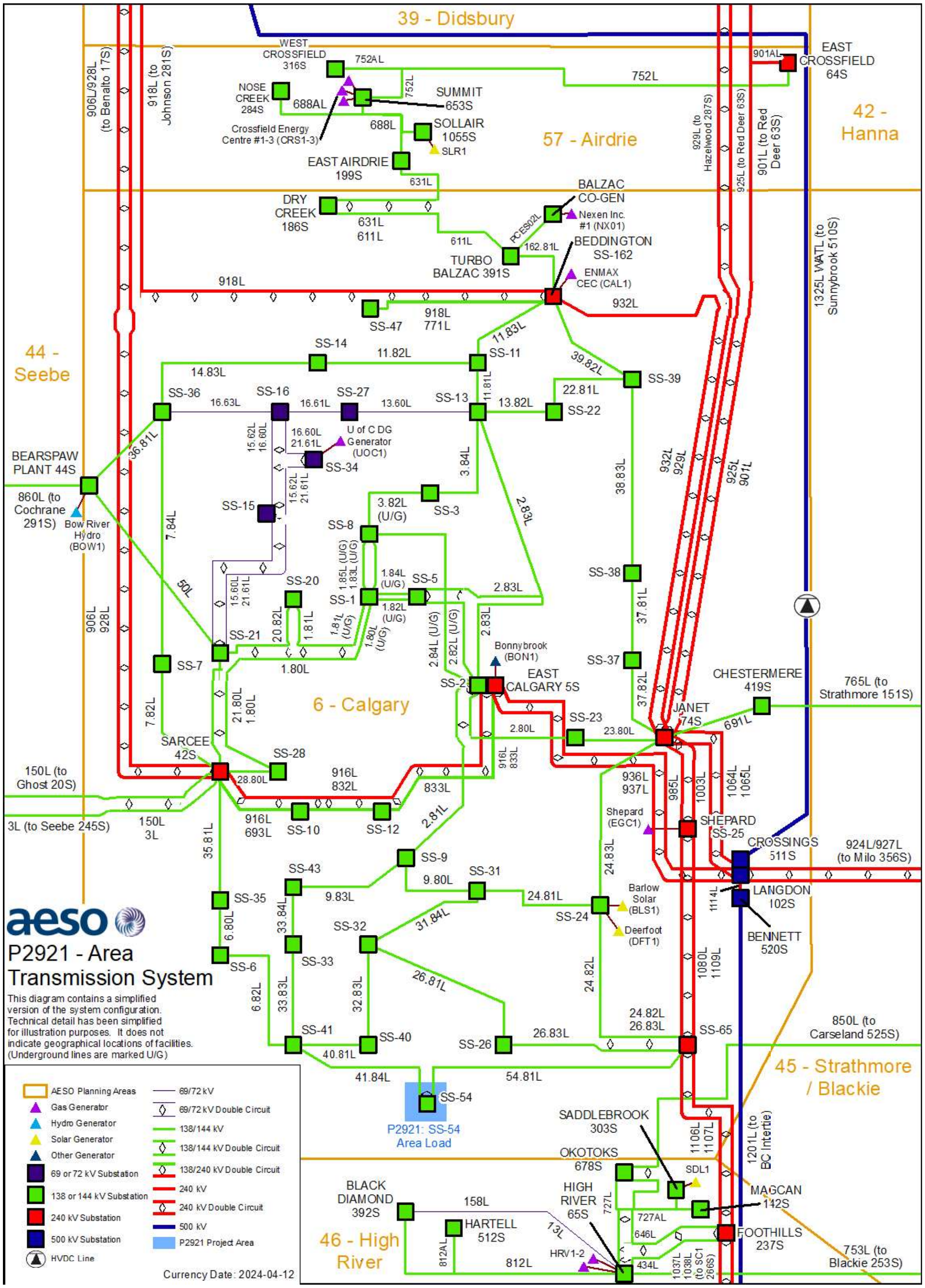
Existing constraints in the Study Area are managed in accordance with the procedures set out in Section 302.1 of the ISO rules, *Real Time Transmission Constraint Management* (TCM Rule).

There are a number of constraints in the Study Area that are mitigated by existing remedial action schemes (RASs) and/or other protection schemes.

The following existing RASs and/or other protection schemes are used to manage constraints in the area:

- RAS 11: Bennett 520S Underfrequency And Power Scheme
- RAS 12: Bennett 520S Undervoltage & Power Scheme
- RAS 136: Direct Transfer Trip to MATL on Loss of 1201L
- RAS 145: Shepard RAS – Mitigation of 138 kV Thermal Constraints on ENMAX System
- RAS 157: Chestermere 419S Load Shed Scheme
- RAS 179: 765L overload mitigation scheme
- RAS 194: Chestermere 419S Area Overload Mitigation and Generation Tripping Scheme

Figure 1-1: Transmission System in the Study Area



2 Connection Alternative

The following alternatives will be studied:

2.1 Alternative 1 – Upgrade ENMAX Substation No. 54 (SS-54)[1]

This alternative included the following developments:

- Upgrade the SS-54 substation, including adding one 138/25kV transformer and one 138 kV circuit breaker; and
- Add or modify associated equipment as required for the above transmission developments.
- The DFO has advised that this alternative will require adding approximately 16 km of distribution feeders.

[1] This is Alternative 3 in the DFOs DDR.

3 Criteria, Standards and Requirements

3.1 AESO Reliability Criteria

The Transmission Planning (TPL) Standards, which are included in the Alberta Reliability Standards, and *Transmission Planning Criteria – Basis and Assumptions (see Attachment A),* (collectively, the Reliability Criteria) will be applied 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. Below is a summary of Category A and Category B system conditions.

Category A, often referred to as the N-0 condition, represents a normal system with no contingencies and all facilities in service. Under this condition, the system must be able to supply all firm load and firm transfers to other areas. All equipment must operate within its applicable rating, voltages must be within their applicable range, and the system must be stable with no cascading outages.

Category B events, often referred to as an N-1 or N-G-1 with the most critical generator out of service, result in the loss of any single specified system element under specified fault conditions with normal clearing. These elements are a generator, a transmission circuit, a transformer, or a single pole of a DC transmission line. The acceptable impact on the system is the same as Category A. Planned or controlled interruptions of electric supply to radial customers or some local network customers, connected to or supplied by the faulted element or by the affected area, may occur in certain areas without impacting the overall reliability of the interconnected transmission systems. To prepare for the next contingency, system adjustments are permitted, including curtailments of contracted firm (non-recallable reserved) transmission service electric power transfers.

The TPL standards, TPL-001-AB-0, and TPL-002-AB1-0, have referenced Applicable Ratings when specifying the required system performance under Category A, and Category B events. For the purpose of applying the TPL standards to the studies documented in this report, Applicable Ratings are defined as follows:

- Normal thermal rating of the line's loading limits for each season;
- The highest specified loading limits for transformers;
- For Category A conditions: Voltage range under normal operating condition per AESO Information Document #2010-007RS, *General Operating Practices – Voltage Control* (ID #2010-007RS). For the busses not listed in ID #2010-007RS, Table 2-1 in the *Transmission Planning Criteria – Basis and Assumptions* applies;
- For Category B conditions: The extreme voltage range values per Table 2-1 in the *Transmission Planning Criteria – Basis and Assumptions; and*
- Desired post-contingency voltage deviation limits for three defined post-event timeframes as provided in Table 3-1.

Table 3-1: Post-Contingency Voltage Deviation Guidelines for Low Voltage Busses

Parameter and reference point	Time Period		
	Post Transient (up to 30 sec)	Post Auto Control (30 sec to 5 min)	Post Manual Control (Steady State)
Voltage deviation from steady state at point of delivery (POD) low voltage bus.	±10%	±7%	±5%

3.2 ISO Rules and Information Documents

ID #2010-007RS will be used to establish system normal (i.e., pre-contingency) voltage profiles for the Study Area.

The TCM Rule will be followed to set up the study scenarios and assess the impact of the Project. In addition, due regard will be given to the following:

- The AESO's *Connection Study Requirements*;
- All Applicable sections mentioned under Division 503 of the ISO Rules, *Technical and Operating Requirements*

4 Scenarios and Assumptions

4.1 Scenarios

The following section describes the scenarios to be studied and the assumptions to be used in the studies.

Connection scenarios must be studied as outlined in Table 4-1.

Table 4-1: Connection Study Scenarios

Scenario No.	Year/Season	System Generation Dispatch Conditions	Scenario Name	Project Load (MW)	Project Generation (MW)
Pre-Project					
1	2028 Summer Peak (SP)	Low Generation (LG)	2028 SP LG Pre-Project	0[a]	0
2	2028 Winter Peak (WP)	LG	2028 WP LG Pre-Project	0[a]	0
Post-Project					
3	2028 SP	LG	2028 SP LG Post-Project	60[a]	0
4	2028 WP	LG	2028 WP LG Post-Project	60[a]	0
5	2033 WP	All generators in Study Area In-Service	2033 WP Post-Project	60	0

a: The total load at SS-54 shall be 20MW in the pre-project and 80MW in the post-project.

4.2 Assumptions

4.2.1 System Project Assumptions

The pre-Project and post-Project connection assessment will not include any system transmission projects because there are no planned system transmission developments in the Study Area that are expected to be in service before the scheduled Project ISD.

4.2.2 Connection Project Assumptions

Table 4-2 summarizes the connection projects in the Study Area that should be included in the studies.

Table 4-2: Planned Connection Projects Included in the Studies

AESO Project No.	AESO Project Name	AESO Planning Area No.	Generation (MW)	Load (MW)	Scheduled ISD	AUC NID Decision No.
P2192	ENMAX FMC Change	6	5	5	October 2025	30419-D01-2025

P2354	ENMAX FMC DER Cogen	6	5	5	October 2025	30419 -D01- 2025

4.2.3 Load Assumptions

The load forecast to be used for the studies is shown in Table 4-3 and is a forecast for the AESO Calgary Planning Region peak based on the preliminary AESO 2023 Long-term Outlook (2023 LTO)[2] with modifications to incorporate the latest forecast intelligence. For the post-Project studies, when the Study Area loads are modified to align with the regional load forecast, the active power to reactive power ratio in the base case scenarios shall be maintained.

Table 4-3: Forecast Load (at AESO Calgary Planning Region Peak)

AESO Planning Region Name	Forecast Peak Load by Year/Season (MW)	
	2028 SP LG	2028 WP LG
Calgary (Area 6)	1734	1746
AIES	11540	12133

4.2.4 Generation Assumptions

The generation forecast to be used for the studies is based on the preliminary 2023 LTO with modifications to incorporate the latest forecast intelligence. The generation assumptions for the studies will assume low generation dispatch conditions. Additional studies may be required in the event of changes to the AESO's corporate forecast.

The existing generation (excluding wind and solar) dispatch conditions for the study scenarios are described in Table 4-4.

Shepard SS-25 unit 2 was determined to be the critical generator, and shall be modelled as being offline to simulate the N-G condition in all the study scenarios.

