APPENDIX A CONNECTION ASSESSMENT

Connection Engineering Study Report for AUC Application

ATCO Muir New POD

File No. 1722
Revision: 1
Date: May 17, 2017

	Name	Date	Signature
Prepared by:	Liuzhong Shi, P. Eng.	May 17. 2017	Liuzhong Shi
Reviewed/ Approved by:	Mohamed Kamh, PhD, P.Eng.	May 17, 2017	

APEGA Permit to Practice P-08200

PROFESSIONAL ENGINEER
LIUZHONG SHI
ALBERTA
May 17, 2017

APEGA
Permit-to-Practice MK
P-8200 May 17, 2017

Executive Summary

Project Overview

ATCO Electric Ltd. (ATCO), in its capacity as the legal owner of an electric distribution system (DFO), submitted a request for system access service to the Alberta Electric System Operator (AESO), to serve new oilfield, industrial, residential and commercial loads in and around the Town of Fox Creek.

The DFO's request for system access service includes a request for a Rate DTS, *Demand Transmission Service*, contract capacity of 19 MW for a new system access service in the Town of Fox Creek area and a request for transmission development (collectively, the Project). Specifically, the DFO requested a new 144/25 kV point-of-delivery (POD) substation located near the sites of the requested loads, west of the Town of Fox Creek.

The scheduled in-service date (ISD) is March 1, 2018.

This report details the engineering studies undertaken to assess the impact of the Project on the performance of the Alberta interconnected electric system (AIES).

Existing System

Geographically, the Project is located in the AESO planning area of Fox Creek (Area 24) which is part of the AESO Northwest Planning Region. Fox Creek (Area 24) is surrounded by the AESO planning areas of Valleyview (Area 23), Grand Cache (Area 22), Hinton/Edson (Area 29) and Swan Hills (Area 26).

From a transmission system perspective, Fox Creek (Area 24) is served by both 138 kV and 144 kV transmission systems. The area is mainly served by the 240/144 kV Little Smoky 813S substation, the 240/138 kV Sagitawah 77S and Bickerdike 39S substations, the 144 kV transmission lines 7L90 and 7L199, and the 138 kV transmission lines 199L, 854L and 720L.

Existing constraints in the Northwest 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).

Study Summary

<u>Study area for the Project</u>

The Study Area for the Project consists of Fox Creek (Area 24), Valley View (Area 23) and Swan Hills (Area 26), and the tie lines connecting these areas to the rest of the AIES. All transmission facilities within the Study Area were studied and were 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 2.1.1).

<u>Studies performed for the Project</u>

Power flow studies were performed for the 2018 winter peak (2018 WP) and the 2018 summer peak (2018 SP) pre-Project and post-Project scenarios.

Voltage stability studies were performed for the 2018 WP post-Project scenario.

Results of the Pre-Project Studies

No Reliability Criteria violations were observed under Category A or Category B conditions. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, were observed under Category B conditions.

Following certain Category B contingencies, POD 25 kV bus voltage levels lower than DFO requirements (as described in Section 2.1.3) were observed at the Fox Creek 741S substation and the Benbow 397S substation, post-auto control.

Transmission Alternatives

The AESO, in consultation with the DFO and the legal owner of transmission facilities (TFO) examined three transmission alternatives to meet the DFO's request for system access service:

Transmission Alternative 1: Upgrade the existing Fox Creek 741S substation

Transmission Alternative 1 involves upgrading the existing Fox Creek 741S substation including adding a third 144/25 kV transformer, the appropriate number of 25 kV circuit breakers, and associated equipment at the Fox Creek 741S substation.

Transmission Alternative 2: Modify the existing Benbow 397S substation

Transmission Alternative 2 involves modifying the existing Benbow 397S substation, including adding the appropriate number of 25 kV circuit breakers and associated equipment.

Transmission Alternative 3: Add the Muir 2018S substation

Transmission Alternative 3 involves adding a new POD substation, to be designated as the Muir 2018S substation. The Muir 2018S substation would include one 144/25 kV transformer, the appropriate number of 25 kV circuit breakers, and associated equipment.

Transmission Alternative Selected for Further Examination

Transmission Alternative 3 was selected for further examination. Transmission Alternative 1 and Transmission Alternative 2 were not selected for further examination because the DFO advised that both alternatives were not technically viable.

Connection Alternatives

The AESO, in consultation with the TFO and DFO, examined four connection alternatives to implement Transmission Alternative 3 (that is, to connect the proposed Muir 2018S substation to the AIES).

Connection Alternative 1: T-tap configuration on the 144 kV transmission line 7L199

Connection Alternative 1 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L199 (between the ATCO Fox Creek 741S substation and AltaLink Fox Creek 347S substation) using a T-tap configuration. This connection alternative would require the addition of one 144 kV circuit, approximately 9 km long, and the addition of one 144 kV circuit breaker at the proposed Muir 2018S substation.

Connection Alternative 2: In-and-out configuration on the 144 kV transmission line 7L199

Connection Alternative 2 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L199 (between the ATCO Fox Creek 741S substation and AltaLink Fox Creek 347S substation) using an in-and-out configuration. This connection alternative would require the addition of two 144 kV circuits, each approximately 9 km long, and the addition of three 144 kV circuit breakers at the proposed Muir 2018S substation or the addition of one 144 kV circuit, approximately 9 km long, and the addition of one switching substation with three 144 kV circuit breakers.

Connection Alternative 3: T-tap configuration on the 144 kV transmission line 7L90

Connection Alternative 3 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L90 (between the Fox Creek 741S substation and Little Smoky 813S substation) using a T-tap configuration. This connection alternative would require the addition of one 144 kV circuit, approximately 7 km long, and the addition of one 144 kV circuit breaker at the proposed Muir 2018S substation.

Connection Alternative 4: In-and-out configuration on the 144 kV transmission line 7L90

Connection Alternative 4 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L90 (between the Fox Creek 741S substation and Little Smoky 813S substation) using an in-and-out configuration. This connection alternative would require the addition of two 144 kV circuits, each approximately 7 km long, and the addition of three 144 kV circuit breakers at the proposed Muir 2018S substation or the addition of one 144 kV circuit, approximately 7 km long, and the addition of one switching substation with three 144 kV circuit breakers.

Connection Alternative Selected for Further Examination

Connection Alternative 3 was selected for further study. Connection Alternatives 1, 2 and 4 involve increased development and hence, increased cost compared to Connection Alternative 3. Therefore, Connection Alternative 1, Connection Alternative 2 and Connection Alternative 4 were not selected for further study.

Results of the Post-Project Studies

No Reliability Criteria violations were observed under Category A or Category B conditions. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, were observed under Category B conditions.

Similar to the pre-Project studies, following certain Category B contingencies, POD 25 kV bus voltage levels lower than DFO requirements were observed at the Fox Creek 741S, Benbow 397S and Deer Hill 1012S substations, post-auto control. The DFOs in the Study Area determined that the observed POD 25 kV bus voltage levels were unacceptable and requested that the AESO develop mitigation measures to address these system performance issues. The AESO determined that the DFO's request for mitigation measures could be met by the addition of one 144 kV 40 MVAr capacitor bank at the Fox Creek 741S substation. The addition of this capacitor bank will address the low voltage levels observed at the POD 25 kV busses in the Fox Creek 741S, Benbow 397S and Deer Hill 1012Ssubstations.

Post-Project power flow and voltage stability studies were completed with the inclusion of one 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation. No Reliability Criteria violations were observed under Category A or Category B conditions. In addition, no POD bus voltage deviations beyond the desired limits set out in Table 2-1, or POD 25 kV bus voltage levels lower than DFO requirements, were observed under Category B conditions.

Conclusions and Recommendations

Based on the study results, Connection Alternative 3, with the addition of a 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation, is technically acceptable. The studies show that the connection of the Project using Connection Alternative 3, with the addition of a 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation would not adversely impact the performance of the AIES.

It is recommended to proceed with the Project using Connection Alternative 3 as the preferred option to respond to the DFO's request for system access service. Connection Alternative 3 includes adding the proposed Muir 2018S substation, including one 144/25 kV transformer, one

144 kV circuit breaker, the appropriate number of 25 kV circuit breakers and associated equipment; and adding a 144 kV circuit to connect the proposed Muir 2018S substation to the existing 144 kV transmission line 7L90 using a T-tap configuration. It is also recommended to add one 144 kV, 40 MVAr capacitor bank and one 144 kV circuit breaker at Fox Creek 741S substation.

Contents

Attachments

Figures

Tables

1. Introduction

This report details the engineering studies conducted to assess the impact of the Project (as defined below) on the performance of the Alberta interconnected electric system (AIES).

1.1. Project

1.1.1. Project Overview

ATCO Electric Ltd. (ATCO), in its capacity as the legal owner of an electric distribution system (DFO), submitted a request for system access service to the Alberta Electric System Operator (AESO), serve new oilfield, industrial, residential and commercial loads in and around the Town of Fox Creek.

The DFO's request for system access service includes a request for a Rate DTS, *Demand Transmission Service*, contract capacity of 19 MW for a new system access service in the Town of Fox Creek area and a request for transmission development (collectively, the Project). Specifically, the DFO requested a new 144/25 kV point-of-delivery (POD) substation located near the sites of the requested loads, west of the Town of Fox Creek.

The scheduled in-service date (ISD) is March 1, 2018.

1.1.2. Load Component

The Project includes a load component:

- Rate DTS, *Demand Transmission Service* (DTS), contract capacity of 19 MW for a new system access service in the Town of Fox Creek area
- Load type: oilfield, industrial, residential and commercial
- Power factor (PF): 0.9 (lagging) has been assumed

1.1.3. Generation Component

There is no generation component associated with the Project.

1.2. Study Scope

1.2.1. Study Objectives

The objectives of the studies are as follows:

- Assess the impact of the Project on the performance of the AIES.
- Identify any violations of the relevant AESO criteria, standards or requirements, both pre-Project and post-Project.
- Recommend mitigation measures, if required, to reliably connect the Project to the AIES.

1.2.2. Study Area

1.2.2.1. Study Area Description

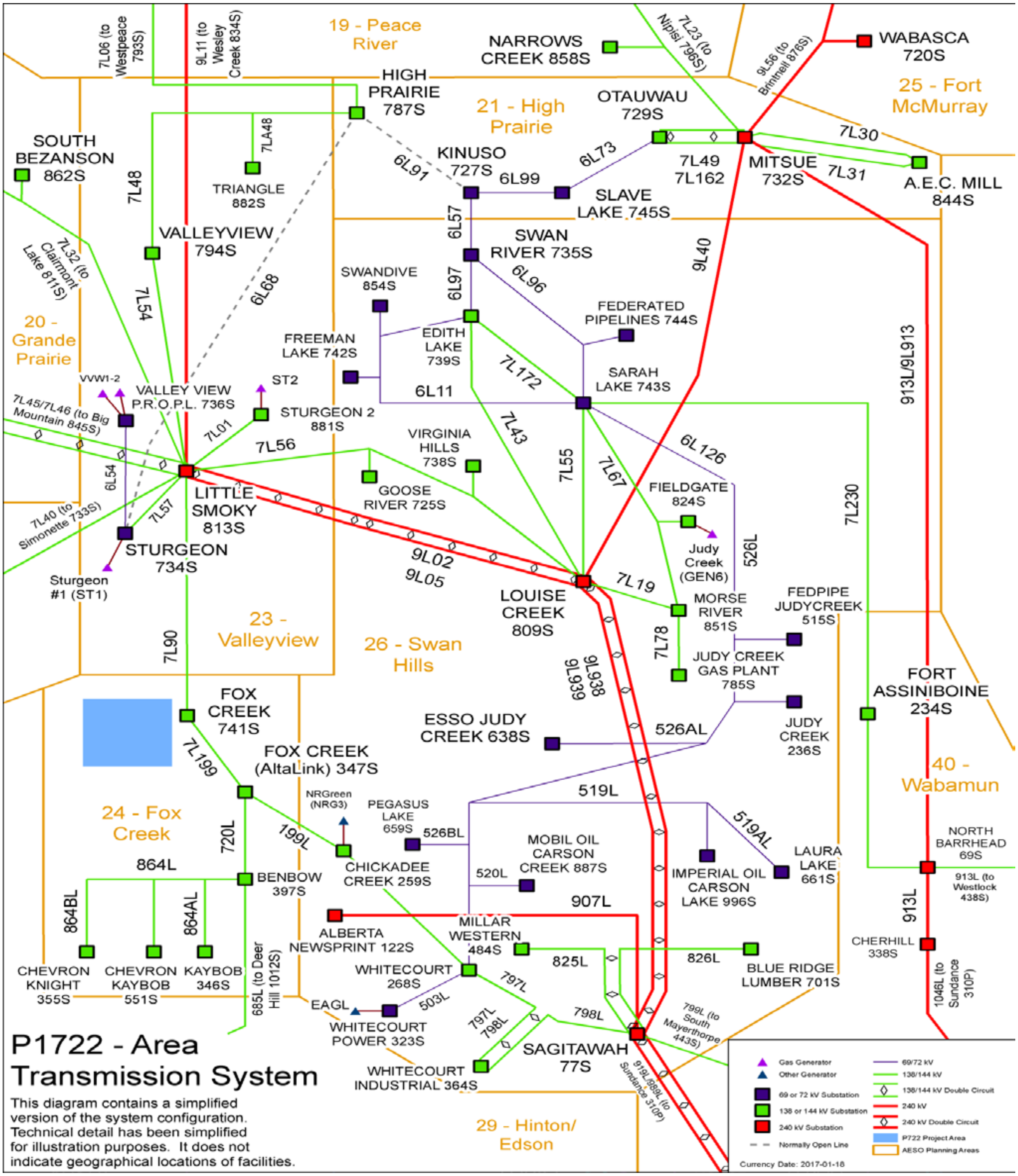
Geographically, the Project is located in the AESO planning area of Fox Creek (Area 24) which is part of the AESO Northwest Planning Region. Fox Creek (Area 24) is surrounded by the AESO planning areas of Valleyview (Area 23), Grand Cache (Area 22), Hinton/Edson (Area 29) and Swan Hills (Area 26).

From a transmission system perspective, Fox Creek (Area 24) is served by both 138 kV and 144 kV transmission systems. The area is served by the 240/144 kV Little Smoky 813S substation, the 240/138 kV Sagitawah 77S and Bickerdike 39S substations, the 144 kV transmission lines 7L90 and 7L199, and the 138 kV transmission lines 199L, 854L and 720L.

The Study Area for the Project consists of Fox Creek (Area 24), Valley View (Area 23) and Swan Hills (Area 26), and the tie lines connecting these areas to the rest of the AIES. All transmission facilities within the Study Area were studied and were 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 2.1.1).

Figure 1-1 shows the existing transmission system in the Study Area.

Figure 1-1: Existing Transmission System in the Study Area



1.2.2.2. Existing Constraints

Existing constraints in the Northwest 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).