Table 4-4: Existing Generation (excluding Wind and Solar) Dispatch Conditions

Facility MPID	MC (MW)	AESO Planning Area No.	Unit Net Generation[a] (MW) by Scenario	
			2028 SP LG	2028 WP LG
BonnyBrook (BON1)	10	6	6	6
Calgary Energy Center (CES1)	330	6	122	122

[2] The AESO Planning Region load and generation forecasts used for the connection studies were based on the *AESO's 2023 Long-Term Outlook (2023 LTO)*. While the AESO has updated its regional forecasts since the connection studies were performed, the use of the current AESO forecast, the *2024 Long-term Outlook* (2024 LTO), would not materially alter the connection study results or affect the conclusions and recommendations in this report.

Facility MPID	MC (MW)	AESO Planning Area No.	Unit Net Generation[a] (MW) by Scenario	
			2028 SP LG	2028 WP LG
Crossfiled Energy center (CRS)			84	129
Shepard (EGC1)	868	6	295 (N-G)[b]	381 (N-G)[b]
Nexen Inc (NX01)	120	6	48	48
Project2192_1_GN	5	6	5	5
Project2354_1_GN	5	6	5	5
U of C generator (UOC1)	12	6	10	11

Notes:
[a] "Unit Net Generation" refers to gross generating unit output (MW) less unit service load.
[b] "N-G" indicates the critical generating unit that is assumed by the AESO to be offline to test the N-G contingency condition

Using this value, the existing and planned solar generation facilities will be dispatched to yield the credible worst-case power flow conditions for the Study Area. Pre-Project dispatch levels for the existing and planned wind and solar generation facilities are shown in Table 4-5.

Table 4-5: Dispatch Conditions for Existing and Planned Solar Generation Projects

Facility Name and Code	MC (MW)	AESO Planning Area No.	Unit Net Generation[a] (MW) by Scenario	
			2028 SP LG	2028 WP LG
Barlow Solar (BLS1)	27	6	17	0
Deerfoot (DFT1)	37	6	24	0
Sollair Solar Energy Plant (SLR1)	75	57	48	0

Note:
[a] ""Unit Net Generation" refers to gross generating unit output (MW) less unit service load.

The post-Project scenario wind and solar generation dispatch levels were identical to the pre-Project scenario dispatch levels shown in Table 4-4 and Table 4-5.

4.2.5 Intertie Flow Assumptions

The intertie flow assumptions for the Alberta-British Columbia (AB-BC), Alberta-Saskatchewan (AB-SK), and Alberta-Montana (MATL) interties are shown in Table 4-6.

For the 2033 WP scenario, the intertie flow values should be set to the AESO planning base cases.

Table 4-6: Intertie Flows by Scenario

Scenario Number	Scenario Name	Import (-) / Export (+) (MW) by Intertie		
		AB-BC	AB-SK	MATL
1,3	2028 SP LG	+750	+150	+183
2,4	2028 WP LG	+475	+50	+75

4.2.6 HVDC Power Order Assumptions

The Western Alberta Transmission Line (WATL) and the Eastern Alberta Transmission Line (EATL) are high-voltage direct current (HVDC) transmission lines. The HVDC power order assumptions for the studies will be set to minimize losses for the pre-Project and post-Project study scenarios.

The reactive power limits of the MVAr exchanges between the HVDC terminals (WATL and EATL) and the connected alternating current (AC) transmission systems are shown in Table 4-7. These limits must be maintained when performing the studies.

Table 4-7: HVDC to Adjacent AC System MVAr Exchange Limits

HVDC Facility	North Terminal Reactive Power Limit (MVAr)	South Terminal Reactive Power Limit (MVAr)
EATL	-85 to 75	-35 to 35
WATL	-75 to 75	-35 to 35

4.2.7 Transmission Facility Ratings

The legal owners of transmission facilities (TFOs) provided the thermal ratings assumptions for the existing transmission lines in the Study Area. Table 4-8 shows the normal ratings and emergency ratings for the key transmission lines in the Study Area, which will be used to perform the engineering studies.

Table 4-8: Thermal Rating Assumptions for Key Transmission Lines in the Study Area

Line ID	From	To	Voltage Class (kV)	Summer Normal Rating (MVA)	Winter Normal Rating (MVA)	Summer Emergency Rating (MVA)	Winter Emergency Rating (MVA)
41.84L	SS-54	SS-41	138	285	287	285	316
54.81L	SS-54	SS-65	138	285	350	285	350
162.81L	Beddington SS-162	TURBOBALZAC 391S	138	287	287	318	373
11.83L	Beddington SS-162	SS-11	138	330	398	330	398
39.82L	Beddington SS-162	SS-39	138	322	408	354	449
901L	REDDEER 63S	CROSSF T 901AL	240	408	494	490	593
906L	BENALTO 17S	SARCEE 42S	240	350	469	420	499
928L	BENALTO 17S	SARCEE 42S	240	453	499	499	499
936L	LANGDON 102S	EASTCALGARY 5S	240	487	604	584	725

Line ID	From	To	Voltage Class (kV)	Summer Normal Rating (MVA)	Winter Normal Rating (MVA)	Summer Emergency Rating (MVA)	Winter Emergency Rating (MVA)
937L	LANGDON 102S	EASTCALGARY 5S	240	487	604	584	725
924L	LANGDON 102S	924LAL	240	547	676	656	811
927L	LANGDON 102S	927AL	240	576	711	691	853
932L	JANET 74S	Beddington SS-162	240	481	581	577	648
925L	JANET 74S	925AL	240	476	571.1	524	619
1003L	JANET 74S	ENMX25S7 SS-25	240	973	1039	1017	1039
985L	JANET 74S	ENMX25S7 SS-25	240	973.1	1038.8	1017	1038.8
901L	JANET 74S	CROSSF T 901AL	240	337	407	404	488
929L	JANET 74S	929AL	240	441	581	529	648
916L	SARCEE 42S	EASTCALGARY 5S	240	408	494	490	593
860L	COCHRANE 291S	BEARSPAW PLANT 44S	138	108	139	119	153
433L	COCHRANE 291S	Horse Creek T793S	138	121	148	133	163
777L	SEEBE 245S	POCATERRA 48S	138	96	115	96	115
631L	EASTAIRDRIE 199S	Dry Creek 186S	138	120	117	132	129
688L	EASTAIRDRIE 199S	688BL	138	121	148	133	163
36.81L	BEARSPAW PLANT 44S	SS-36	138	143	172	172	186
918L	Beddington SS-162	Johnson 281S	240	340	553	408	664
611L	TURBOBALZAC 391S	Dry Creek 186S	138	119	147	131	162
3L	SARCEE 42S	SPRINGBANK 272S	138	103	134	113	147
37.82L	JANET 74S	SS-37	138	287	287	352	430
23.80L	JANET 74S	SS-23	138	285	287	285	350
24.83L	JANET 74S	SS-24	138	322	408	352	430
691L	JANET 74S	CHESTERMERE 419S	138	85	90	94	99
753L	HIGHRIVER 65S	BLACKIE 253S	138	121	143	133	143
733L	GLEICHEN 179S	Namaka 428S 428S	138	120	148	132	163
733L	STRATHMORE 151S	Namaka 428S 428S	138	120	148	132	163
765L	STRATHMORE 151S	CHESTERMERE 419S	138	117	134	129	147
754L	BAYMAG 437S	742L JCT 754L	138	153	189	168	208
752L	EASTCROSSFIELD 64S	AIRD TAP 752AL	138	119	136	131	150.1
161L	QUEENSTOWN 504S	161AL	138	117	120	129	160
3L	SPRINGBANK 272S	JUMP TP2 3AL	138	118	146	130	161
1201L	Bennett 520S	1201L 1201L	500	1222	1386	1589	2078
688L	Summit 653S	SUMMITTP 688AL	138	121	148	133	163
752L	Summit 653S	AIRD TAP 752AL	138	121	142	133	156.1
1107L	SS-65	Foothills 237S	240	971	1207	1071	1330
1109L	SS-65	SS-25	240	487	604	584	725

Line ID	From	To	Voltage Class (kV)	Summer Normal Rating (MVA)	Winter Normal Rating (MVA)	Summer Emergency Rating (MVA)	Winter Emergency Rating (MVA)
1080L	SS-65	SS-25	240	487	604	584	725
1106L	SS-65	1106AL	240	971	1207	1071	1330
1037L	Foothills 237S	SC1 266S	240	973	1208	1071	1330
1038L	Foothills 237S	SC1 266S	240	973	1208	1071	1330
1106L	Foothills 237S	1106AL	240	971	1207	1071	1330
924L	MILO 356S	Langdon 102S	240	547	675.9	656	811
225L	Spring Coulee 385S	Glenwood 229S	69	22	26	24	29
225L	Spring Coulee 385S	Magrath 225S	69	24	24	28	29
1048L	Goose Lake 103S	Peigan 59S	240	611	751	751	831
1049L	Goose Lake 103S	Peigan 59S	240	611	751	751	901
786L	Coleman 799S	Natal	138	99	132	109	145
1036L	Milo 356S	Traver 554S	240	481	581	577	697
616L	Goose Lake 103S	616AL tap	138	153	190	168	209
616L	Peigan 59S	616AL tap	138	111	141	122	155
924L	MILO 356S	924AL	240	547	676	656	811
927L	MILO 356S	927AL	240	576	711	691	853

Note:
"CT" indicates that the transmission line is limited by current transformer.

"L" indicates that the transmission line rating is limited by the line

"M" indicates that the transmission line rating is limited for reasons other than protection equipment, transformer, current transformer, line, ganged switch, circuit breaker, or regulator.

The TFOs provided the details of the substation transformers in the Study Area. The key transformers in the Study Area are shown in Table 4-9.

Table 4-9: Summary of Key Transformer Ratings in the Study Area

Substation Name and Number	Transformer ID	Transformer Voltages (kV)	Transformer Rating (MVA)
Janet 74S	T1	240/138	341.8
Janet 74S	T2	240/138	341.8
Foothills 237S	T1	240/138	400
Foothills 237S	T2	240/138	400
East Calgary 5S	T1	240/138	400
East Calgary 5S	T2	240/138	400
SS-162	T1	240/138	400
SS-162	T2	240/138	400
SS-65	T1	240/138	400
SS-65	T2	240/138	400
Peigan 59S	T1	240/138	179
Windy Flats 138S	T1	240/138	400

Substation Name and Number	Transformer ID	Transformer Voltages (kV)	Transformer Rating (MVA)
Windy Flats 138S	T2	240/138	400

The TFOs provided the details of the shunt elements in the Study Area. The key shunt elements in the Study Area are shown in Table 4-10.

Table 4-10: Summary of Key Shunt Elements in the Study Area

Substation Name and Number	Voltage Class (kV)	Capacitors		Reactors	
		Number of Switched Shunt Blocks	Total at Nominal Voltage (MVAr)	Number of Switched Shunt Blocks	Total at Nominal Voltage (MVAr)
Strathmore 151S	138	1	24.46		
Hussar 431S	138	1	9.17		
Blackie 253S	138	1	24.46		
Magcan 142S	138	1	24.46		
SS-2	138	2	160		
Janet 74S	240	2	268.8		
Janet 74S	138	2	146.74		
Langdon 102S	240	SVC (Continuous)	2x(108.14 to -148.1)		
Sarcee 42S	240	2	201.6		
Sarcee 42S	138	1	48.92		
East Airdire 199S	138	1	27.17		
SS-21	138	1	48.91		
SS-14	138	2	48.92		
SS-38	138	1	48.11		
SS-31	138	1	48.11		
SS-41	138	1	53.96		
Canmore 118S	138	1	24.55		
Windy Flats 138S	240			2	75
Pincher Creek 396S	138	1	24.46		
Dry Creek 186S	138	1	27.17		

4.2.8 Voltage Profile Assumption

ID #2010-007RS will be used to establish system normal (i.e., pre-contingency) voltage profiles for key area busses prior to commencing any studies. Table 2-1 of the *Transmission Planning Criteria – Basis and Assumptions* applies for the busses not included in ID #2010-007RS. These voltages will be used to set the voltage profile for the study base cases prior to the power flow studies.

5 Study Methodology

The studies to be performed for this connection assessment are identified in Table 5-1.

Table 5-1: Summary of the Studies to be Performed

Scenario No. and Name		Power Flow		Voltage Stability		Short Circuit
		Category		Category		Category A
		A	B	A	B	
Pre-Project						
1	2028 SP LG Pre-Project	X	X			
2	2028 WP LG Pre-Project	X	X	X*	X*	X
Post-Project						
3	2028 SP LG Post-Project	X	X			
4	2028 WP LG Post-Project	X	X	X	X	X
5	2033 WP Post-Project					X

Notes:

*Only if Post-Project studies show potential issues.

For the engineering studies, all transmission facilities 69kV and above, within the Study Area and the transmission lines connecting this planning area to neighbouring planning areas will be studied and monitored to assess the impact of the Project on the performance of the AIES, including any violations of the Reliability Criteria (as defined in Section 3.1).

5.1 Power Flow Studies

Power flow studies will be performed to identify thermal and voltage criteria violations as per the Reliability Criteria, and any deviations from the limits listed in Table 3-1.

For information purposes, the Studies Consultant must also provide, as a separate file, a list of any transmission elements where the thermal loading exceeds 95% of the element's normal rating under Category A and Category B conditions.

For the Category B power flow studies, the transformer taps and switched shunt reactive compensating devices such as shunt capacitors and reactors will be locked and continuous shunt devices will be enabled.

Voltage deviations at point-of-delivery (POD) low voltage busses will also be assessed for both the pre-Project and post-Project networks by first locking all tap changers and area shunt reactive compensating devices to identify any post-transient voltage deviations above 10%. Second, tap changers will be allowed to move while shunt reactive compensating devices remained locked to determine if any voltage deviations above 7% would occur in the area. Third, all the taps and shunt reactive compensating devices will be allowed to adjust, and voltage deviations above 5% will be reported.

The scenarios to be studied are shown in Table 5-1.

5.1.1 Contingencies to be Studied

Power flow studies will be performed for the Category A and all Category B conditions in the Study Area.

5.2 Voltage Stability Studies

The objective of the voltage stability studies is to determine the ability of the transmission system to maintain voltage stability margin at all busses under Category A and Category B conditions. The power-voltage (PV) curve is a representation of voltage change as a result of increased power transfer between two systems. The incremental transfers will be reported at the collapse point.

Voltage stability studies will be performed for the post-Project scenarios. For load connection projects, the load level modeled in post-Project scenarios is the same as, or higher than, in pre-Project scenarios. Therefore, voltage stability studies for pre-Project scenarios will only be performed if post-Project scenarios show voltage stability criteria violations.

Voltage stability studies will be performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology. WECC voltage stability criteria states, for load areas, post-transient voltage stability margin is required for the area modeled at a minimum of 105% of the reference load level for Category A conditions and for Category B conditions. For this standard, the reference load level is the maximum established planned load.

Typically, voltage stability studies are carried out assuming the worst case scenarios in terms of loading. In this connection assessment, the voltage stability studies will be performed by increasing load in Calgary (Area 6) and increasing generation in Wabamun (Area 40).

The scenarios and cases to be studied are shown in Table 5-1.

5.2.1 Contingencies to be Studied

Voltage stability studies will be performed for all Category B contingencies in the Study Area. The Category A condition and the five contingencies with the smallest stability margin will be presented in the results.

5.3 Short-Circuit Current Level Studies

A maximum fault level must be provided for the substations in the vicinity of the Project assuming normal system operation with all transmission elements in service and generation dispatched. Three-phase faults and single line-to-ground faults will be simulated. Polar coordinates and per-unit values will be used for reporting the results.

Winter peak scenarios will be used for the short-circuit studies because winter peak scenarios generally produce higher short-circuit current levels than summer peak scenarios.

Estimated maximum three-phase faults and single line-to-ground short-circuit current levels will be reported for the following substations:

- SS-41

- SS-26
- SS-65
- SS-54

Further sensitivity studies, in consultation with the TFO, may be required if the primary short-circuit analysis indicates a potential to exceed or approach the existing fault rating of the transmission facilities.

The scenarios to be studied are as shown in Table 5-1.

6 Mitigation Measures

6.1 Development

Mitigation measures may be required if the post-Project study results identify system performance issues. Mitigation measures for the Project may involve modifying or adding real-time operational practices and/or remedial action schemes (RASs).

The Studies Consultant must notify the AESO of any system performance issues in a timely manner, following which the AESO Studies Engineer may instruct the Studies Consultant as follows:

- Develop tables showing the constraint effective factors[3] for generation or load based on thermal criteria violations that are observed.
- Collaborate with the AESO to propose changes, if any, to the connection alternatives that could remove the requirement for a RAS.
- Collaborate with the AESO to study modifications to existing and/or planned RASs, proposed by the AESO, to ensure the coordination of existing protection schemes with the addition of any proposed protection schemes.
- Collaborate with the AESO to identify and study new RASs, if any, that may be required to ensure system reliability is maintained after connecting the Project to the AIES.

The AESO Studies Engineer will work closely with the Studies Consultant and guide the development and/or modifications of the proposed mitigation measures to ensure system reliability, security and compliance with AESO ID #2018-018T, *Provision of System Access Service and the Connection Process*.

6.2 Evaluation

6.2.1 Post-Mitigation Studies

Studies to evaluate the effectiveness of mitigation measures, if required, will be performed in accordance with the technical criteria, assumptions, and methods provided in this Study Scope and in accordance with further instructions from the AESO.

6.2.2 Constraint Effective Factor Studies

Constraint effective factor analysis are used to determine the generator- and load- constraint effective factors and to identify the most effective generators or loads to manage the thermal criteria violations, if any, that are observed under Category B conditions.

[3] Constraint effective factor studies are performed to determine the generator- and load- constraint effective factors. Constraint effective factors are used to estimate the ability of generators and loads to manage transmission constraints. A generator's or load's constraint effective factor is defined as the change in power flow over a specific transmission line following a change in the generator's energy production or in the load's energy consumption. The greater the constraint effective factor, the more effective a generator or load can be in managing a thermal criteria violation on the specific transmission line.

7 Changes to Study Assumptions

This study will utilize the AESO's planning base cases, which are based on the AESO's current corporate forecast (2023 LTO) with modifications to incorporate the latest forecast intelligence. Sensitivity studies or restudy may be required in the event of revisions to the AESO's corporate forecast, forecast intelligence, or other study assumptions. Additional engineering studies may also be required to assess new connection alternatives, changes to project ISD, or delays in proposed system developments. Any additional or revised study requirements shall be captured in a signed Study Scope Amendment document.

Attachment A:
Transmission Planning Criteria – Basis and Assumptions

Transmission Planning Criteria - Basis and Assumptions

Version 1.0

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1. Introduction

This document presents the reliability standards, criteria, and assumptions to be used as the basis for planning the Alberta Transmission System. The criteria, standards and assumptions identified in this document supersede those previously established.

2. Transmission Reliability Standards and Criteria[1]

The AESO applies the following Alberta Reliability Standards to ensure that the transmission system is planned to meet applicable performance requirements under a defined set of system conditions and contingencies. A brief description of each of these standards is given below:

1. **TPL-001-AB-0: System Performance Under Normal Conditions**
   Category A represents a normal system condition with all elements in service (N-0). All equipment must be within its applicable rating, voltages must be within their applicable ratings and the system must be stable with no cascading outages. Under Category A, electric supply to load cannot be interrupted and generating units cannot be removed from service.

2. **TPL-002-AB-0: System Performance Following Loss of a Single BES Element**
   Category B events result in the loss of any single element (N-1) under specified fault conditions with normal clearing. The specified elements are a generating unit, a transmission circuit, a transformer or a single pole of a direct current transmission line. The acceptable impact on the system is the same as Category A with the exception that radial customers or some local network customers, including loads or generating units, are allowed to be disconnected from the system if they are connected through the faulted element. The loss of opportunity load or opportunity interchanges is allowed. No cascading can occur.

3. **TPL-003-AB-0: System Performance Following Loss of Two or More BES Elements**
   Category C events result in the loss of two or more bulk electric system elements (sequential, N-1-1 or concurrent, N-2) under specified fault conditions and include both normal and delayed fault clearing. All of the system limits for Category A and B events apply with the exception that planned and controlled loss of firm load, firm transfers and/or generation is acceptable provided there is no cascading.

4. **TPL-004-AB-0: System Performance Following Extreme BES Events**
   Category D represents a wide variety of extreme, rare and unpredictable events, which may result in the loss of load and generation in widespread areas. The system may not be able to reach a new stable steady state, which means a blackout is a possible outcome. The AESO needs to evaluate these events, at its discretion, for risks and consequences prior to creating mitigation plans.

5. **FAC-014-AB-2: Establishing and Communicating System Operating Limits**
   The AESO is required to establish system operating limits where a contingency is not mitigated through construction of transmission facilities.

2.1 Thermal Loading Criteria

The AESO Thermal Loading Criteria require that the continuous thermal rating of any transmission element is not exceeded under normal and post-contingency operating conditions. Thermal limits are

[1] A complete description of these standards are given in: AESO. *Alberta Reliability Standards*. Available from http://www.aeso.ca/rulesprocedures/17004.html

assumed to be 100% of the respective normal summer and winter ratings. Emergency limits are not considered in the planning evaluations.

2.2 Voltage Range and Voltage Stability Criteria

The normal minimum and maximum voltage limits as specified in the following table are used to identify Category A system voltage violations, while the extreme minimum and maximum limits are used to identify Category B and C system violations. Table 2-1 presents the acceptable steady state and contingency state voltage ranges for the AIES. Table 2-2 provides voltage stability criteria used to test the system performance.