1.2.2.3. AESO Long-Term Transmission Plan

The *AESO 2015 Long-term Transmission Plan* (2015 LTP)[1] includes plans for the following system transmission developments in the Fox-Creek-Valleyview and the Swan Hills–High Prairie sub-regions in the near term (by 2020), as shown in Table 1-1 below.[2]

Table 1-1: 2015 LTP Fox Creek-Valleyview and Swan Hills–High Prairie Near-Term Components

Time Frame	Development
Near-term	**Fox Creek-Valleyview sub-region:** • Increase 240/144 kV transformer capacity at Little Smoky substation • Add new 240 kV lines from Little Smoky substation to Fox Creek substation (ATCO) • Expand Fox Creek substation to include 240/144 kV facilities • Add new 240 kV lines from Fox Creek substation to Bickerdike substation near Edson • Open 144 kV line between Fox Creek and Little Smoky substations • Add voltage support at Fox Creek substation **Swan Hills–High Prairie sub-region** • Add second 144/72 kV transformer at Otauwau substation near Town of Slave Lake

1.2.3. Studies Performed

The following pre-Project studies were performed:

- Power flow

The following post-Project studies were performed:

- Power flow
- Voltage stability

1.3. Report Overview

The Executive Summary provides a high-level summary of the report and its conclusions. Section 1 provides an introduction to the Project and provides a high-level description of the study scope. Section 2 describes the criteria, system data, and other assumptions used in the studies. Section 3 describes the study methodology. Section 4 discusses the pre-Project studies results. Section 5 presents the alternatives examined and selected for further study. Section 6

---

[1] The 2015 LTP document is available on the AESO website.

[2] The 2015 LTP identifies the near-term transmission developments in the Swan Hills–High Prairie and the Fox-Creek-Valleyview sub-regions on pages 50 and 51, respectively.

provides the post-Project studies results. Section 7 discusses any dependencies the Project may have. Section 8 presents the conclusions and recommendations of this assessment.

2. Criteria, System Data, and Study Assumptions

2.1. Criteria, Standards, and Requirements

2.1.1. AESO Reliability Criteria

The Transmission Planning (TPL) Standards, which are included in the Alberta Reliability Standards, and the AESO's *Transmission Planning Criteria – Basis and Assumptions*[3] (collectively, the Reliability Criteria) were 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 Alberta Reliability Standards include the TPL standards that specify the desired system performance under different contingency categories with respect to the Applicable Ratings. The transmission system performance under various system conditions is defined in Appendix 1 of the TPL standards. For the purpose of applying the TPL standards to this study, the Applicable Ratings shall mean:

- Seasonal continuous thermal rating of the line's loading limits.
- Highest specified loading limits for transformers.
- For Category A conditions: Voltage range under normal operating condition should follow the AESO Information Document #2010-007RS, *General Operating Practices – Voltage Control* (ID #2010-007RS). ID #2010-007RS relates to Section 304.4 of the ISO rules, *Maintaining Network Voltage*. 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.*

[3] Filed under a separate cover

- Desired post-contingency voltage change limits for point-of-delivery (POD) low voltage busses during three defined post-event time periods are provided inTable 2-1, below.

Table 2-1: Desired Post-Contingency Voltage Deviations for POD 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 POD low voltage bus	±10%	±7%	±5%

2.1.2. AESO Rules

ID #2010-007RS was applied to establish pre-contingency voltage profiles in the Study Area. The TCM Rule was followed in setting up the study scenarios and in assessing the impact of the Project. In addition, due regard was given to the AESO's *Connection Study Requirements* document and the AESO's *Generation and Load Interconnection Standard*.

2.1.3. DFO Requirements for POD 25 kV Bus Voltage Levels

In addition to the AESO's guidelines for desired post-contingency voltage change limits for POD low voltage busses presented in Table 2-1 above, FortisAlberta Inc. advised the AESO that the required POD 25 kV bus voltage levels at FortisAlberta's PODs in the study area (including Benbow 397S and Deer Hill 1012S substations) should not be lower than 25.729 kV during Category A and Category B conditions (post-auto control)[4] to ensure compliance to the CSA Standard at the customer utilization point. In addition, ATCO Electric DFO advised the AESO that the POD 25 kV bus voltage at Fox Creek 741S should be greater than or equal to 25.729 kV during Category A and Category B conditions (post-auto control) to ensure that ATCO Electric DFO planning guidelines are fulfilled with respect to the steady-state voltage requirements for the 25 kV system.

In the event that POD 25 kV bus voltage levels lower than 25.729 kV are observed, the applicable DFO would be consulted to confirm that the observed low voltage level will not impose any risk to the DFO's facilities. Measures to mitigate low voltage levels on POD 25 kV busses would only be developed if requested by the DFO.

2.2. Study Scenarios

The scheduled ISD of the Project is March 1, 2018. Therefore, the studies were performed using the 2018 summer peak (SP) and winter peak (WP) scenarios.

Table 2-2 provides a list of the study scenarios. This connection assessment will assume a PF of 0.9 lagging for the load associated with the Project.

Table 2-2: List of the Connection Study Scenarios

Scenario	Year/Season Load	Pre-Project/Post-Project	Project Load (MW)	Project Generation (MW)

[4] Auto control refers to adjusting automatic equipment such as on-load tap changer (LTC) transformer tap positions.

Scenario	Year/Season Load	Pre-Project/Post-Project	Project Load (MW)	Project Generation (MW)
1	2018 SP	Pre-Project	0	0
2	2018 WP	Pre-Project	0	0
3	2018 SP	Post-Project	25	0
4	2018 WP	Post-Project	25	0

2.3. Load and Generation Assumptions

2.3.1. Load Assumptions

The AESO planning area and region forecasts used for the studies are based on the *AESO 2014 Long-term Outlook* (2014 LTO). As part of its planning responsibilities, the AESO updates its corporate forecasts routinely to ensure they reflect the latest economic projects, factors and timing. While the AESO has updated its regional forecasts since the connection studies were performed, the use of the current AESO forecast, the *AESO 2016 Long-term Outlook*, would not materially alter the connection study results or affect the conclusions and recommendations in this report.

Table 2-3 presents the load conditions and assumptions used in the studies. For the studies, when base cases were modified to align with the load forecast in the 2014 LTO, the active power to reactive power ratio in the base case scenarios was maintained.

Table 2-3: Load Forecast (2014 LTO at Alberta Internal Load Peak)

Planning Area/Region	Study Case	Forecast Peak Load (MW)
Valley View (Area 23)	2018 SP	20.2
	2018 WP	23.8
Fox Creek (Area 24)	2018 SP	106.1
	2018 WP	110.8
Swan Hills (Area 26)	2018 SP	361.4
	2018 WP	381.7
Northwest Planning Region	2018 SP	1349.8
	2018 WP	1502.6
Alberta Internal Load without Losses	2018 SP	12017.3
	2018 WP	13369.5

2.3.2. Generation Assumptions

The generation assumptions for the studies are described in Table 2-4. The Whitecourt Cogen unit was identified as the critical generator. It was turned off to represent the N-G study condition for all study scenarios.

Table 2-4: Generator dispatch in the study scenarios

Existing/Future	Unit Name	Bus Number	Unit ID	AESO Planning Area	PMax (MW)	2018 SP Unit Net Generation (MW)	2018 WP Unit Net Generation (MW)
Existing	Whitecourt Cogen	408	1	26	31.8	offline	offline
Existing	Valleyview Unit 1	1171	1	23	52.7	0	0
Existing	Valleyview Unit 2	1173	2	23	52.7	0	0
Existing	Alberta Newsprint	2296, 4296	G1-G10	26	10×6.5	29	35
Existing	NRGreen generation	2674	G1	26	18.6	11	14

2.3.3. Intertie Flow Assumptions

The Alberta-British Columbia, Alberta-Montana, and Alberta-Saskatchewan intertie power flows are expected to have no material impact on the connection assessment for the Project. Therefore, the intertie flows were assumed to be the same as in the AESO planning base cases and were not adjusted for the studies.

2.3.4. High-Voltage DC (HVDC) Power Order

The Western Alberta Transmission Line (WATL) and the Eastern Alberta Transmission Line (EATL) assumptions were expected to have minimal effect on the assessment of the Project's impact on the performance of the AIES. Therefore, the HVDC assumptions were the same as in the AESO planning base cases and were not adjusted for the studies.

2.4. System Projects

No system projects were included in the study scenarios. The near-term system projects identified in the 2015 LTP (see Section 1.2.2.3) were not considered in the studies.

2.5. Connection Projects

There are no connection projects in the Study Area that are ahead of the Project in the AESO Connection Queue. As a result, no connection projects were included in the study scenarios.

2.6. Facility Ratings and Shunt Elements

The legal owner of transmission facilities (TFO) provided thermal ratings for the transmission lines in the vicinity of the Study Area. The seasonal continuous ratings and short-term emergency ratings for the key transmission lines in the Study Area are shown in Table 2-5.

Table 2-5: Key Transmission Line Ratings in the Study Area

Line ID	Line Description	Voltage Class (kV)	Seasonal Continuous Rating (MVA)		Short-term Emergency Rating (MVA)	
			Summer	Winter	Summer	Winter
7L90	Fox Creek 741S – Little Smoky 813S	144	114	146	129	157
7L199	Fox Creek 741S – Fox Creek 347S	144	114	146	129	157

720L	Fox Creek 347S – Benbow 397S	138	86	91	95	100
199L	Fox Creek 347S – Whitecourt 268S	138	85	90	94	99
685L	Benbow 397S – Deer Hill 1012S	138	167	201	184	218
854L	Deer Hill 1012S – 854L tap point)	138	283	287	311	373
854L	854L tap point - Bickerdike 39S	138	263	263	311	373

The TFO also provided the facility ratings of the key existing transformers in the Study Area, as shown in Table 2-6.

Table 2-6: Summary of Key Transformer Ratings in and around the Study Area

Substation Name and Number	Transformer ID	Transformer Voltages (kV)	Rating (MVA)
Little Smoky 813S	901T/902T	240/144/25	H-X 200 H-Y 66
LouiseCreek 809S	901T/902T	240/144/25	H-X 200 H-Y 66
Bickerdike 39S	T1/T2	240/138 kV	180/240/269
Fox Creek 741S	701T/702T	144/25	25/33.3/Prov 41.6

The key capacitor banks in the Study Area are identified in Table 2-7 below.

Table 2-7: Table Summary of Key Shunt Elements in the Study Area

Substation Name and Number	Nominal Bus Voltage (kV)	Capacitors			Reactors			SVC
		Number of Switched Shunt Blocks	Total at Nominal Voltage (MVAr)	Status in Study Cases	Number of Switched Shunt Blocks	Total at Nominal Voltage (MVAr)	Status in Study (on or off)	Total at Nominal Voltage (MVAr)
Fox Creek 741S	25	1 x4.8	4.8	Switched as required				
Little Smoky 813S	144	3x30	90	Switched as required				
	34.5	-	-					+/-100
	25	-	-		2x20	40	Switched as required	
Louise Creek 809S	144	52.8			(-20)+(-10)	-30	Switched as required	
	25				(-20)+(-10)	-30	Switched as required	

2.7. Voltage Profile Assumptions

ID #2010-007RS was 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 all the busses not included in ID #2010-007RS.

These voltages were used to set the voltage profile for the study base cases prior to power flow studies.

3. Study Methodology

All connection studies were completed using PTI PSS/E version 33.

3.1. Connection Studies Carried Out

The studies that were carried out for this connection assessment are identified in Table 3-1.

Table 3-1: Studies performed

Scenario		System Conditions Category	Power Flow	Voltage Stability
1	2018 SP pre-Project	Category A and Category B	X	
2	2018 WP pre-Project	Category A and Category B	X	
3	2018 SP post-Project	Category A and Category B	X	
4	2018 WP post-Project	Category A and Category B	X	X

3.2. Power Flow Studies

Power flow studies were conducted for all study scenarios to identify any thermal and voltage criteria violations as per the Reliability Criteria, and to identify any POD voltage deviations from the desired limits in Table 2-1. The purpose of the power flow analysis is to quantify any violations in the Study Area both for the pre-Project and post-Project study scenarios. For the Category B power flow studies, transformer taps and switched shunt reactive compensating devices such as shunt capacitors and reactors were locked and continuous shunt devices were enabled.

POD low voltage bus deviations were 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 were 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 taps and shunt reactive compensating devices were allowed to adjust, and voltage deviations above 5%, if any, were reported.

3.2.1. Contingencies Studied

Power flow studies performed for all Category B contingencies in the Study Area. All transmission facilities in the Study Area were monitored for Reliability Criteria violations.

3.3. Voltage Stability Studies

The objective of the voltage stability analysis is to determine the ability of the transmission system to maintain voltage stability 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 are reported at the collapse point.

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

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

Typically, voltage stability analysis is carried out assuming the worst case loading scenarios. For the Project's worst case scenario, load was increased in the Study Area and the corresponding generation was increased in Calgary (Area 6) and Sheerness (Area 43).

3.3.1. Contingencies Studied

Voltage stability studies were performed for all Category B contingencies in the Study Area. All transmission facilities in the Study Area were monitored for Reliability Criteria violations.

4. Pre-Project System Assessment

4.1. Power Flow

The pre-Project power flow diagrams are provided in Attachment A.

4.1.1. Scenario 1: 2018 SP Pre-Project

Category A Condition

No Reliability Criteria violations were observed.

Category B Conditions

No Reliability Criteria violations were observed. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, were observed.

POD 25 kV bus voltage levels lower than DFO requirements were observed post-auto control, as shown in Table 4-1.

Table 4-1: Post-Auto Control POD 25 kV Bus Voltage Levels - 2018 SP Pre-Project Scenario

Contingency	Substation Name and Number	Bus No.	DFO Required Minimum Voltage (kV)	Observed Post Auto-Control Voltage (kV)
7L90 (Little Smoky 813S - Fox Creek 741S)	Fox Creek 741S	19175	25.729	25.0
		18175		25.4
854L (Deer Hill 1012S - Bickerdike 39S)	Benbow 397S	4412		25.6

4.1.2. Scenario 2: 2018 WP Pre-Project

Category A Condition

No Reliability Criteria violations were observed.

Category B Conditions

No Reliability Criteria violations were observed. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, were observed.

POD 25 kV bus voltage levels lower than DFO requirements were observed post-auto control, as shown in Table 4-2.

Table 4-2: Post-Auto Control POD 25 kV Bus Voltage Levels - 2018 WP Pre-Project

<table>
<tr><th>Contingency</th><th>Substation Name and Number</th><th>Bus No.</th><th>DFO Required Minimum Voltage (kV)</th><th>Observed Post Auto-Control Voltage (kV)</th></tr>
<tr><td rowspan="2">7L90 (Little Smoky 813S to Fox Creek 741S)</td><td rowspan="2">Fox Creek 741S</td><td>19175</td><td rowspan="3">25.729</td><td>24.8</td></tr>
<tr><td>18175</td><td>25.2</td></tr>
<tr><td>854L (Deer Hill 1012S to Bickerdike 39S)</td><td>Benbow 397S</td><td>4412</td><td>25.5</td></tr>
</table>

5. Connection Alternatives

This section of the report discusses the transmission alternatives that were examined by the AESO, in consultation with the DFO and TFO, to respond to the DFO's request for system access service (Transmission Alternatives). This section further discusses the specific connection alternatives that were derived from the selected transmission alternative (Connection Alternatives).