Table 2-1: Acceptable Range of Steady State Voltage (kV)

Nominal Voltage	Extreme Minimum	Normal Minimum	Normal Maximum	Extreme Maximum
500	475	500	525	550
240	216	234	252	264
260 (Northeast & Northwest)*	234	247	266	275
144	130	137	151	155
138	124	135	145	152
72	65	68.5	75.5	79
69	62	65.5	72.5	76

Table 2-2: Voltage Stability Criteria

Performance Level	Disturbance (1)(2)(3)(4) Initiated by: Fault or No fault DC Disturbance	MW Margin (P-V method) (5)(6)(7)	MVAr Margin (V-Q method) (6)(7)
A	Any element such as: One Generator One Circuit One Transformer One Reactive Power Source One DC Monopole	≥ 5%	Worst Case Scenario(8)
B	Bus Section	≥ 5%	50% of Margin Requirement in Level A
C	Any combination of two elements such as: A Line and a Generator A Line and a Reactive Power Source Two Generators Two Circuits Two Transformers Two Reactive Power Sources DC Bipole	≥ 2.5%	50% of Margin Requirement in Level A

Performance Level	Disturbance (1)(2)(3)(4) Initiated by: Fault or No fault DC Disturbance	MW Margin (P-V method) (5)(6)(7)	MVAr Margin (V-Q method) (6)(7)
D	Any combination of three or more elements. i.e.: Three or More Circuits on ROW Entire Substation Entire Plant Including Switchyard	> 0	> 0

2.3 Transient Stability Analysis Assumptions

Standard fault clearing times as shown in Table 2-3 are used for the new facilities or when the actual clearing times are not available for the existing facilities. Double line-to-ground faults are applied for the Category C5 events with normal clearing times. Single line-to-ground faults are applied for Category C6 to C9 events with delayed clearing times as depicted in Table 2-4 and Table 2-5.

Table 2-3: Fault Clearing Times

Nominal	Near End	Far End
kV	**Cycles**	**Cycles**
500	4	5
240	5	6
144/138 with telecommunications	6	8
144/138 without telecommunications	6	30

Table 2-4: Stuck Breaker Clearing Times for Lines

Fault Clearing Time			Fault Clearing Time			Fault Clearing Time		
138/144 kV			240 kV			500 kV		
Near End	Far End	2nd Ckt (for C5 and C7 Only)	Near End	Far End	2nd Ckt (for C5 and C7 Only)	Near End	Far End	2nd Ckt (for C5 and C7 Only)
15	24	24	12	6	14	9	5	11

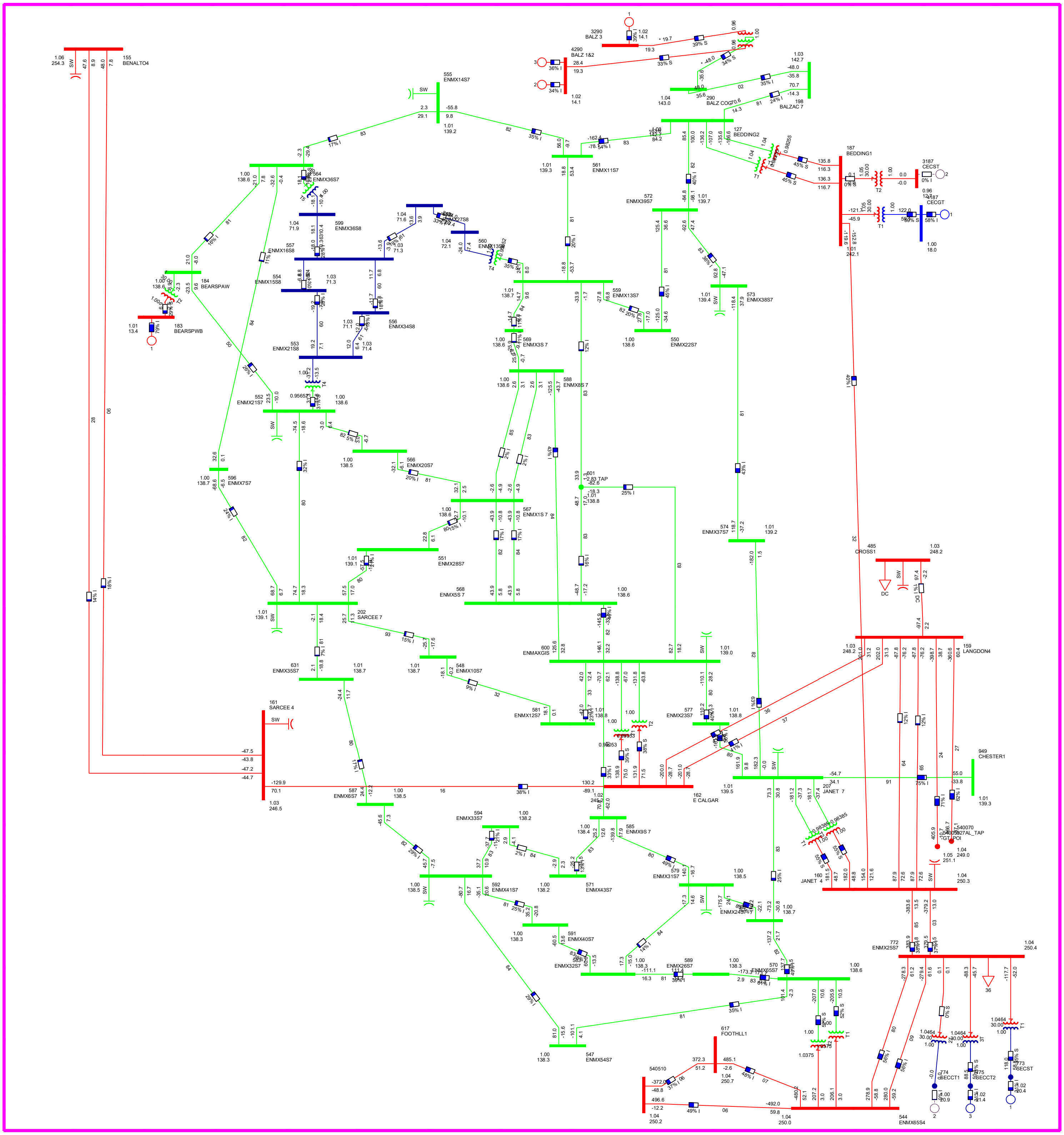
Table 2-5: Stuck Breaker Clearing Times for Transformers

Fault Clearing Time (Cycles)						Fault Clearing Time (Cycles)					
240/138 kV						500/240 kV					
Fault on 240 kV Side			Fault on 138 kV Side			Fault on 500 kV Side			Fault on 240 kV Side		
240 kV Side	138 kV Side	2nd Ckt (for Breaker Fail)	138 kV Side	240 kV Side	2nd Ckt (for Breaker Fail)	500 kV Side	240 kV Side	2nd Ckt (for Breaker Fail)	240 kV Side	500 kV Side	2nd Ckt (for Breaker Fail)
12	6	14	15	5	24	9	5	11	12	4	14

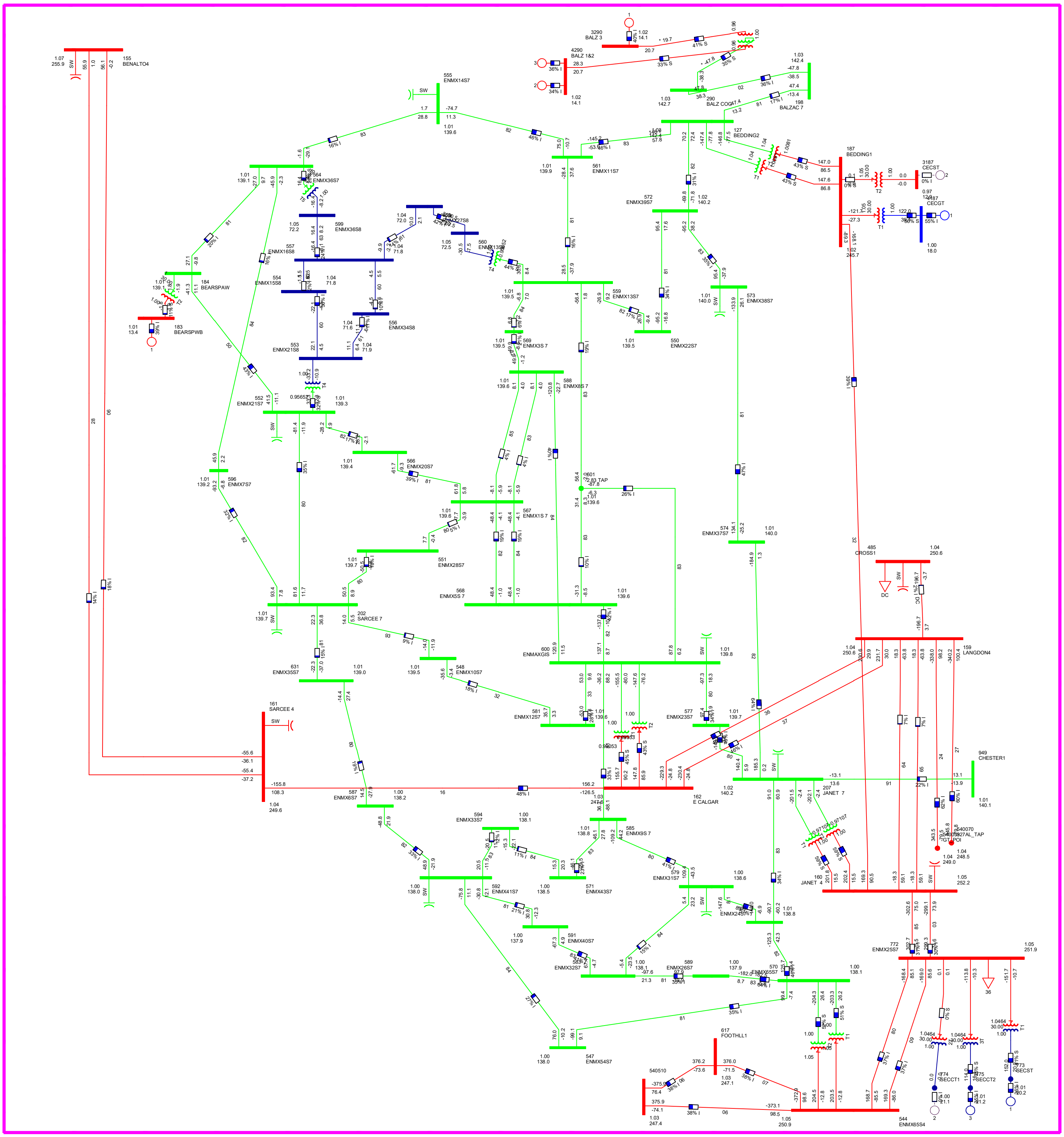
Attachment A2: Pre-Project Power Flow Diagrams

1. 2028SP - Pre Project Cat A Power Flow Diagram
2. 2028WP - Pre Project Cat A Power Flow Diagram
3. 2028SP - Pre Project Cat B (1080L Out) Power Flow Diagram
4. 2028SP - Pre Project Cat B (1109L Out) Power Flow Diagram

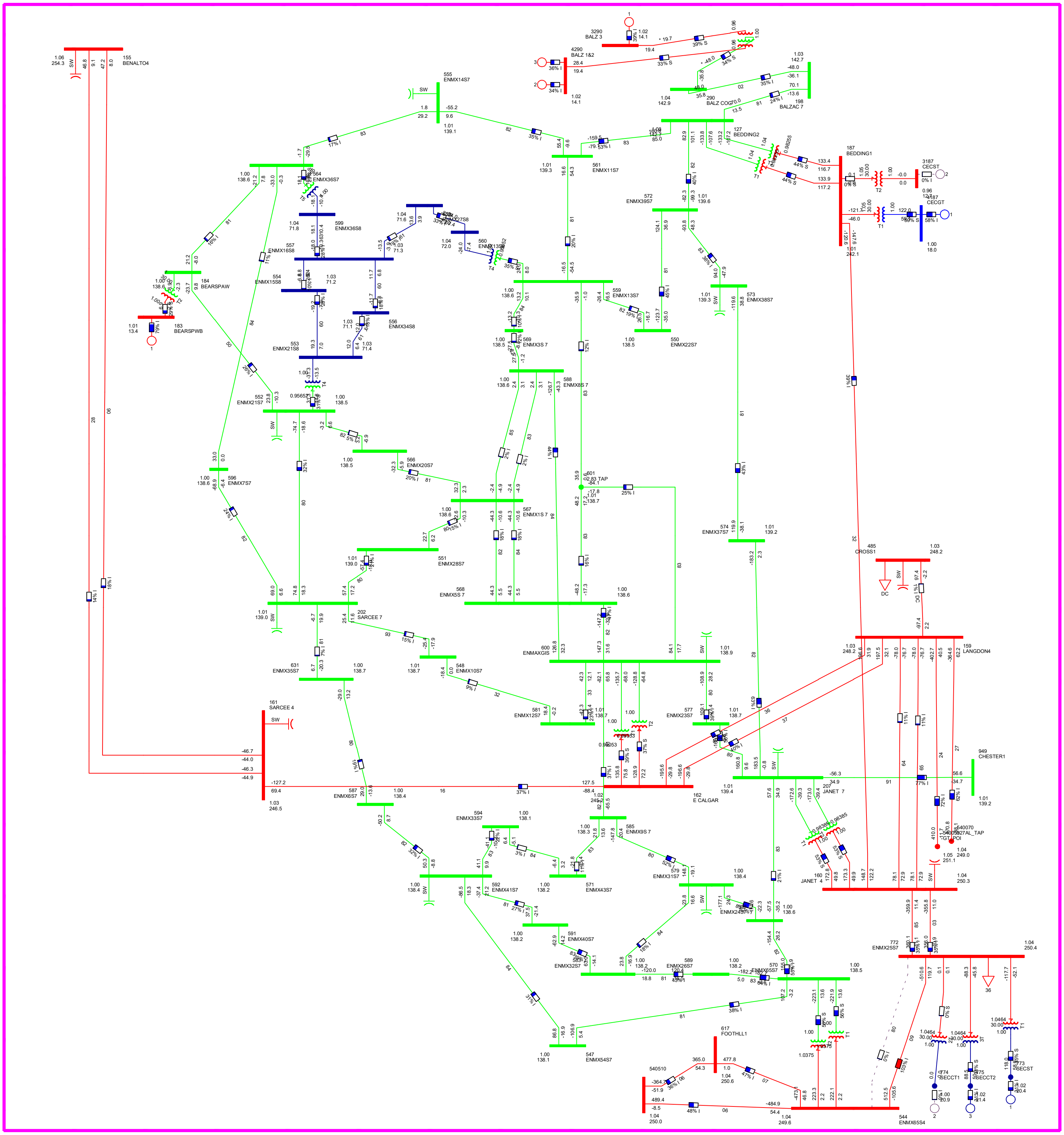
2028SP - Pre Project Cat A Power Flow Diagram



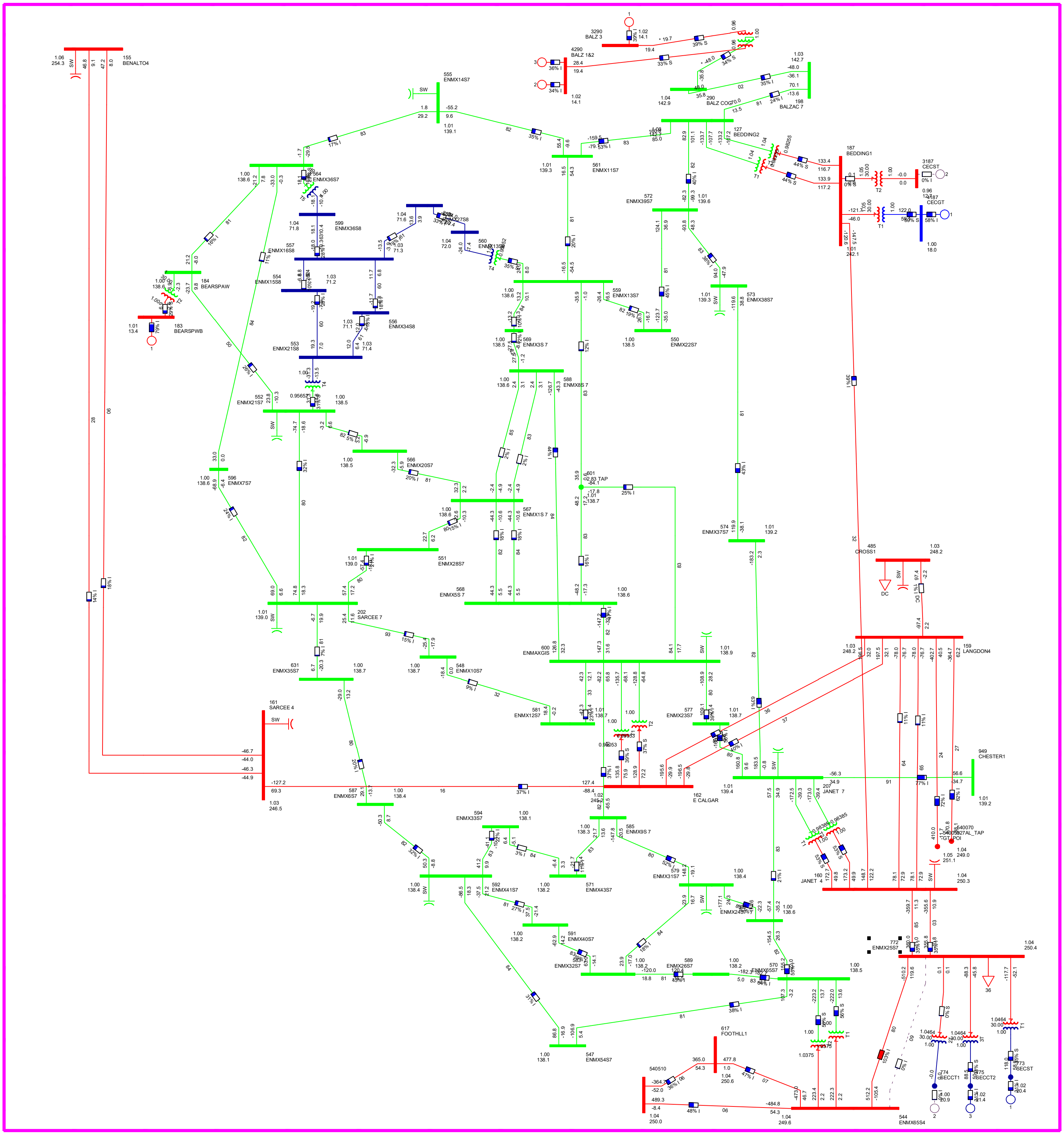
2028WP - Pre Project Cat A Power Flow Diagram



2028SP - Pre Project Cat B (1080L Out) Power Flow Diagram



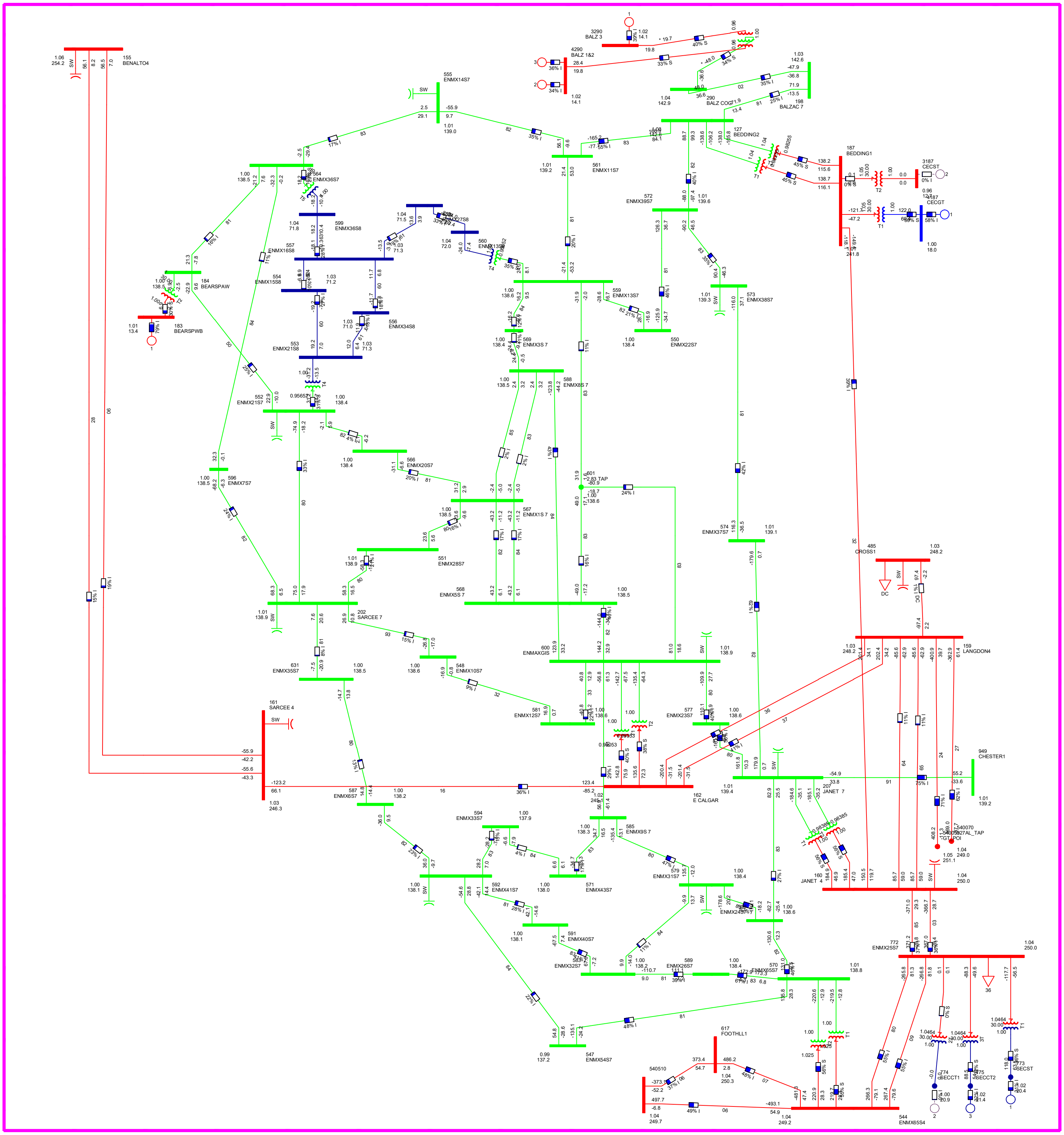
2028SP - Pre Project Cat B (1109L Out) Power Flow Diagram