5.1. Transmission Alternatives

The AESO, in consultation with the DFO and the TFO, examined three transmission alternatives to meet the DFO's request for system access service.

5.1.1. Transmission Alternatives Description

Below is a description of the developments associated with the transmission alternatives that were examined for the Project.[5]

Transmission Alternative 1: Upgrade the existing Fox Creek 741S substation

Transmission Alternative 1 involves upgrading the existing Fox Creek 741S substation, including adding a third 144/25 kV transformer, the appropriate number of 25 kV circuit breakers, and associated equipment at the Fox Creek 741S substation.

Transmission Alternative 2: Modify the existing Benbow 397S substation

Transmission Alternative 2 involves modifying the existing Benbow 397S substation, including adding the appropriate number of 25 kV circuit breakers and associated equipment.

Transmission Alternative 3: New Muir 2018S substation

Transmission Alternative 3 involves adding a new POD substation, to be designated as the Muir 2018S substation. The Muir 2018S substation would include one 144/25 kV transformer, the appropriate number of 25 kV circuit breakers, and associated equipment.

5.1.2. Transmission Alternative Selected for Further Examination

Transmission Alternative 3 was selected for further examination. Transmission Alternative 1 and Transmission Alternative 2 were not selected for further examination because the DFO advised that both alternatives were not technically viable, and did not meet the DFO's distribution planning criteria.

5.2. Connection Alternatives

5.2.1. Connection Alternatives Description

The AESO, in consultation with the TFO and DFO, examined four connection alternatives to implement Transmission Alternative 3 (that is, to connect the proposed Muir 2018S substation to the AIES).

Connection Alternative 1: T-tap configuration on the 144 kV transmission line 7L199

[5] These alternatives reflect more up to date engineering design than the alternatives identified in the ATCO *Distribution Deficiency Report, Muir 2018S POD*, which is filed under a separate cover.

Connection Alternative 1 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L199 (between the ATCO Fox Creek 741S substation and AltaLink Fox Creek 347S substation) using a T-tap configuration. This connection alternative would require the addition of one 144 kV circuit, approximately 9 km long, and the addition of one 144 kV circuit breaker at the proposed Muir 2018S substation.

Connection Alternative 2: In-and-out configuration on the 144 kV transmission line 7L199

Connection Alternative 2 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L199 (between the ATCO Fox Creek 741S substation and AltaLink Fox Creek 347S substation) using an in-and-out configuration. This connection alternative would require the addition of two 144 kV circuits, each approximately 9 km long, and the addition of three 144 kV circuit breakers at the proposed Muir 2018S substation or the addition of one 144 kV circuit, approximately 9 km long, and the addition of one switching substation with three 144 kV circuit breakers.

Connection Alternative 3: T-tap configuration on the 144 kV transmission line 7L90

Connection Alternative 3 involves connecting the proposed Muir 2018S substation to the 144 kV transmission line 7L90 (between the Fox Creek 741S substation and Little Smoky 813S substation) using a T-tap configuration. This connection alternative would require the addition of one 144 kV circuit, approximately 7 km long, and the addition of one 144 kV circuit breaker at the proposed Muir 2018S substation.

Connection Alternative 4: In-and-out configuration on the 144 kV transmission line 7L90

Connection Alternative 4 involves connecting the proposed Muir 2018S substation to the existing 144 kV transmission line 7L90 (between Fox Creek 741S substation and Little Smoky 813S substation) using an in-and-out configuration. This connection alternative would require the addition of two 144 kV circuits, each approximately 7 km long, and the addition of three 144 kV circuit breakers at the proposed Muir 2018S substation or the addition of one 144 kV circuit, approximately 7 km long, and the addition of one switching substation with three 144 kV circuit breakers.

5.2.2. Connection Alternatives Selected for Further Studies

Connection Alternative 3 was selected for further detailed studies.

5.2.3. Connection Alternatives Not Selected for Further Studies

Connection Alternatives 1, 2 and 4 involve increased development and hence, increased cost compared to Connection Alternative 3. Therefore, Connection Alternative 1, Connection Alternative 2 and Connection Alternative 4 were not selected for further study.

6. Technical Analysis of Connection Alternative 3

This section includes the results of the post-Project power flow and voltage stability studies for Connection Alternative 3.

6.1. Power Flow Studies

The post-Project power flow diagrams are provided in Attachment B.

6.1.1. Scenario 3: 2018 SP Post-Project

Category A Condition

No Reliability Criteria violations were observed.

Category B Conditions

No Reliability Criteria violations were observed. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, were observed.

POD 25 kV bus voltage levels lower than DFO requirements were observed post-auto control, as shown in Table 6-1.

Table 6-1: Post-Auto Control POD 25 kV Bus Voltage Levels - 2018 SP Post-Project Scenario

Contingency	Substation Name and Number	Bus No.	DFO Required Minimum Voltage (kV)	Observed Post Auto-Control Voltage (kV)
7L90 (Fox Creek 741S - Little Smoky 813S)	Fox Creek 741S	19175	25.729	25.0
		18175		25.4
854L (Deer Hill 1012S - Bickerdike 39S)	Benbow 397S	4412		25.0
	Fox Creek 741S	19175		25.2
		18175		25.6
	Deer Hill 1012S	2678		25.5
685L (Deer Hill 1012S - Benbow 397S)	Benbow 397S	4412		25.2
	Fox Creek 741S	19175		25.4

6.1.2. Scenario 4: 2018 WP Post-Project

Category A condition

No Reliability Criteria violations were observed.

Category B conditions

No Reliability Criteria violations were observed. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, were observed.

POD 25 kV bus voltage levels lower than DFO requirements were observed post-auto control, as shown in Table 6-2.

Table 6-2: Post-Auto Control POD 25 kV Bus Voltage Levels - 2018 WP Post-Project Scenario

<table>
<tr><th>Contingency</th><th>Substation Name and Number</th><th>Bus No.</th><th>DFO Required Minimum Voltage (kV)</th><th>Observed Post Auto-Control Voltage (kV)</th></tr>
<tr><td rowspan="2">7L90 (Fox Creek 741S - Little Smoky 813S)</td><td rowspan="2">Fox Creek 741S</td><td>19175</td><td rowspan="8">25.729</td><td>24.8</td></tr>
<tr><td>18175</td><td>25.2</td></tr>
<tr><td rowspan="4">854L (Deer Hill 1012S - Bickerdike 39S)</td><td>Benbow 397S</td><td>4412</td><td>24.9</td></tr>
<tr><td rowspan="2">Fox Creek 741S</td><td>19175</td><td>25.0</td></tr>
<tr><td>18175</td><td>25.5</td></tr>
<tr><td>Deer Hill 1012S</td><td>2678</td><td>25.4</td></tr>
<tr><td rowspan="2">685L (Deer Hills 1012S - Benbow 397S)</td><td>Benbow 397S</td><td>4412</td><td>25.2</td></tr>
<tr><td>Fox Creek 741S</td><td>19175</td><td>25.6</td></tr>
</table>

6.2. Mitigation Measure Selection

6.2.1. Mitigation Measures for Identified Issues

During both pre-Project and post-Project studies, following certain Category B contingencies POD 25 kV bus voltage levels lower than DFO requirements were observed, post-auto control, at the Fox Creek 741S, Benbow 397S and Deer Hill 1012Ssubstations.

The DFOs in the Study Area determined that the observed POD 25 kV bus voltage levels were unacceptable and requested that the mitigation measures should be developed to address these distribution system performance issues. To mitigate the observed low voltage levels at POD 25 kV busses, either a transmission capacitor bank would be required at Fox Creek 741S substation or Benbow 397S substation, or distribution capacitors would be required at both Fox Creek 741S substation and Benbow 397S substation. Each of these mitigation measures is assessed further in Section 6.2.2 below.

6.2.2. Mitigation Measure Assessment

<u>Mitigation Measure 1: Add a transmission capacitor bank at Fox Creek 741S substation</u>

A Reactive Power – Voltage (QV) study was performed to determine the amount of reactive power required at the Fox Creek 741S substation to address low voltage levels at the POD 25 kV busses at the Fox Creek 741S, Benbow 397S and Deer Hill 1012S substations under any Category B contingency. WECC Voltage Support and Reactive Power Planning Standards states, for load areas, QV study should be conducted based on a 105% of the reference load level for worst Category B conditions. For this standard, the reference load level is the maximum established planned load.

To determine the minimum capacitor bank capacity required to address the low voltage levels observed at the POD 25 kV busses, QV analysis was undertaken for the 144 kV bus at the Fox Creek 741S substation, based on a 105% of the reference load level for worst Category B conditions. Voltage levels on the most critical 25 kV busses at the Fox Creek 741S substation and Benbow 397S substation were monitored. QV analysis was conducted for the 2018 WP post-connection scenario, which represents the worst case scenario. Two key Category B contingencies were studied: loss of the 144 kV transmission line 7L90 and loss of the 138 kV transmission line 854L.

The results of the QV analysis demonstrate that a minimum 40 MVAr capacitor bank at the Fox Creek 741S substation would be sufficient to address the observed low voltage levels at POD 25 kV busses, following the key Category B contingencies, as shown in Figure 6-1 and Figure 6-2.

Figure 6-1: POD 25 kV Bus Voltage Levels versus Reactive Power at Fox Creek 741S Substation 144 kV Bus for the 7L90 Contingency - 2018 WP Post-Project Scenario

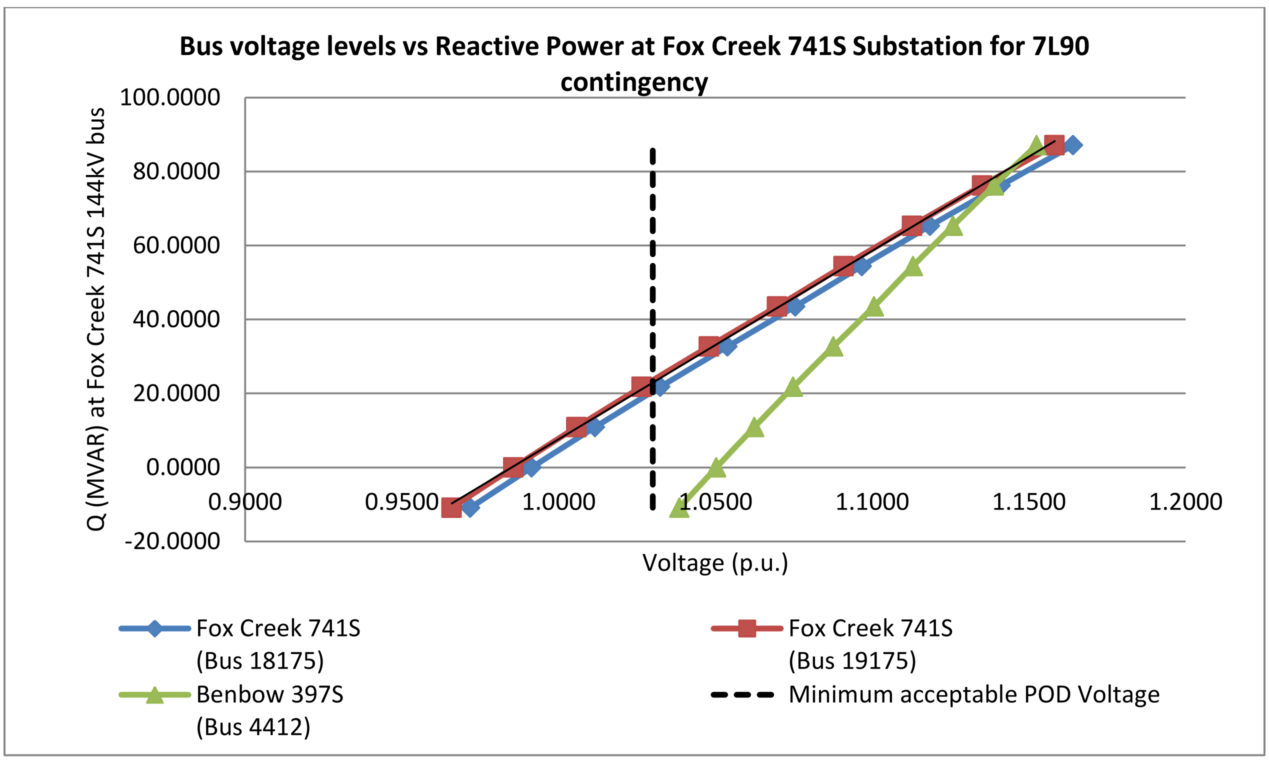
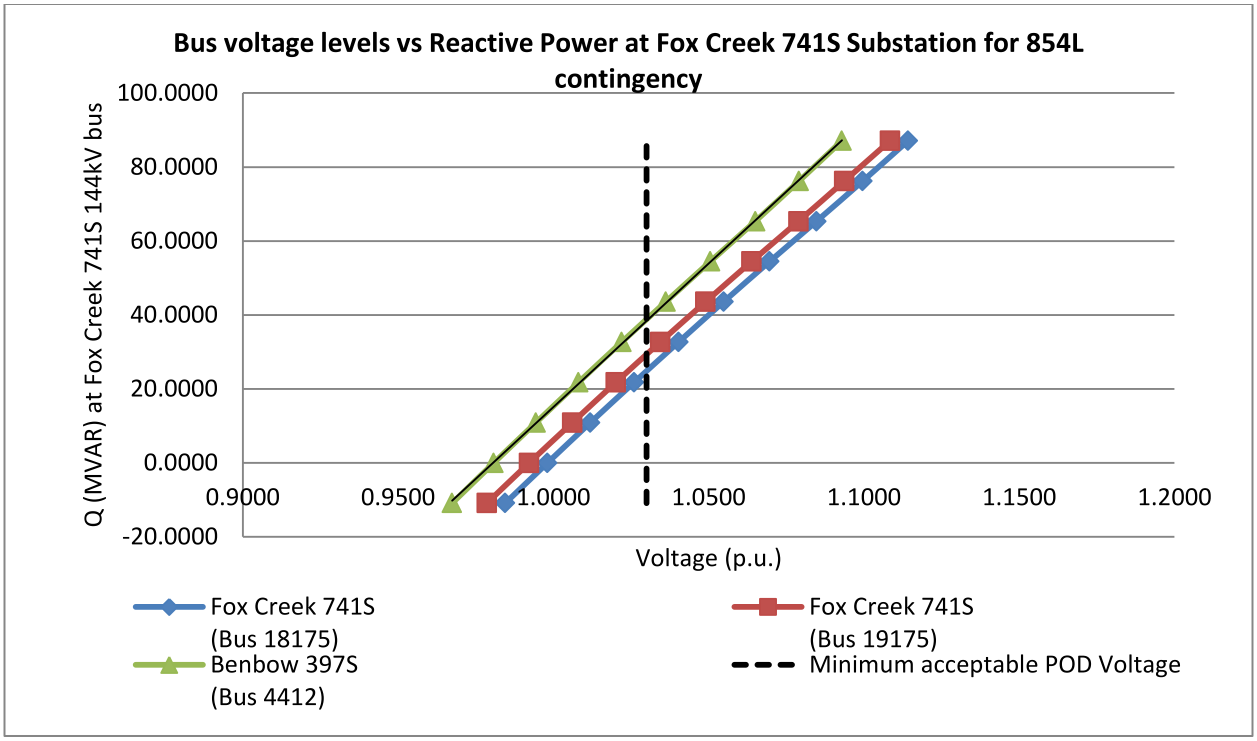


Figure 6-2: POD 25 kV Bus Voltage Levels versus Reactive Power at Fox Creek 741S Substation 144 kV bus for the 854L Contingency - 2018 WP Post-Project Scenario



Mitigation Measure 2: Add a transmission capacitor bank at Benbow 397S substation

Similar to Mitigation Measure 1, a QV study was performed to determine the amount of reactive power required at Benbow 397S substation to address low voltage levels at the POD 25 kV busses at the Fox Creek 741S, Benbow 397S and Deer Hill 1012Ssubstations under any Category B contingency. WECC Voltage Support and Reactive Power Planning Standards states, for load areas, QV study should be conducted based on a 105% of the reference load level for worst Category B conditions. For this standard, the reference load level is the maximum established planned load.