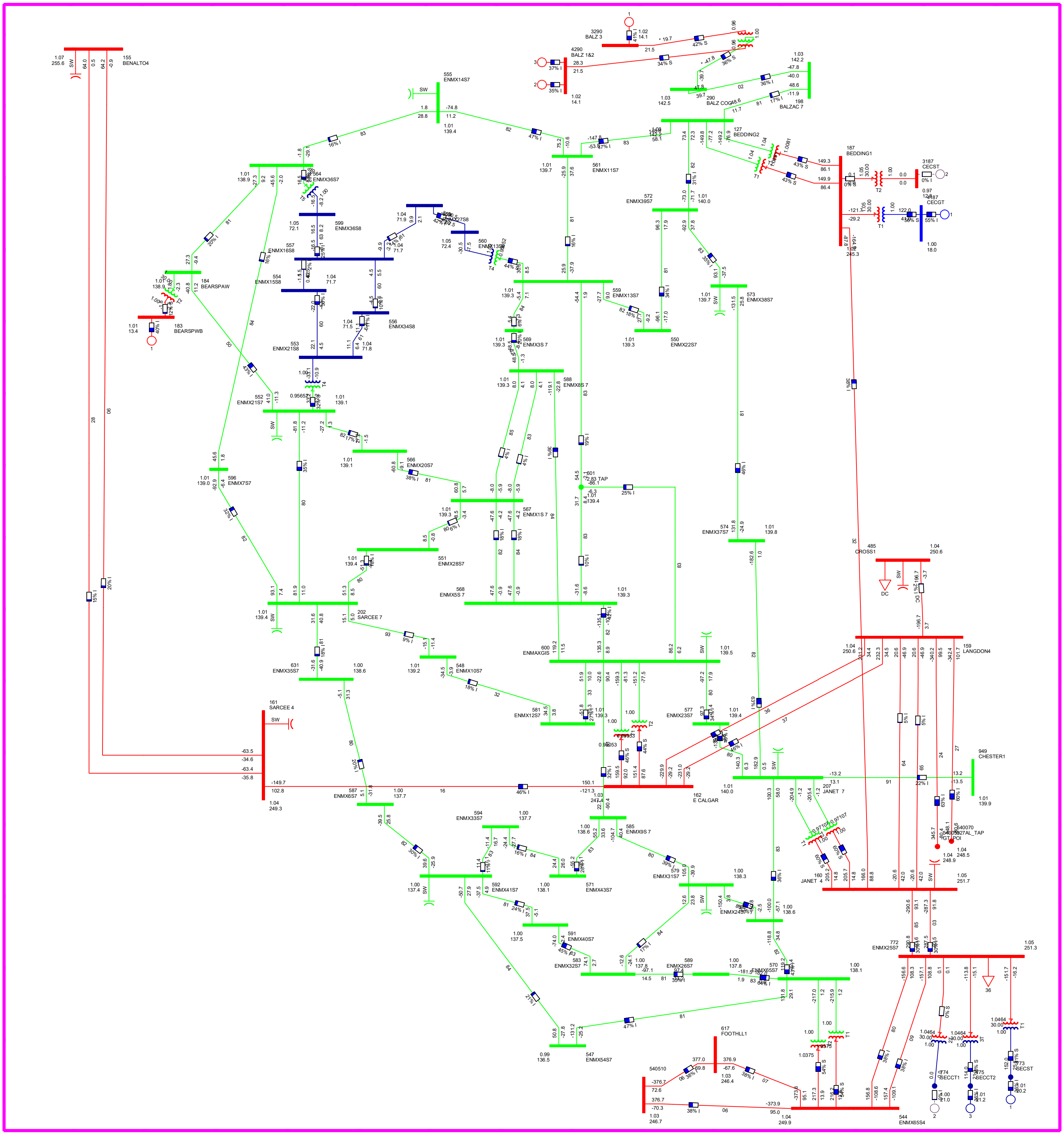
Attachment A3: Post-Project Power Flow Diagrams

1. 2028SP - Post Project Cat A Power Flow Diagram
2. 2028WP - Post Project Cat A Power Flow Diagram
3. 2028SP - Post Project Cat B (1080L Out) Power Flow Diagram
4. 2028SP - Post Project Cat B (1109L Out) Power Flow Diagram

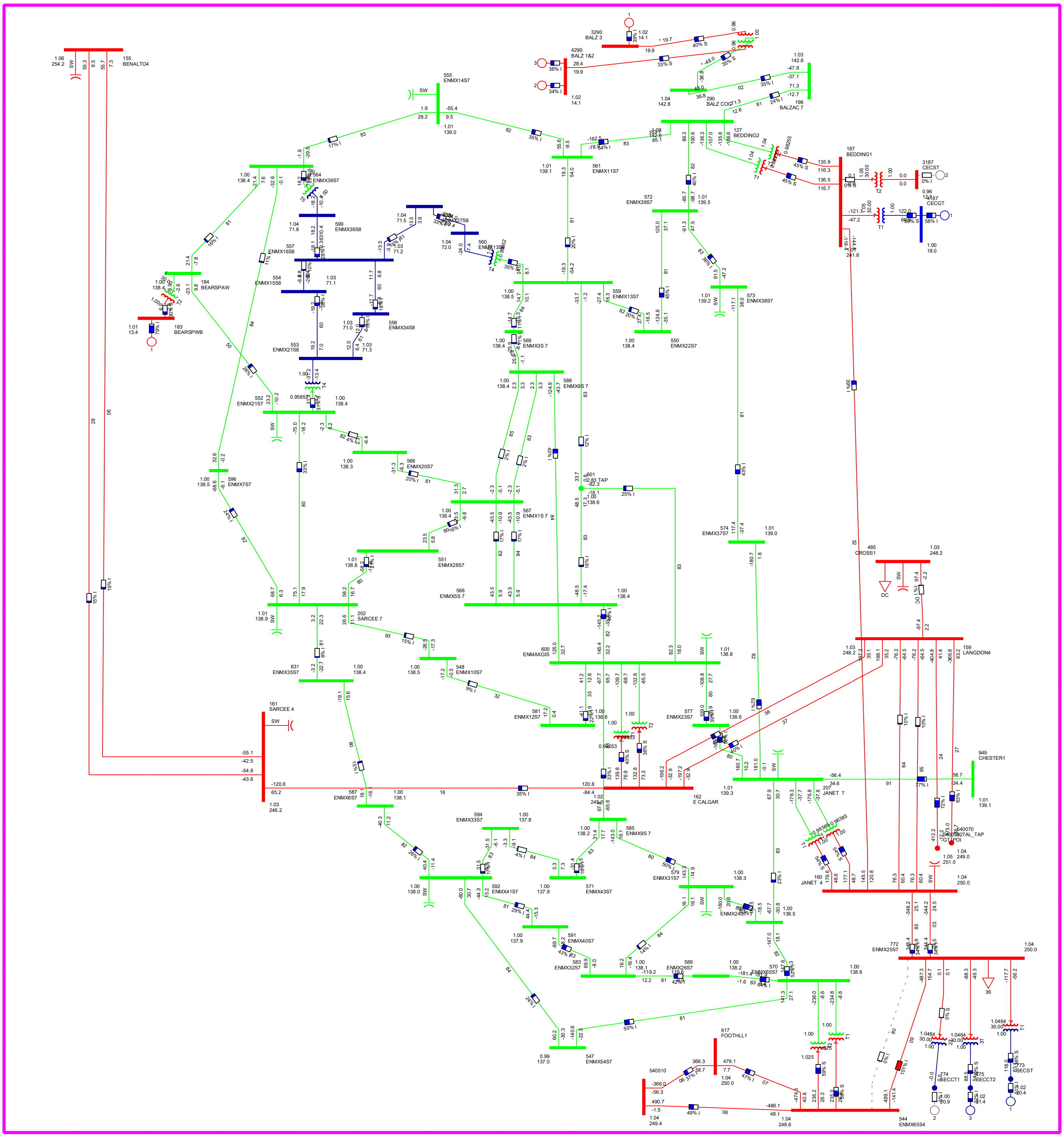
2028SP - Post Project Cat A Power Flow Diagram



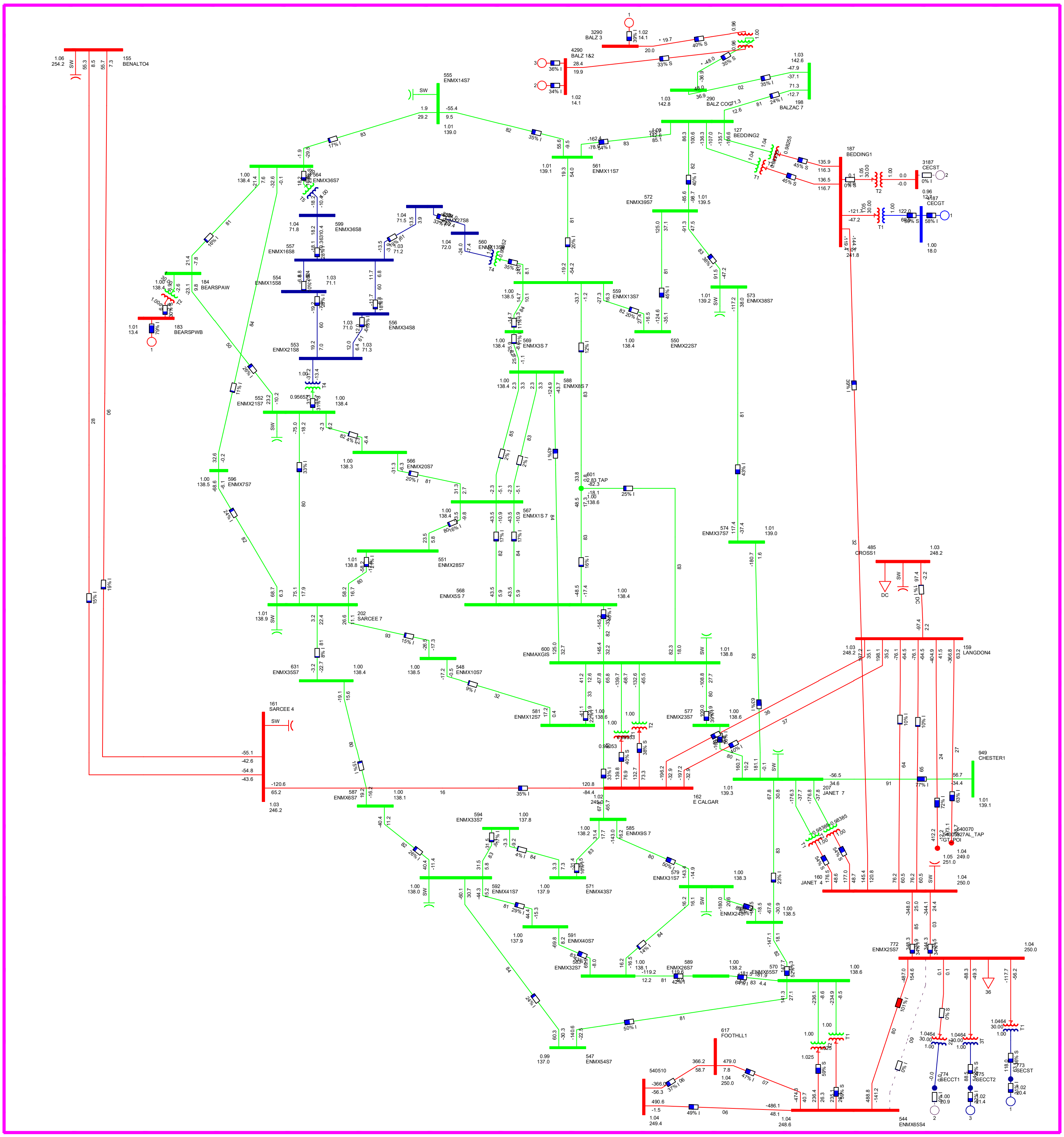
2028WP - Post Project Cat A Power Flow Diagram



2028SP - Post Project Cat B (1080L Out) Power Flow Diagram



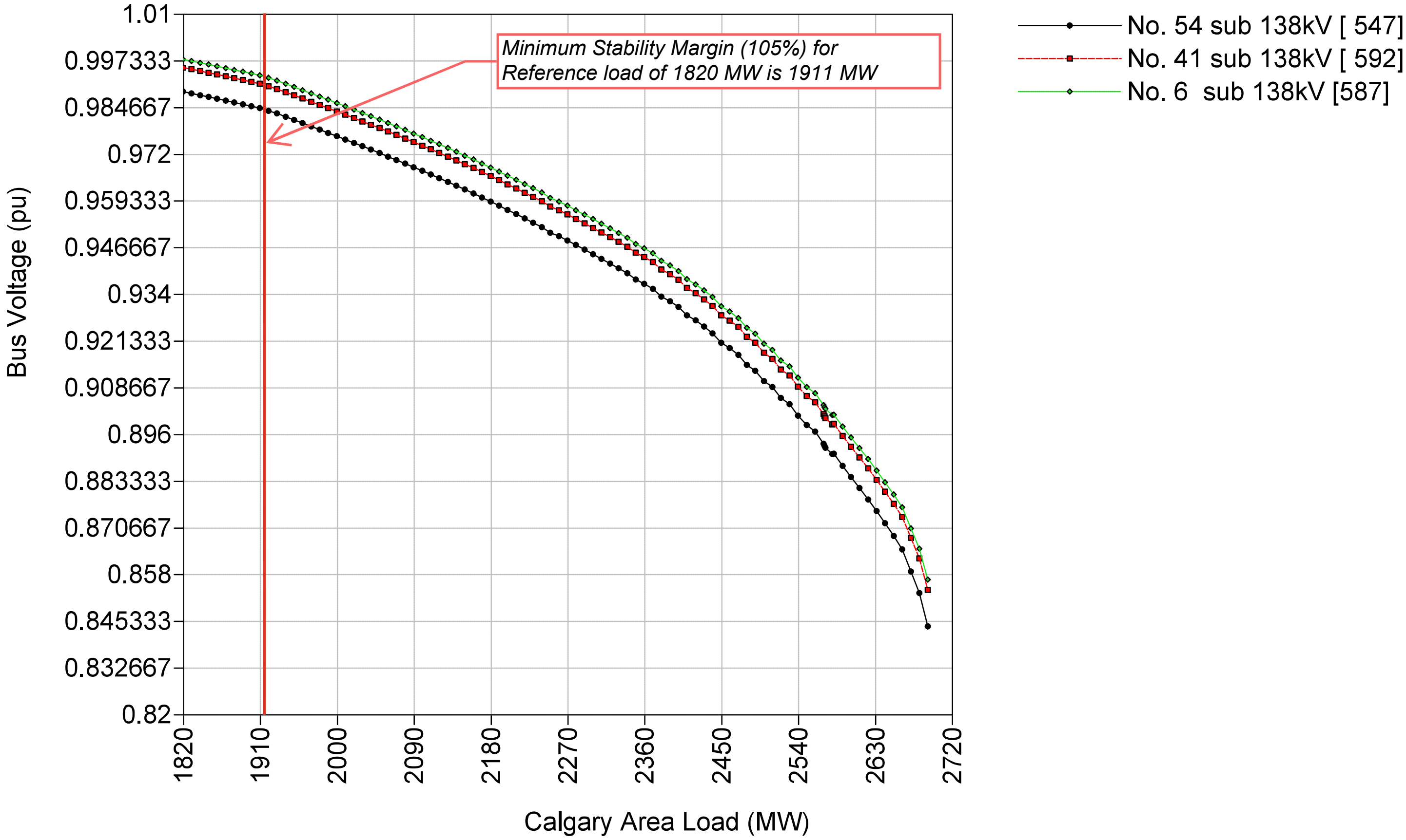
2028SP - Post Project Cat B (1109L Out) Power Flow Diagram



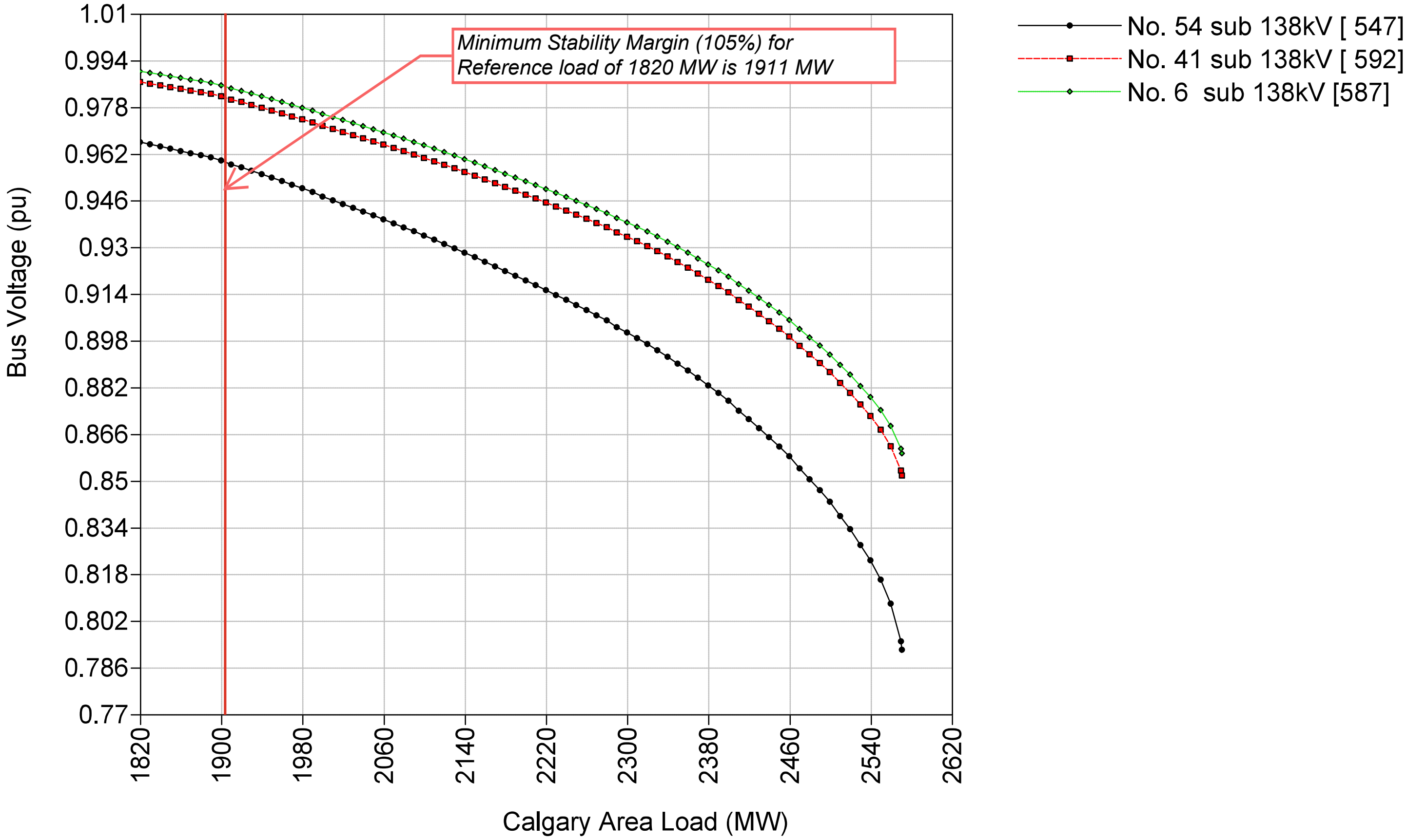
Attachment A4: Post-Project Voltage Stability Diagrams

1. 2028WP - Post Project Voltage Stability Diagram (Pre Contingency “N-0”)
2. 2028WP - Post Project Voltage Stability Diagram (Contingency – 54.81L out)
3. 2028WP - Post Project Voltage Stability Diagram (Contingency – 924L out)
4. 2028WP - Post Project Voltage Stability Diagram (Contingency – 927L out)
5. 2028WP - Post Project Voltage Stability Diagram (Contingency – 906L out)
6. 2028WP - Post Project Voltage Stability Diagram (Contingency – 928L out)