To determine the minimum capacitor bank capacity required to address the low voltage levels observed at the POD 25 kV busses, QV analysis was undertaken for the 138 kV bus at the Benbow 397S substation, based on a 105% of the reference load level for worst Category B conditions. Voltage levels on the most critical 25 kV busses at the Fox Creek 741S substation and the Benbow 397S substation were monitored. QV analysis was conducted for the 2018 WP post-connection scenario, which represents the worst case scenario. Two key Category B contingencies were studied; loss of the 144 kV transmission line 7L90 and loss of the 138 kV transmission line 854L.

The results of the QV analysis demonstrate that a minimum 37 MVAr capacitor bank at the Benbow 397S substation would be sufficient to address the observed low voltage levels at POD 25 kV busses, following the key Category B contingencies, as shown in Figure 6-3 and Figure 6-4. However, the addition of a 37 MVAr capacitor bank at the Benbow 397S substation leads to transmission voltage levels above 145 kV,[6] on 138 kV facilities in the vicinity of the Benbow 397S substation. Please see the power flow diagrams presented in Attachment C. Therefore Mitigation Measure 2 was not considered a viable mitigation measure, and was ruled out.

Figure 6-3: POD 25 kV Bus Voltage Levels versus Reactive Power at Benbow 397S Substation 138 kV Bus for the 7L90 Contingency - 2018 WP Post-Project Scenario

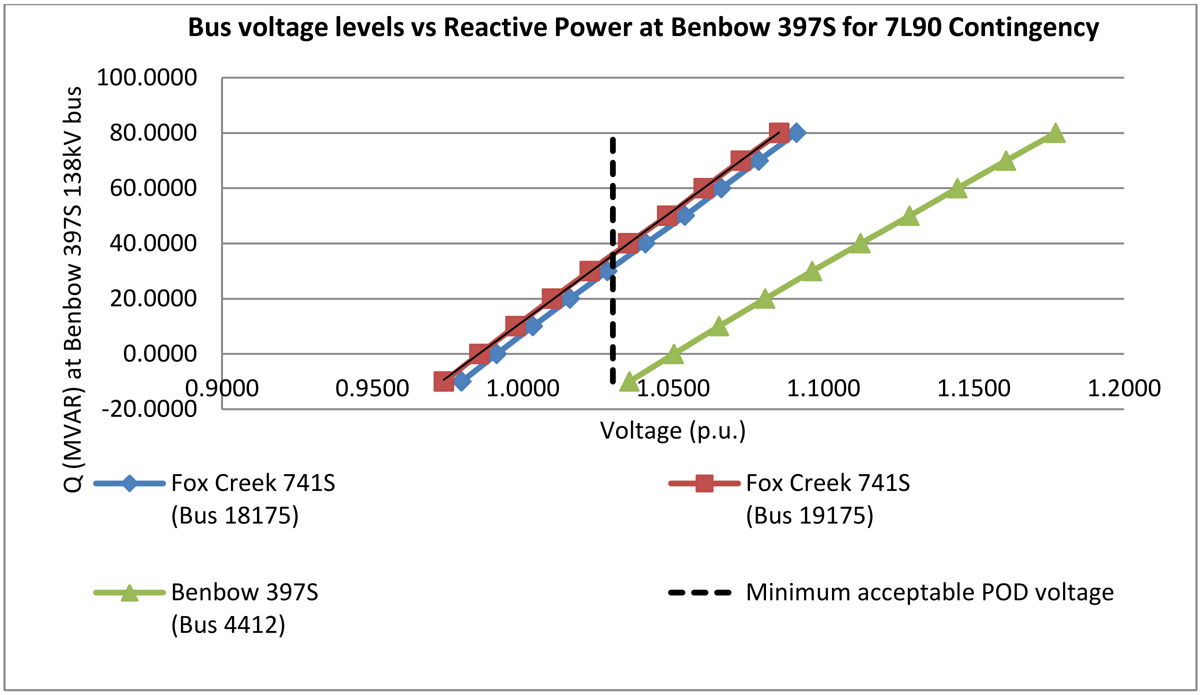
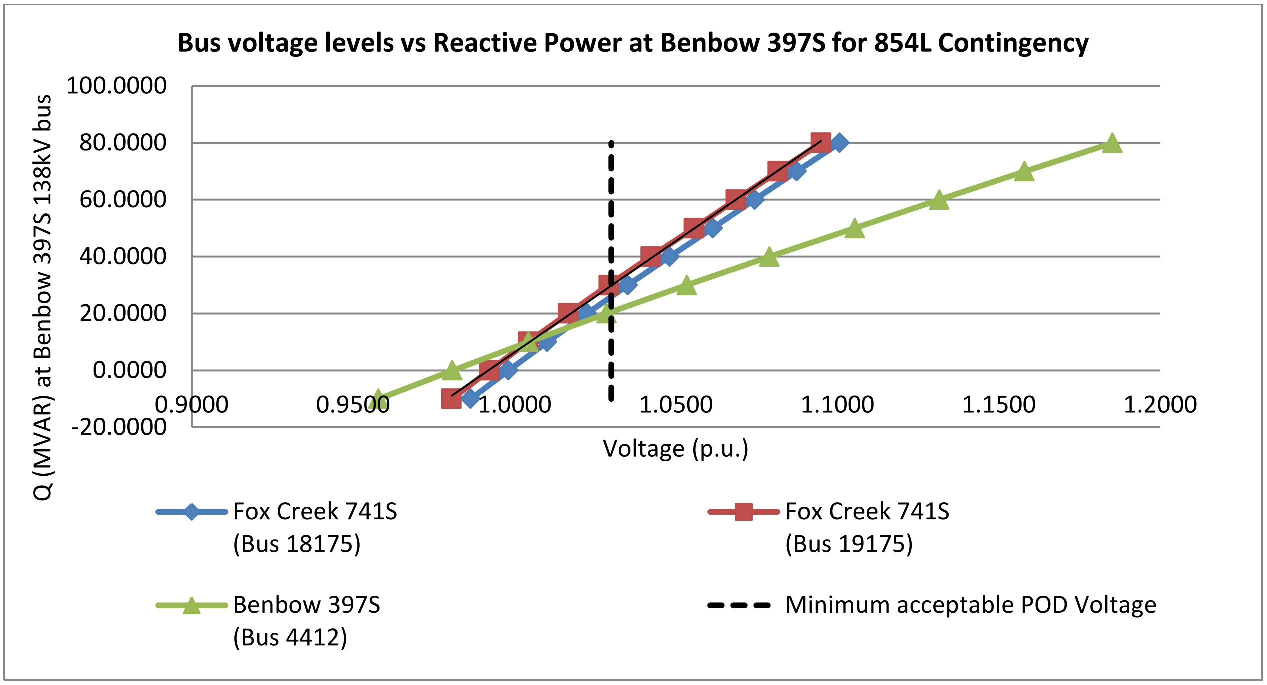


Figure 6-4: POD 25 kV Bus Voltage Levels versus Reactive Power at Benbow 397S Substation 138 kV Bus for the 854L Contingency - 2018 WP Post-Project Scenario

[6] As per the AESO's *Transmission Planning Criteria – Basis and Assumptions,* 145 kV is the normal maximum voltage for 138 kV facilities.



Mitigation Measure 3: Add distribution capacitors at Fox Creek 741S substation and Benbow 397S substation

Adding distribution capacitors at Fox Creek 741S substation would require expansion of the existing 25 kV bus connected to transformer 701T. ATCO, in its capacity as TFO, has confirmed that expansion of the 25 kV bus connected to transformer 701T at Fox Creek 741S substation is not viable due to space limitations between the bus and the control building. Therefore Mitigation Measure 3 is not considered a viable mitigation measure, and was ruled out.

6.2.3. Mitigation Measure Selection

The addition of one 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation can address the low voltage levels observed at the POD 25 kV busses in the Fox Creek 741S, Benbow 397S and Deer Hill 1012Ssubstations.

The addition of one 144 kV 40 MVAr capacitor bank at the Fox Creek 741S substation would not affect the selection of the Connection Alternative, as it is expected that similar or greater reactive power support would be required for Connection Alternatives 1, 2 and 4.

6.2.3.1. Analysis of the Selected Mitigation Measure

A steady-state capacitor bank switching study was conducted to identify the magnitude of the voltage step change using the 2018 WP post-Project scenario. The switching study was completed with the selected Mitigation Measure 1, namely adding a 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation.

The voltage step change of the busses at the ATCO Fox Creek 741S, proposed Muir 2018S, and the AltaLink Fox Creek 347S substations, with a 144 kV, 40 MVAr capacitor bank at the Fox

Creek 741S substation, are shown in Table 6-3 for the 2018 WP post-Project scenario under the Category A condition. The voltage step changes are considered satisfactory by the DFOs as the capacitor bank is designated with infrequent rural switching status.

Table 6-3: Switching Step Change under the Category A Condition - 2018 WP Post-Project Scenario

Substation Name and Number	Bus No.	kV Base	Pre-Cap Switching per unit (p.u.).	Post-Cap Switching p.u.	Step Change (%)
Fox Creek 741S (ATCO)	1175	138	1.021	1.055	3.3
	18175	25	1.046	1.084	3.6
	19175	25	1.041	1.079	36
Muir 2018S	1130	138	1.022	1.054	3.1
	14130	25	1.039	1.073	3.3
Fox Creek 347S (AltaLink)	12	138	1.022	1.048	2.5

6.3. Power Flow Studies with Mitigation Measure

This section provides the results for the post-Project power flow studies with the inclusion of one 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation. All power flow diagrams are provided in Attachment D.

6.3.1. Scenario 3: 2018 SP Post-Project

No Reliability Criteria violations were observed under the Category A condition.

No Reliability Criteria violations were observed under Category B conditions. In addition, no POD bus voltage deviations beyond the desired limits set out in Table 2-1, or POD 25 kV bus voltage levels lower than DFO requirements, were observed.

6.3.2. Scenario 4: 2018 WP Post-Project

No Reliability Criteria violations were observed under the Category A condition.

No Reliability Criteria violations were observed under Category B conditions. In addition, no POD bus voltage deviations, beyond the desired limits set out in Table 2-1, or POD 25 kV bus voltage levels lower than DFO requirements, were observed.

6.4. Voltage Stability Studies with Mitigation Measure

Based on the results of the power flow studies in Section 6.1, it was determined that mitigation measures would be required. This section provides the results for the post-Project voltage stability studies with the inclusion of one 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation. The voltage stability plots are presented in Attachment E.

6.4.1. Scenario 4: 2018 WP Post-Project

For the post-Project Scenario 4, the reference load level for the Study Area is 516.3 MW. For Category B contingencies, the minimum incremental load transfer is 5.0% of the reference load or 26.1 MW (0.05 x 516.3 MW = 25.8 MW).

Table 6-4 summarizes the voltage stability results under the Category A condition and for the four three contingencies under Category B conditions. The voltage stability margin was met for all studied conditions.

Table 6-4: Voltage Stability Analysis Results - 2018 WP Post-Project Scenario

Contingency	From	To	Maximum incremental transfer (MW)	Meets transfer criteria?
System Normal			586.9	Yes
854L	Deer Hill 1012S	Bickerdike 39S	563.8	Yes
685L	Benbow 397S	Deer Hill 1012S	566.9	Yes
798L	Whitecourt Industrial 364S	Sagitawah 77S	584.3	Yes

7. Project Dependencies

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

8. Conclusions and Recommendations

Based on the study results, Connection Alternative 3, with the addition of a 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation, is technically acceptable. The studies show that the connection of the Project using Connection Alternative 3, with the addition of a 144 kV, 40 MVAr capacitor bank at the Fox Creek 741S substation would not adversely impact the performance of the AIES.

It is recommended to proceed with the Project using Connection Alternative 3 as the preferred option to respond to the DFO's request for system access service. Connection Alternative 3 includes adding the proposed Muir 2018S substation, including one 144/25 kV transformer, one 144 kV circuit breaker, the appropriate number of 25 kV circuit breakers and associated equipment; and adding a 144 kV circuit to connect the proposed Muir 2018S substation to the existing 144 kV transmission line 7L90 using a T-tap configuration. It is also recommended to add one 144 kV, 40 MVAr capacitor bank and one 144 kV circuit breaker at Fox Creek 741S substation.

The conductor used for the 144 kV circuit should have a minimum thermal rating similar to the existing 144 kV transmission line 7L90. The minimum transformation capacity required for the 144/25 kV transformer at the proposed Muir 2018S substation is 22 MVA.

A maximum capability of 50 MVA is recommended for the 144/25 kV transformer at the proposed Muir 2018S substation, based on good electric industry practice and under advisement from ATCO, in its capacity as the TFO, regarding its asset management and inventory practices.

ATTACHMENT A

Pre-Project Load Flow Diagrams (Scenarios 1 and 2)

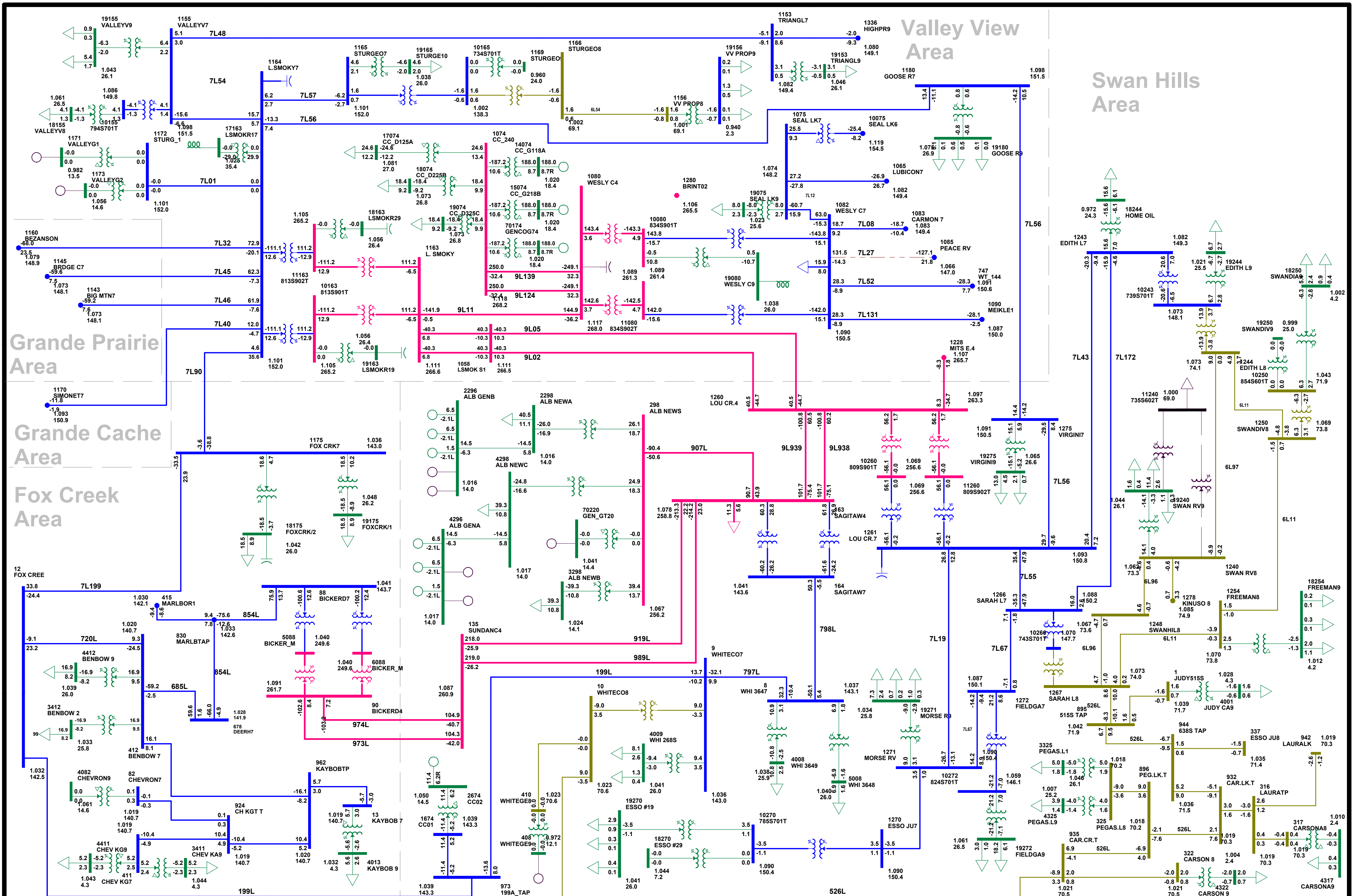
Existing System Load Flow Results

Load Flow Diagrams

The pre-Project load flow diagrams for Category A and selected Category B contingencies are provided in this section. The following table presents the list of the load flow diagrams. Please note that Whitecourt generation is turned off for these cases.

Table A-1: List of pre-Project load flow diagrams

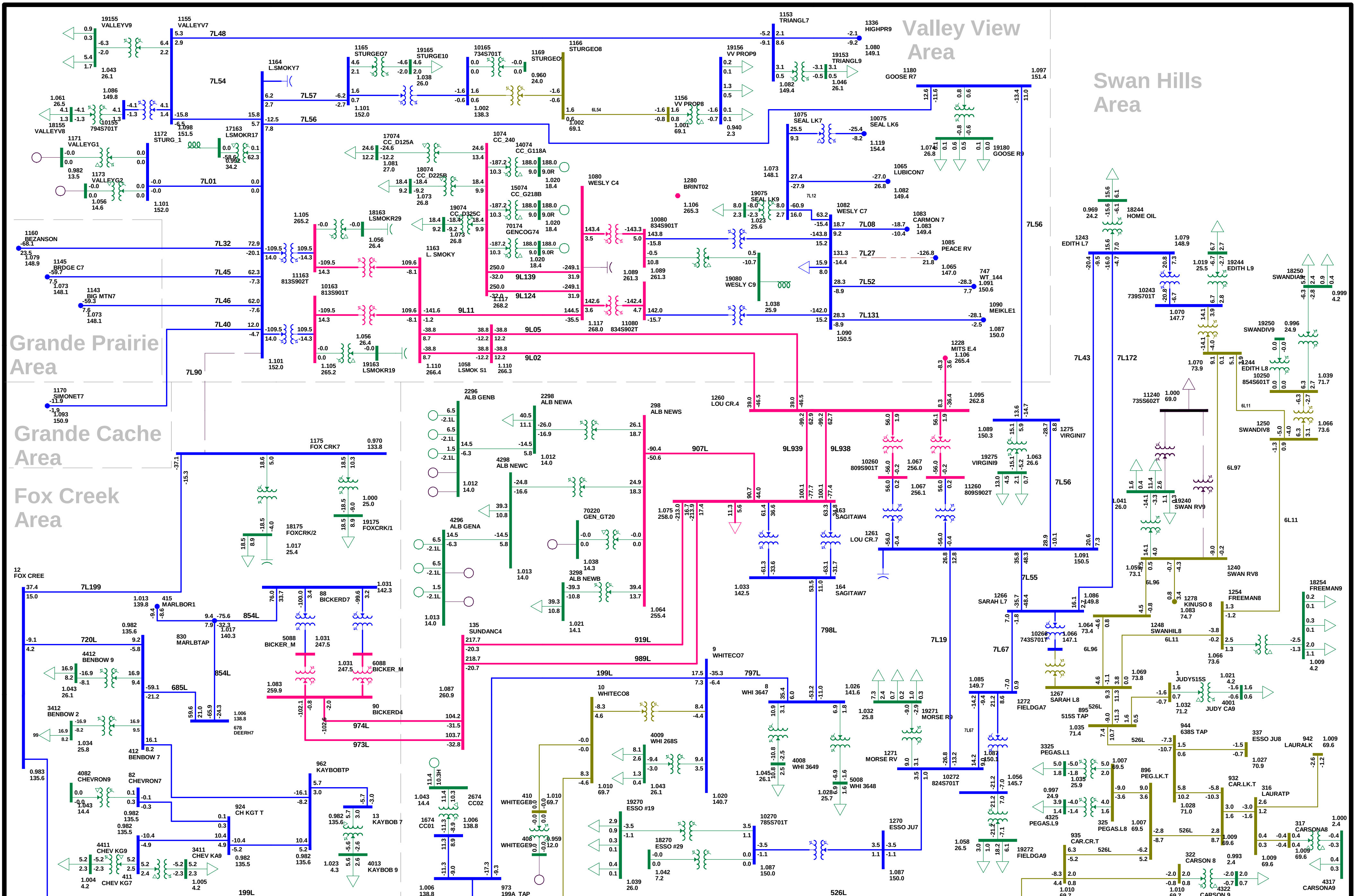
Scenario	Power flow diagram	Page number
2018 SP	N-G, System Normal Condition	A-3
	N-G-1, Loss of 7L90	A-4
	N-G-1, Loss of 854L	A-5
	N-G-1, Loss of 685L	A-6
2018 WP	N-G, System Normal Condition	A-7
	N-G-1, Loss of 7L90	A-8
	N-G-1, Loss of 854L	A-9
	N-G-1, Loss of 685L	A-10



P1722 - Pre-connection

CATEGORY A, N-0
2018 SP PRE_PROJECT A-3
WED, APR 05 2017 18:21

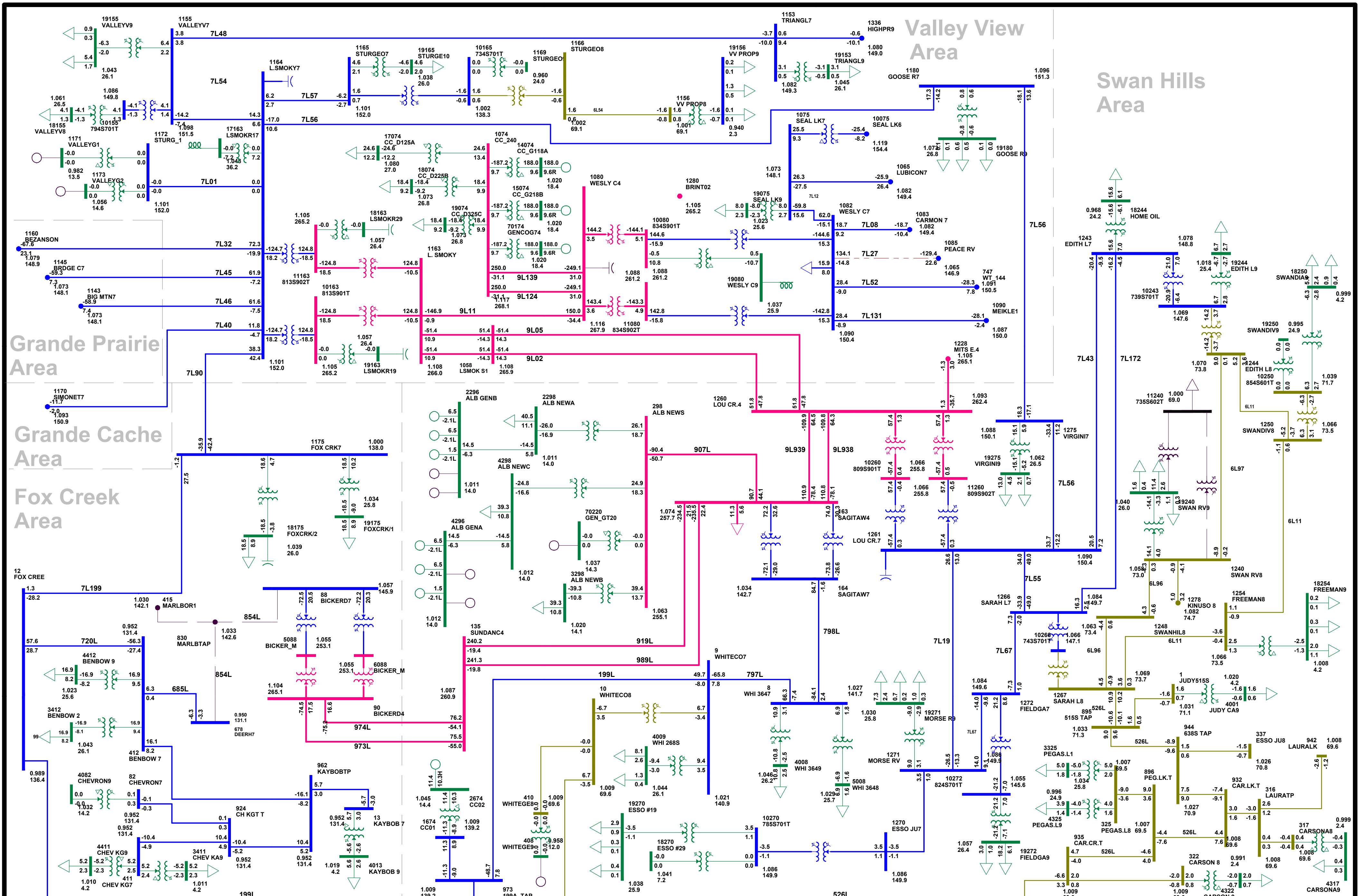
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY B, LOSS OF 7L90
2018 SP PRE_PROJECT A-4
WED, APR 05 2017 18:19

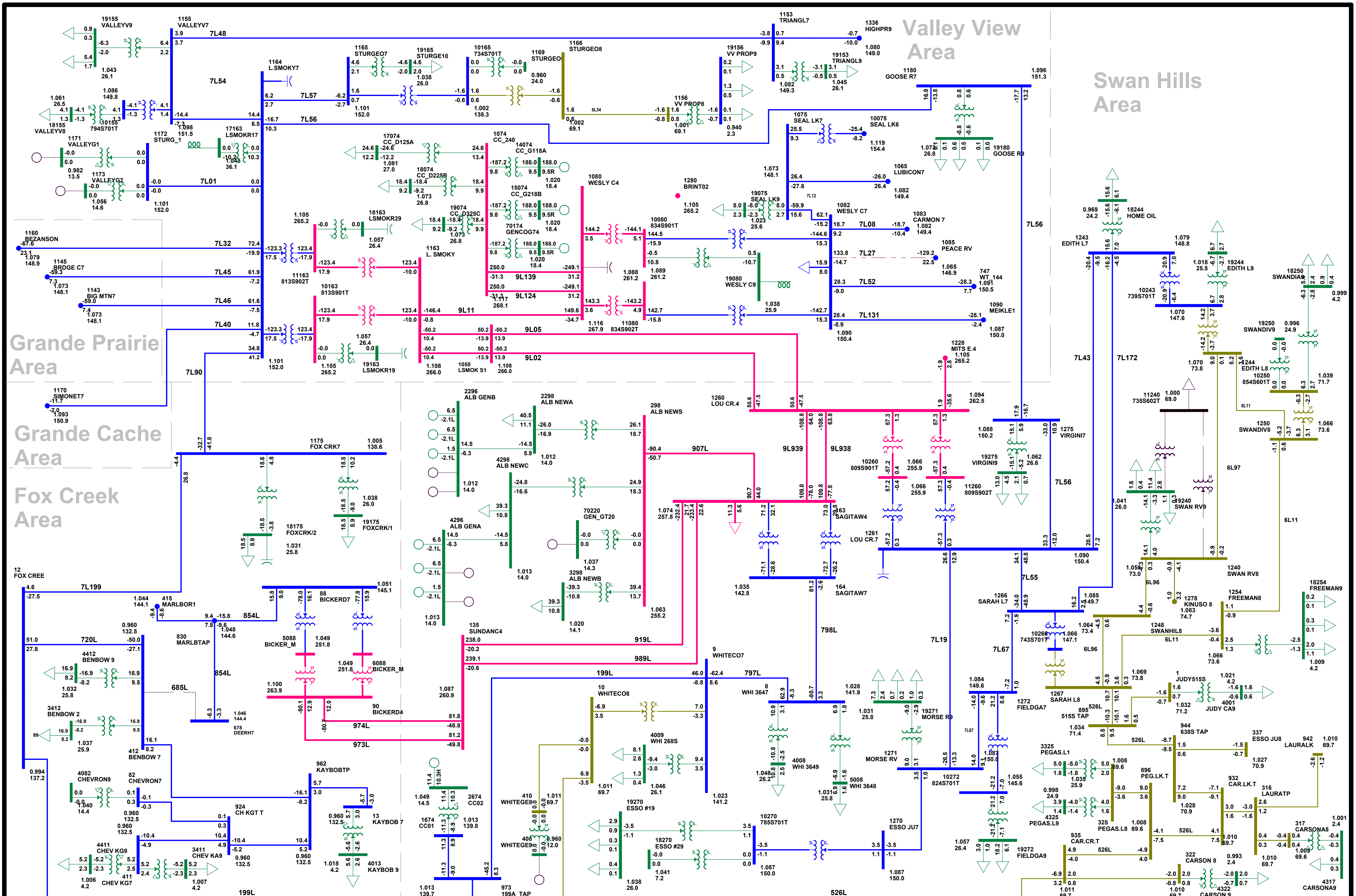
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY B, LOSS OF 854L
2018 SP PRE_PROJECT A-5
WED, APR 05 2017 18:22