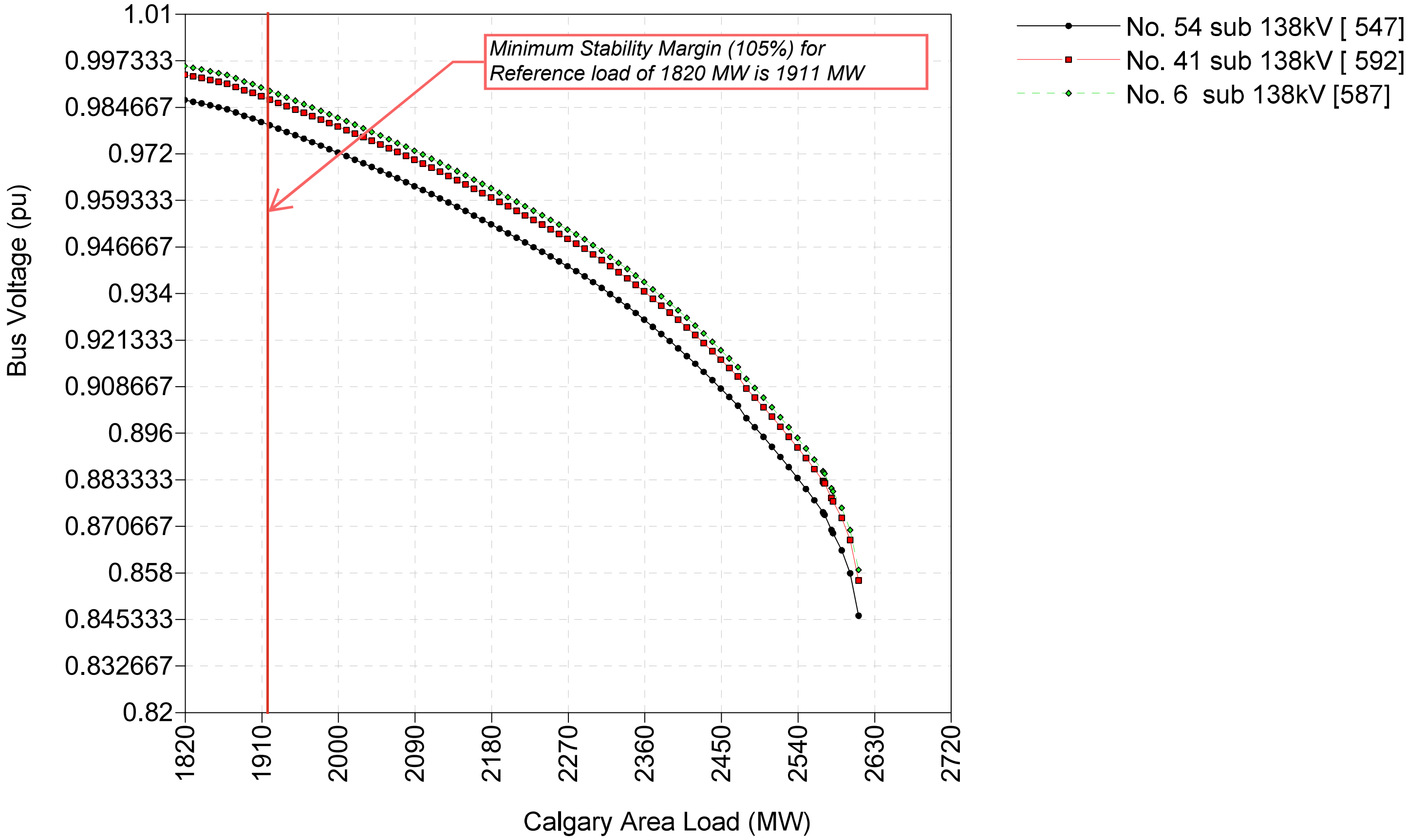
Calgary (Area 6) PV Analysis
Case: 2028WP Post Project
Contingency: Pre Contingency



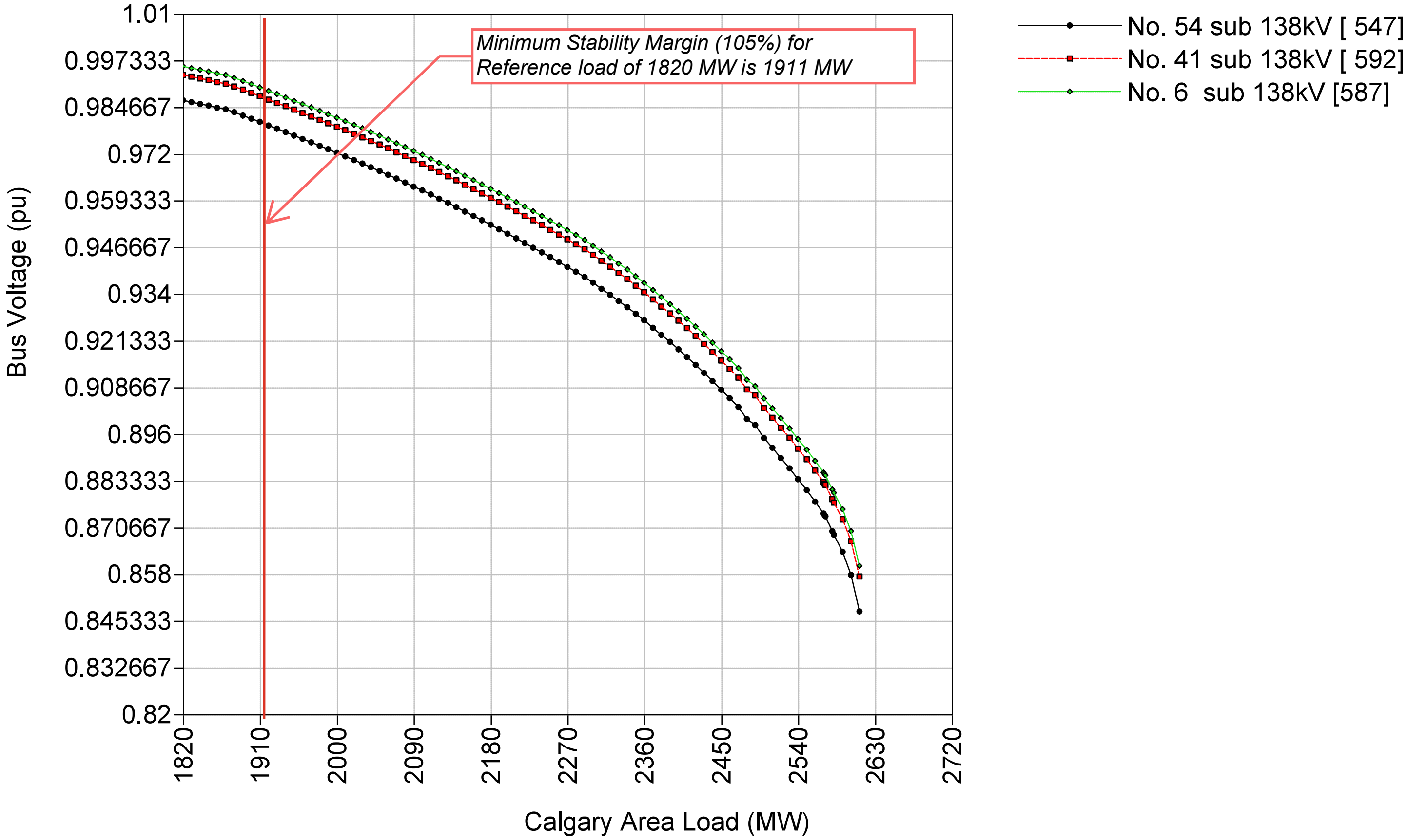
Calgary (Area 6) PV Analysis
Case: 2028WP Post Project
Contingency: 54.81L



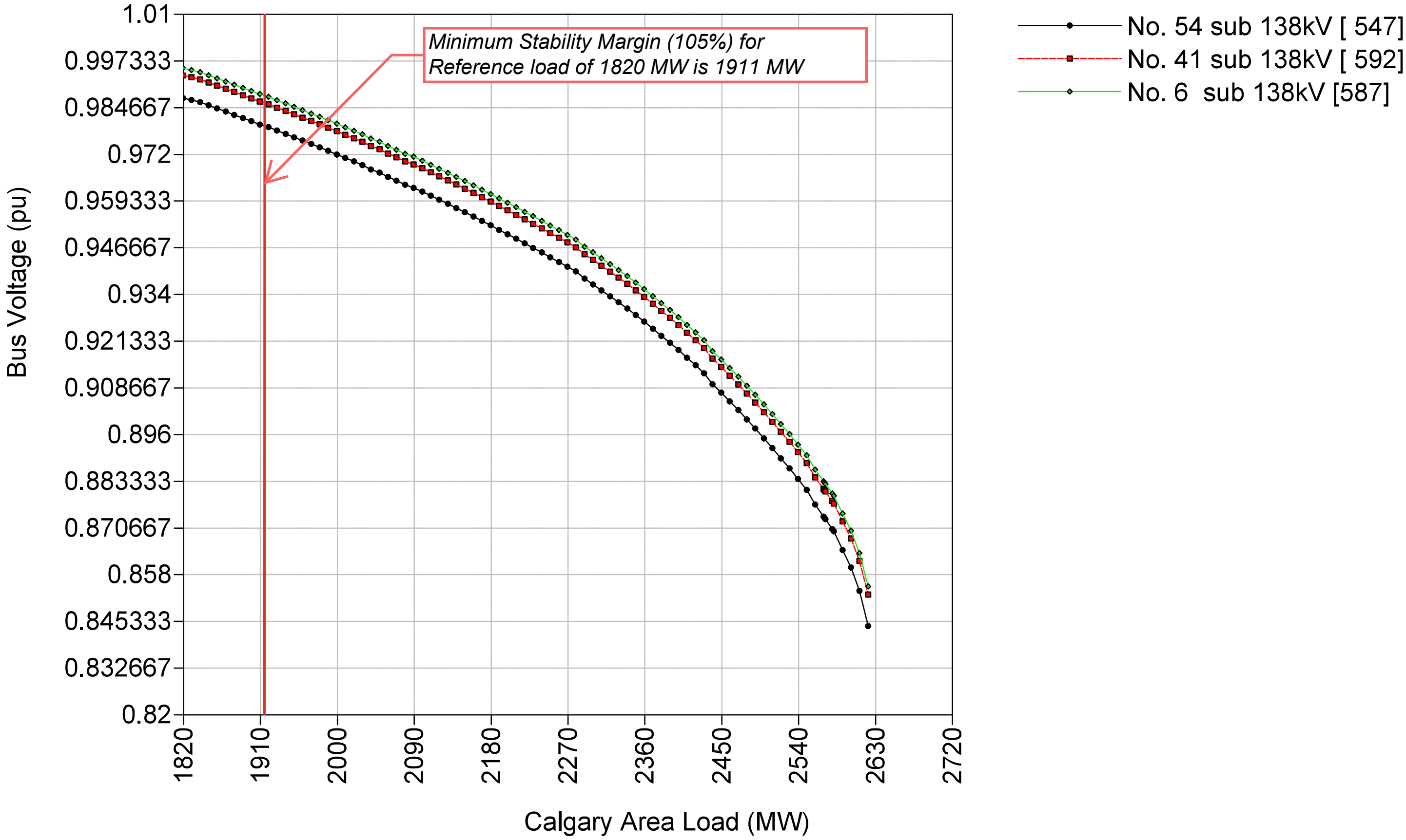
Calgary (Area 6) PV Analysis
Case: 2028WP Post Project
Contingency: 924L



Calgary (Area 6) PV Analysis
Case: 2028WP Post Project
Contingency: 927L



Calgary (Area 6) PV Analysis
Case: 2028WP Post Project
Contingency: 906L



Calgary (Area 6) PV Analysis
Case: 2028WP Post Project
Contingency: 928L