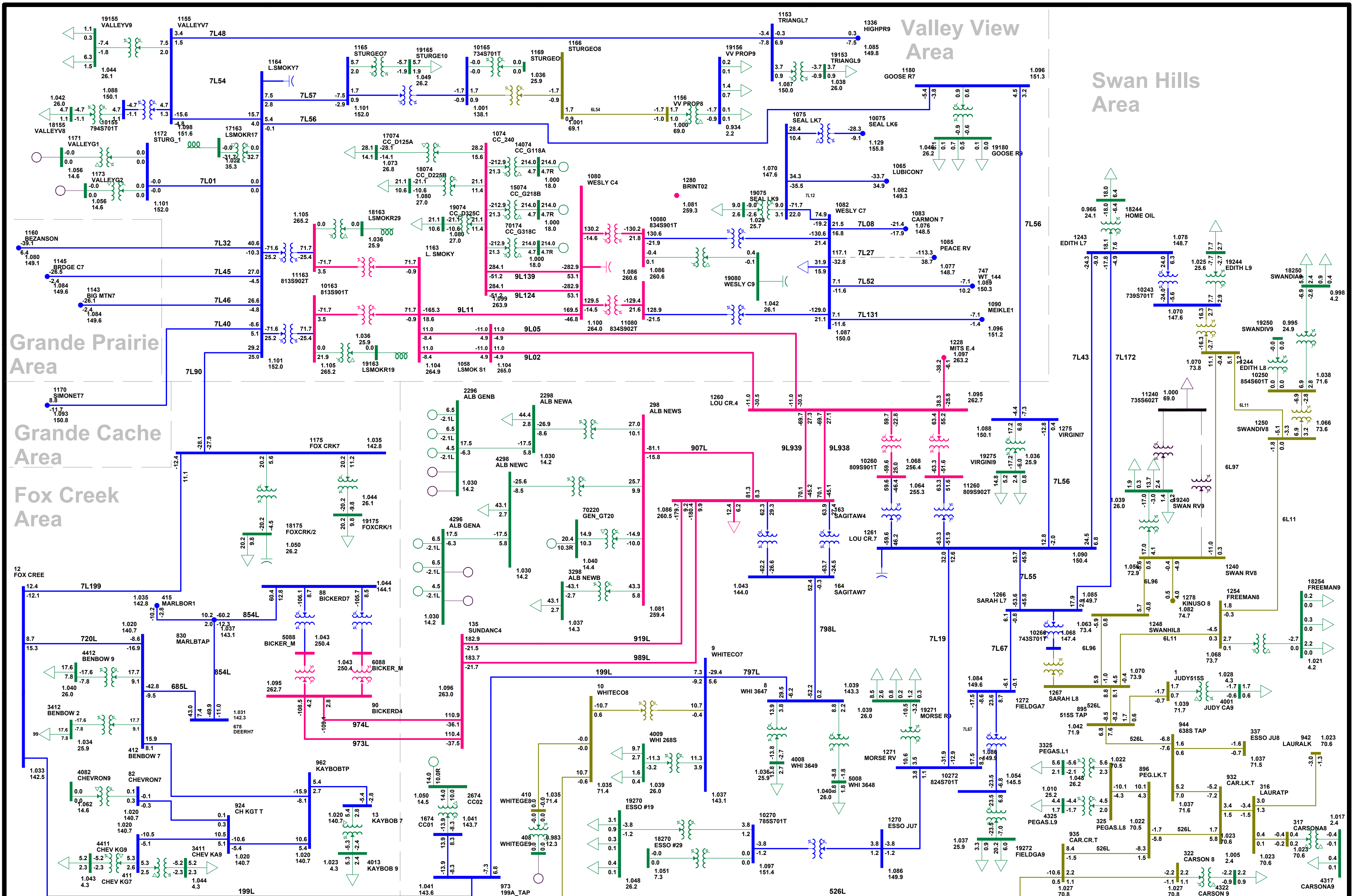
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY B, LOSS OF 685L
2018 SP PRE_PROJECT A-6
WED, APR 05 2017 18:23

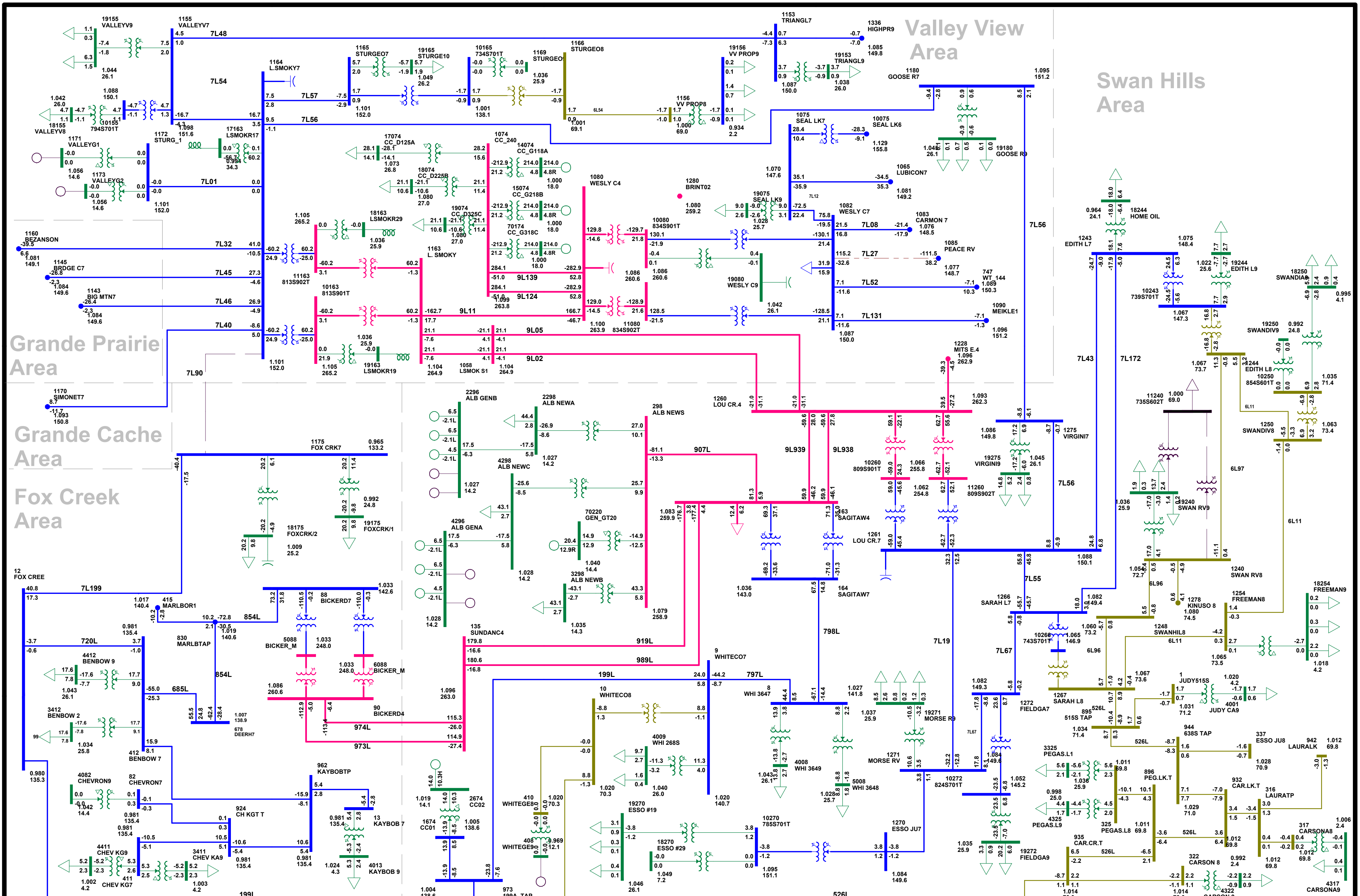
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY A, N-0
2018 WP PRE_PROJECT A-7
WED, APR 05 2017 18:25

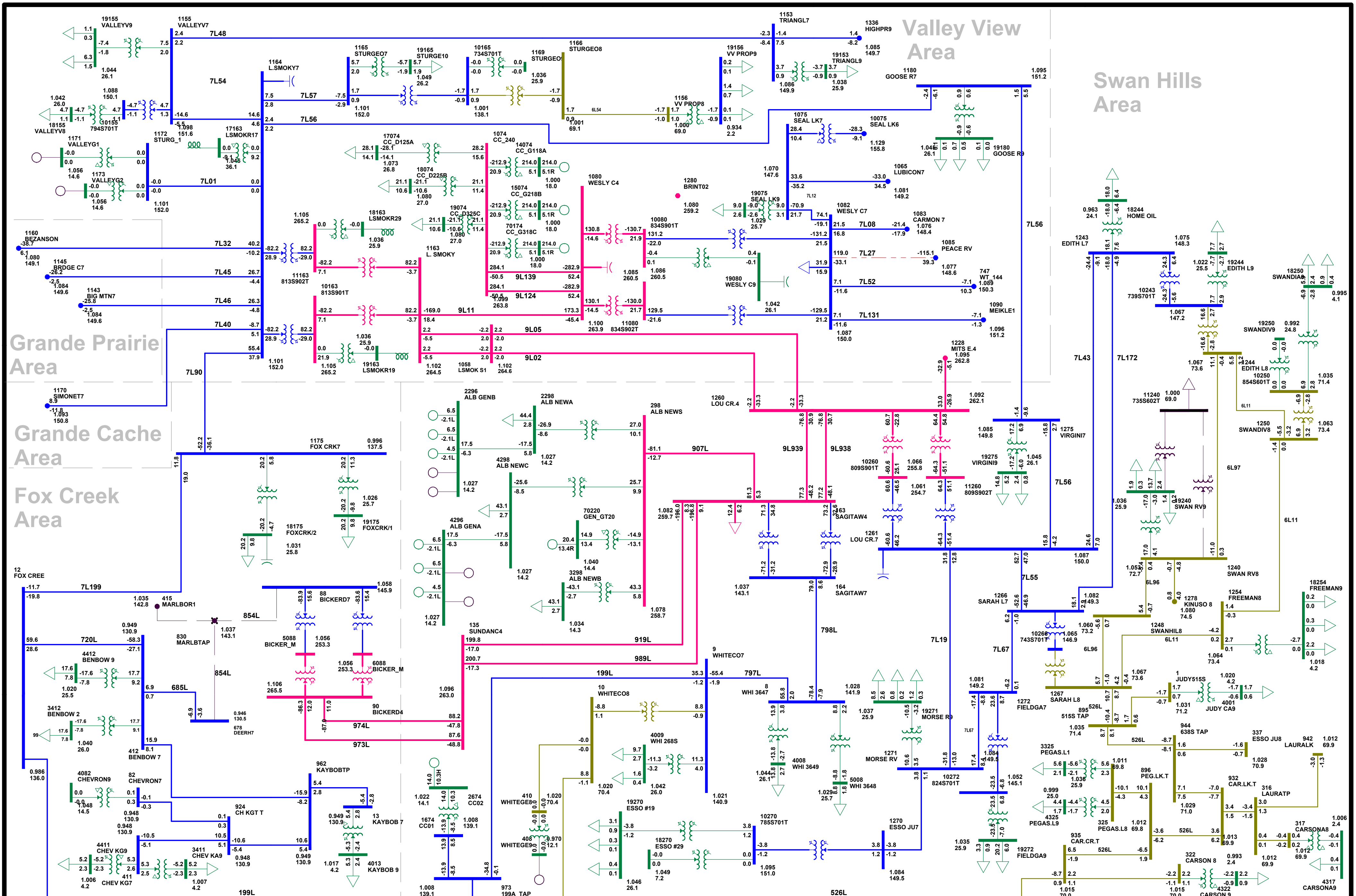
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY B, LOSS OF 7L90
2018 WP PRE_PROJECT A-8
WED, APR 05 2017 18:26

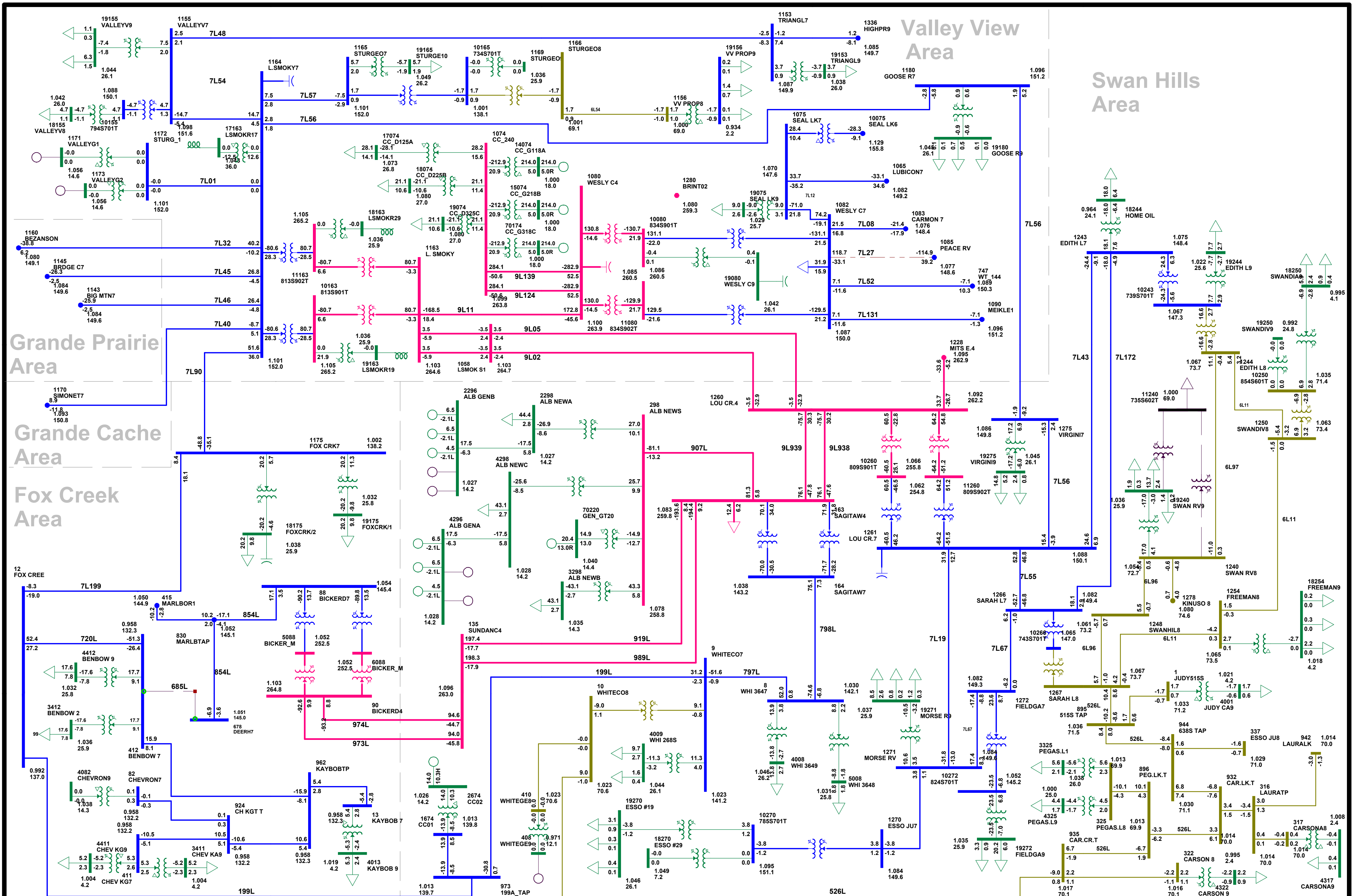
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.1400V 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY B, LOSS OF 854L
2018 WP PRE_PROJECT A-9
WED, APR 05 2017 18:27

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Pre-connection

CATEGORY B, LOSS OF 685L
2018 WP PRE_PROJECT A-10
WED, APR 05 2017 18:28

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000

ATTACHMENT B

Alternative 3 Load Flow Diagrams (Scenarios 3 and 4)

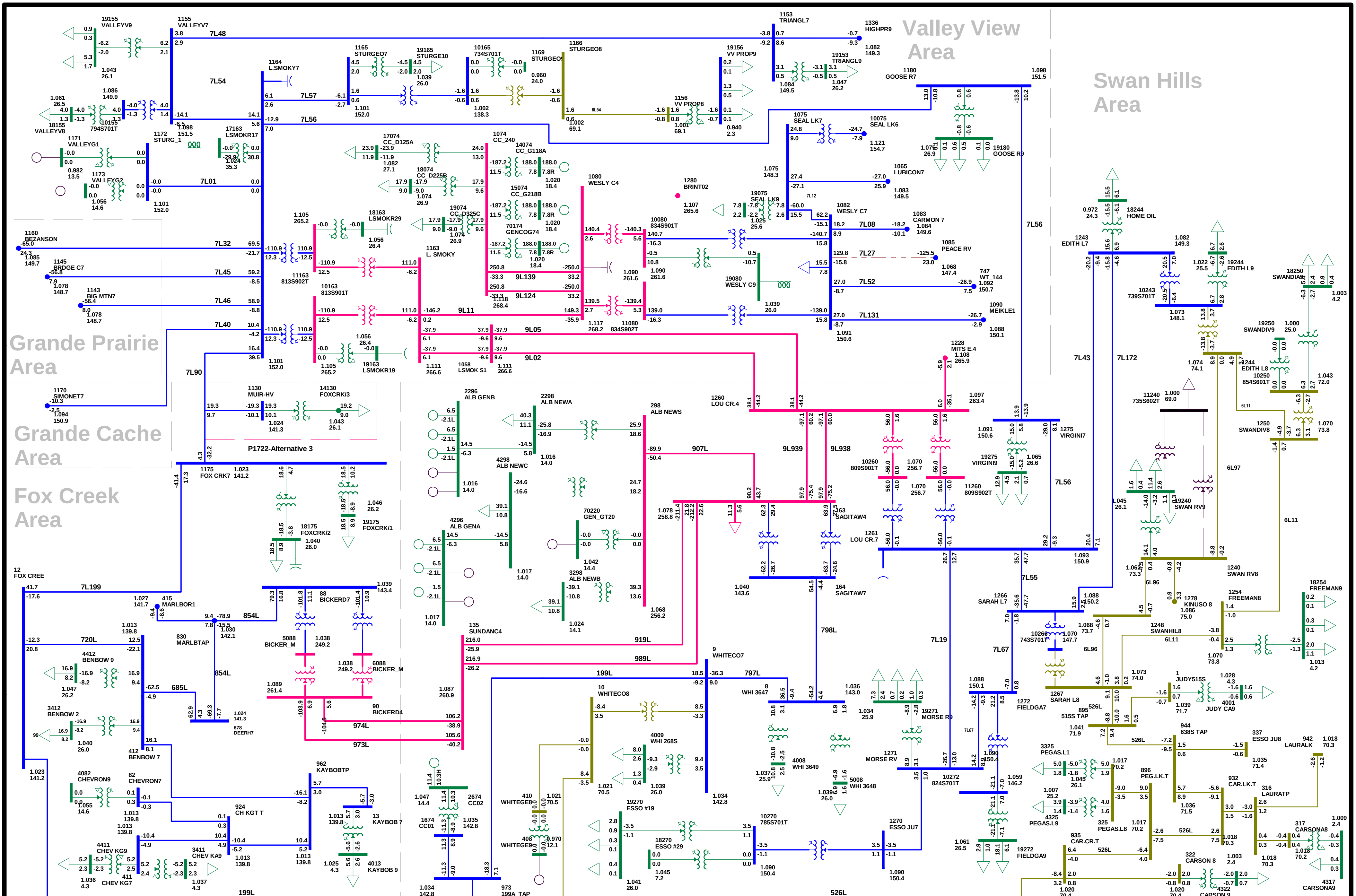
Alternative 3 Load Flow Analysis Results (Scenarios 3 and 4)

Load Flow Diagrams

The Alternative 3 load flow diagrams for Category A and selected Category B contingencies are provided in this section. The following table presents the list of the load flow diagrams. Please note that Whitecourt generation is turned off for these cases.

Table B-1: List of post-Project Alternative 3 load flow diagrams

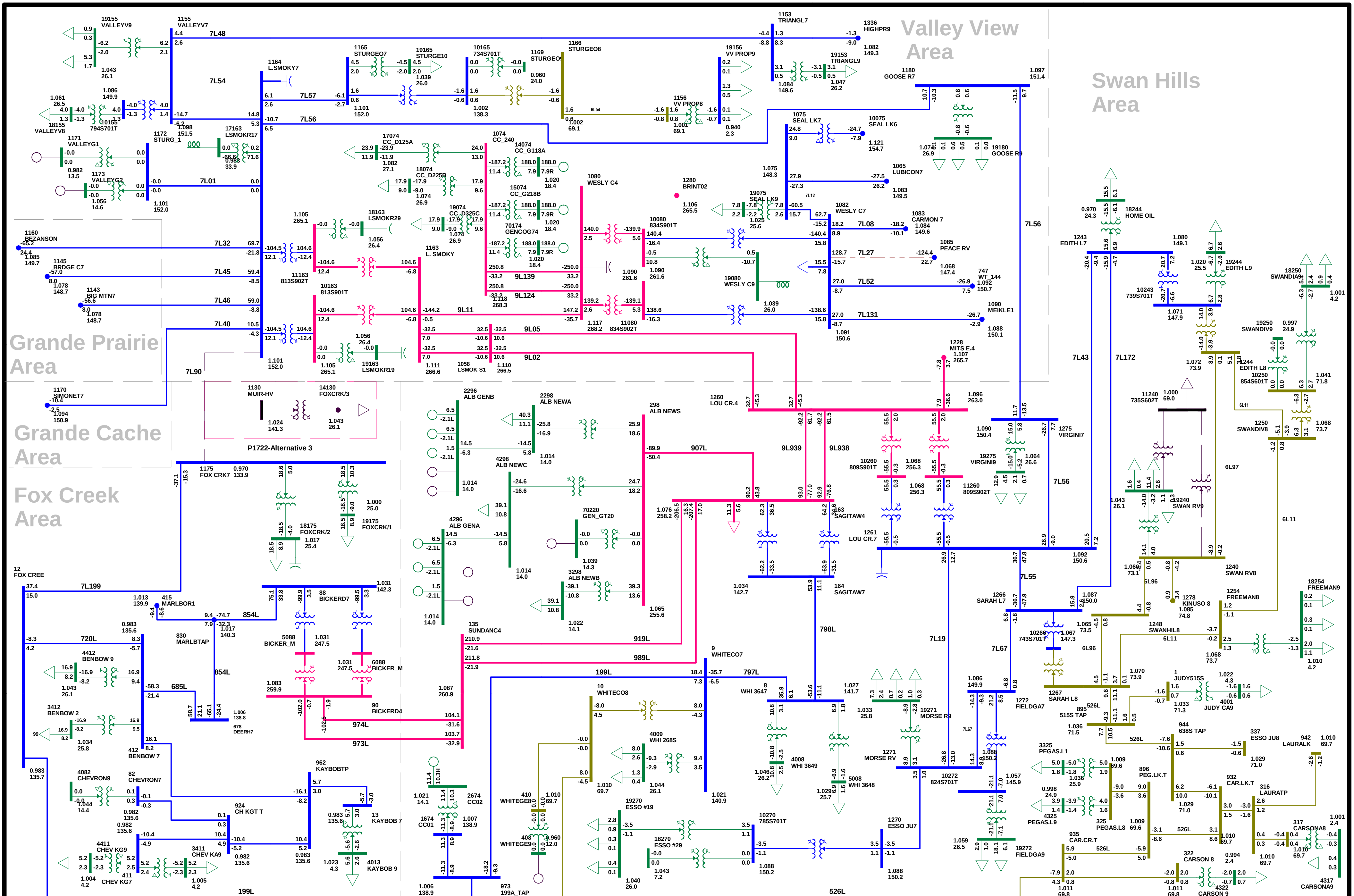
Scenario	Power flow diagram	Page number
2018 SP	N-G, System Normal Condition	B-3
	N-G-1, Loss of 7L90	B-4
	N-G-1, Loss of 854L	B-5
	N-G-1, Loss of 685L	B-6
2018 WP	N-G, System Normal Condition	B-7
	N-G-1, Loss of 7L90	B-8
	N-G-1, Loss of 854L	B-9
	N-G-1, Loss of 685L	B-10



P1722 - Muir New POD

CATEGORY A, N-0
2018 SP ALTERNATIVE 3 B-3
WED, APR 05 2017 17:35

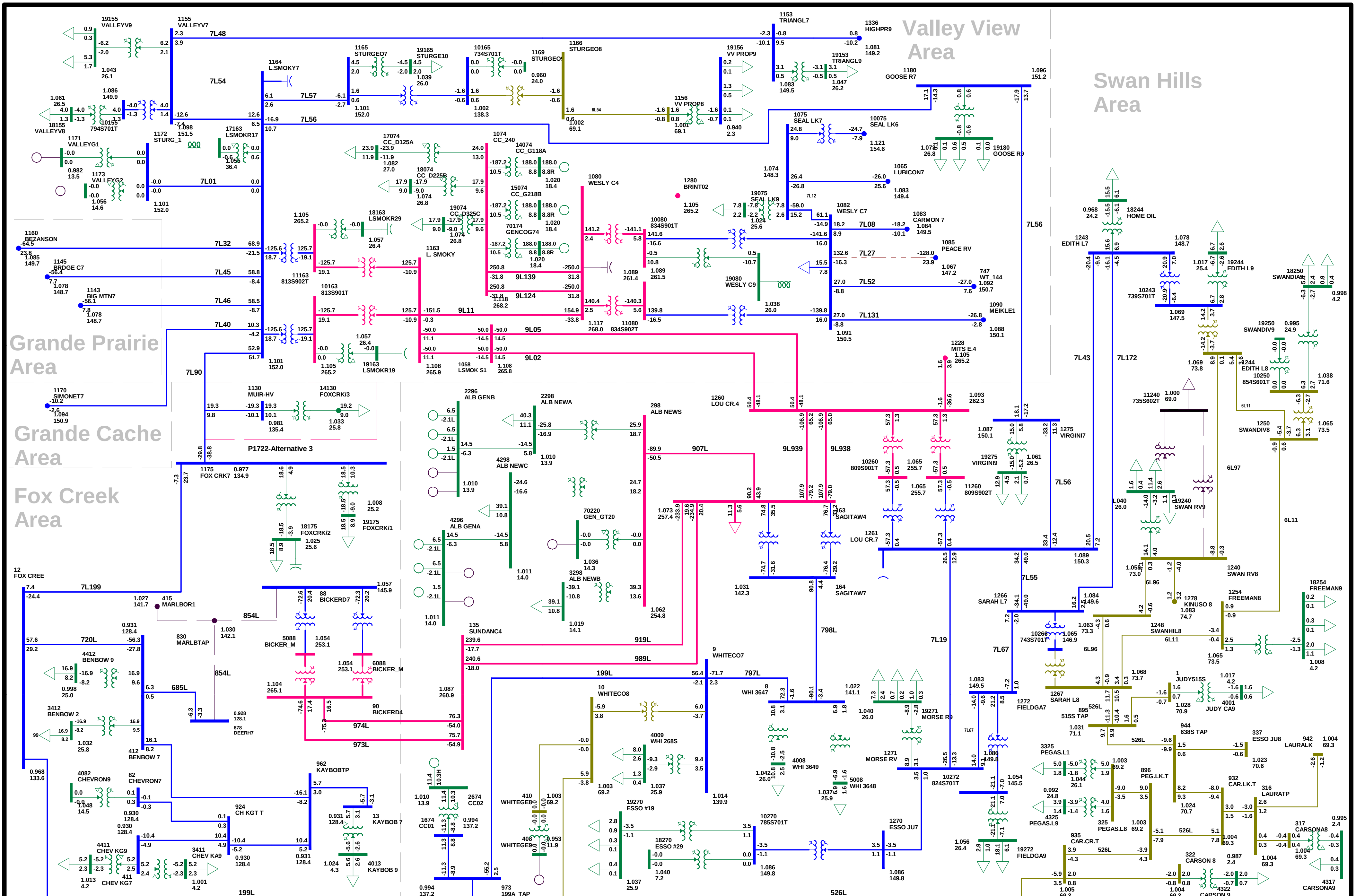
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY A, LOSS OF 7L90
2018 SP ALTERNATIVE 3 B-4
WED, APR 05 2017 17:36

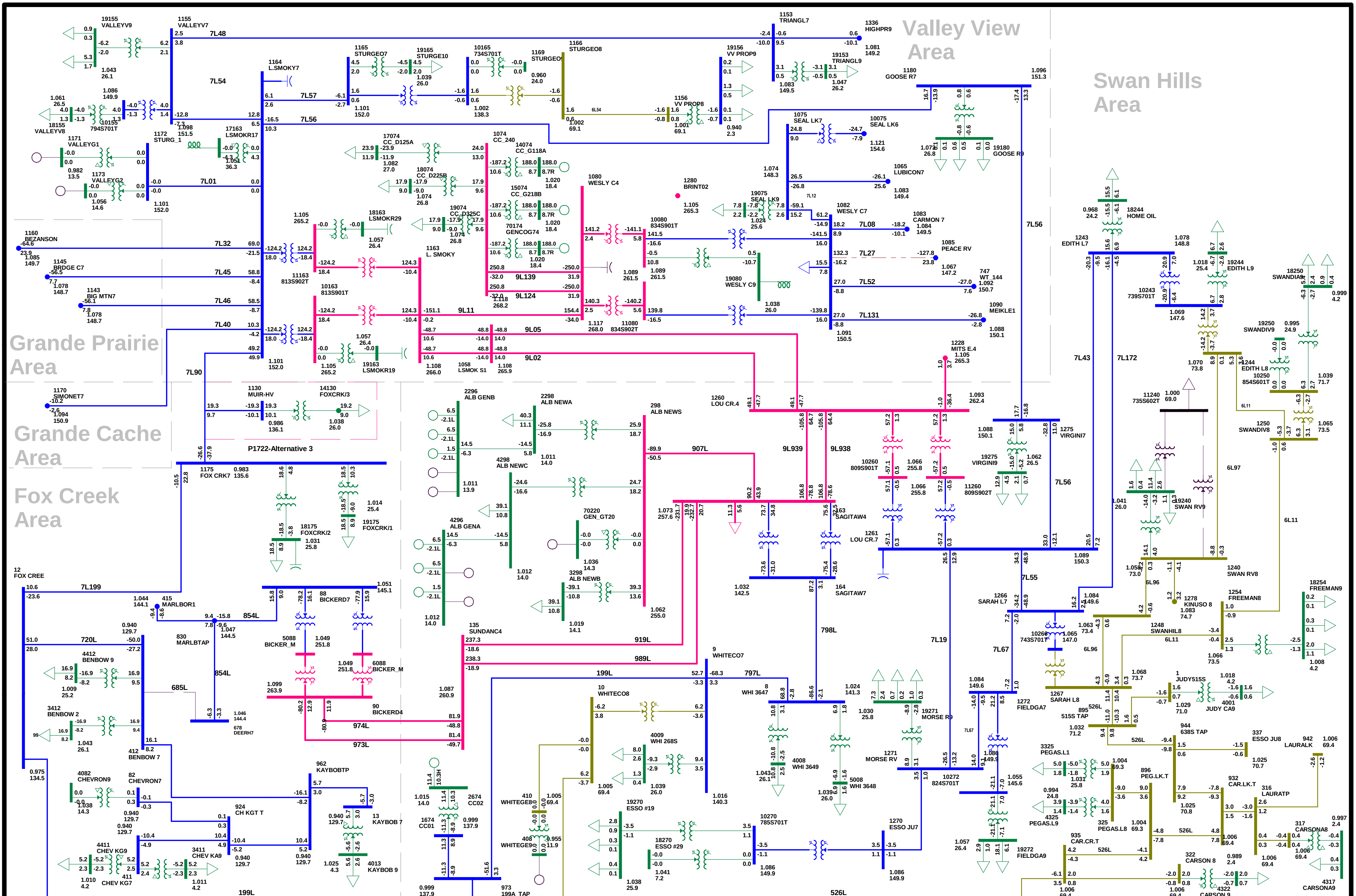
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 854L
2018 SP ALTERNATIVE 3 B-5
WED, APR 05 2017 17:44

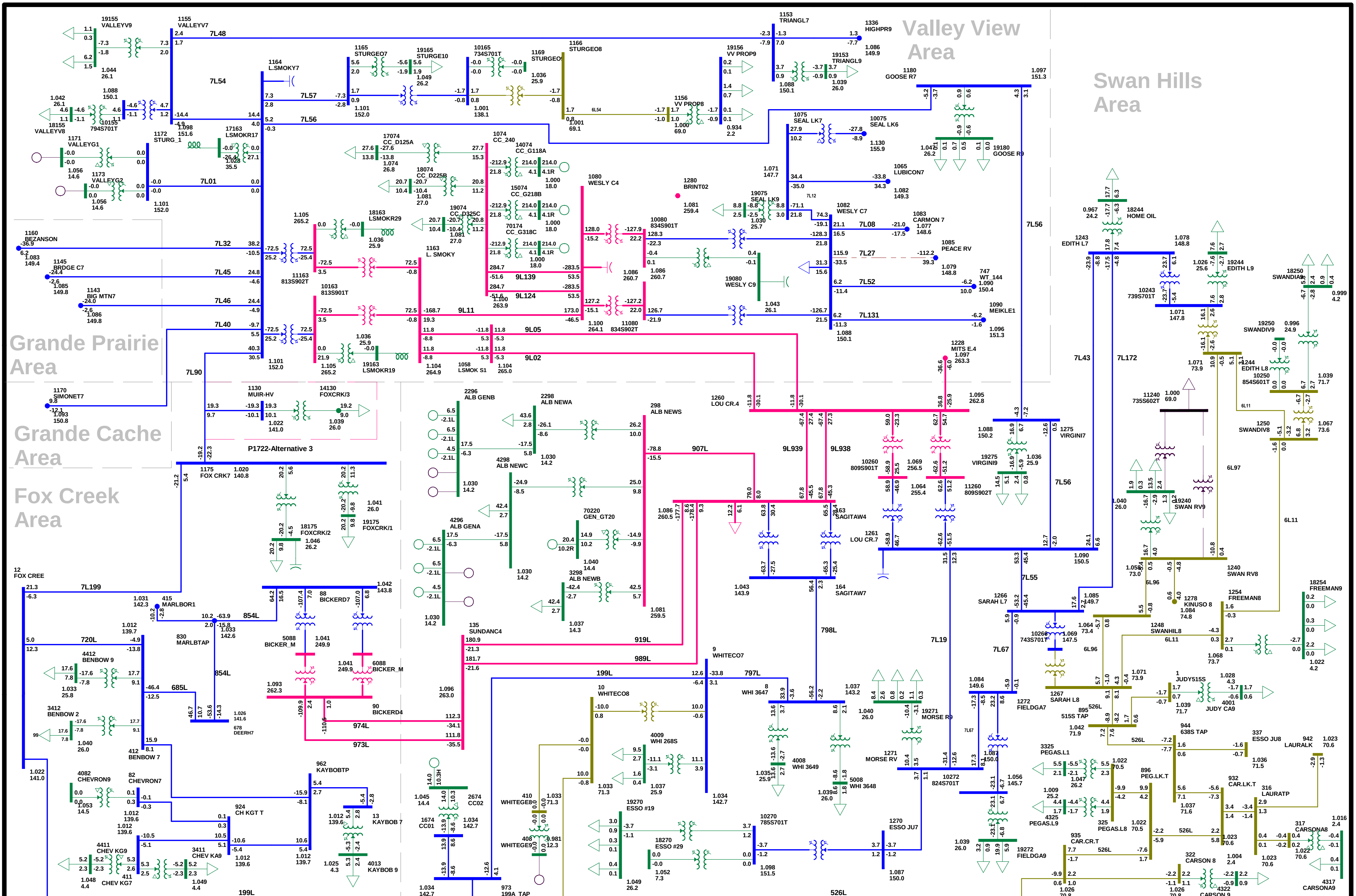
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 685L
2018 SP ALTERNATIVE 3 B-6
WED, APR 05 2017 17:47

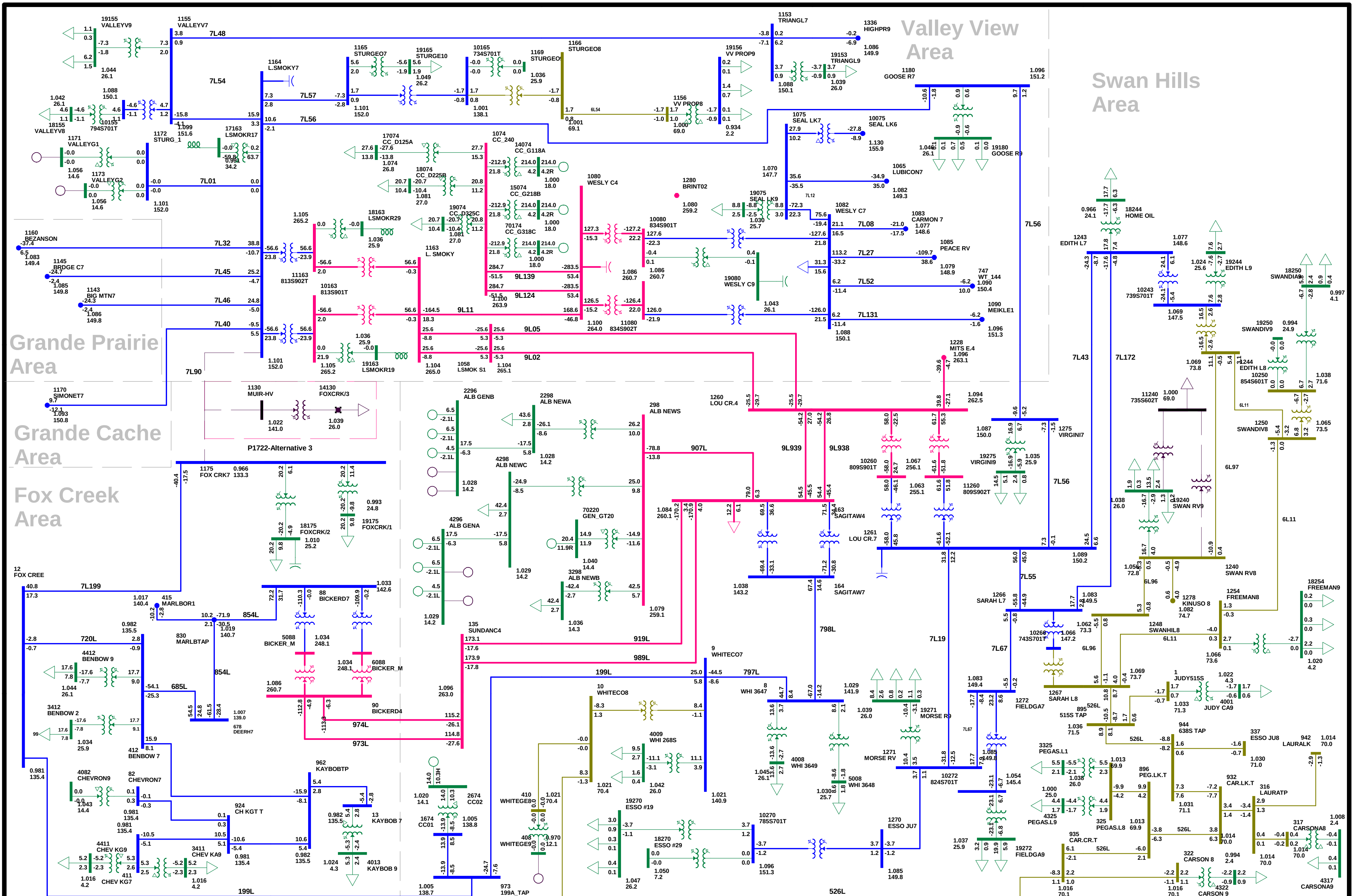
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY A, N-0
2018 WP ALTERNATIVE 3 B-7
WED, APR 05 2017 17:48

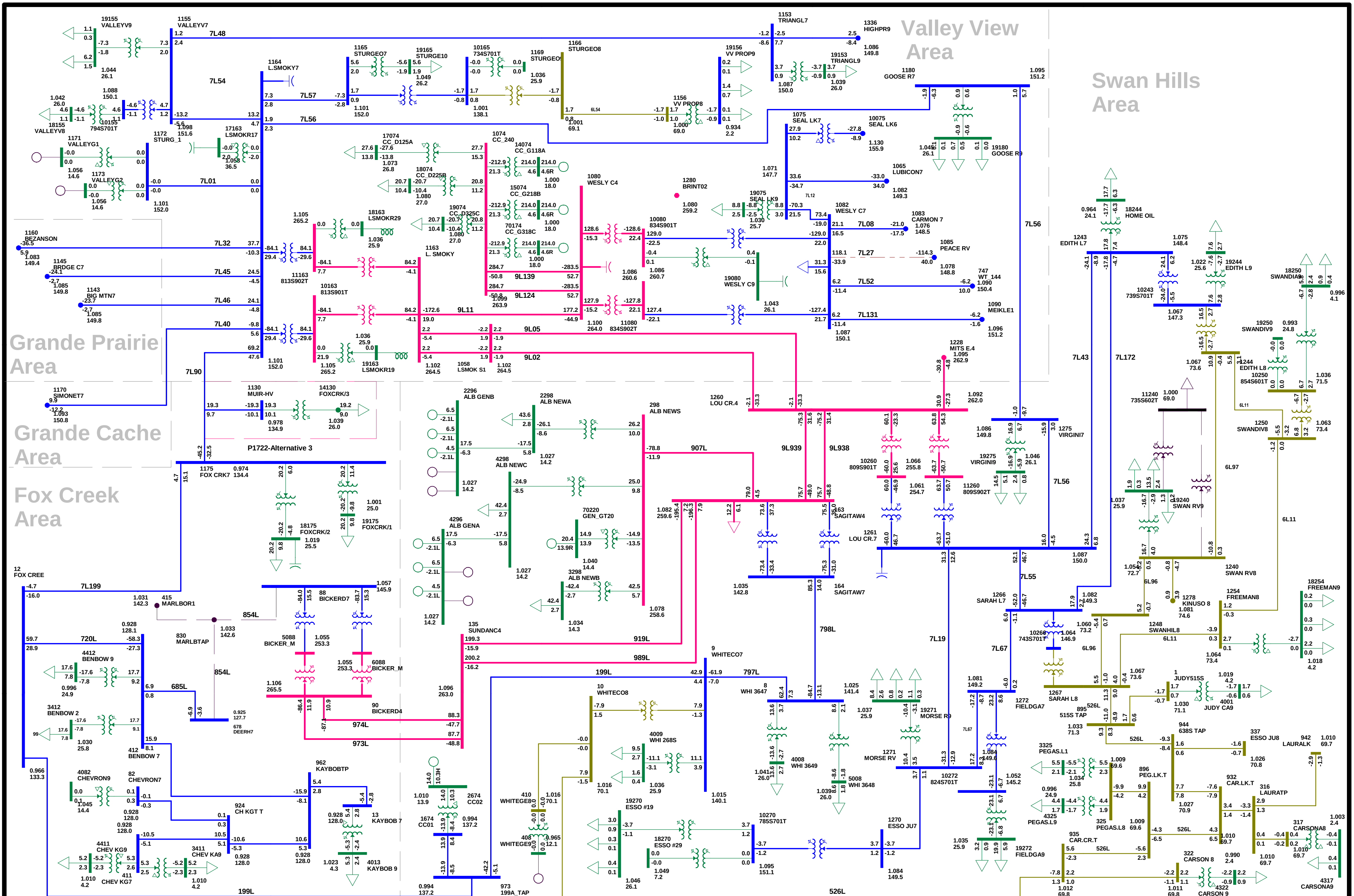
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 7L90
2018 WP ALTERNATIVE 3 B-8
WED, APR 05 2017 17:50

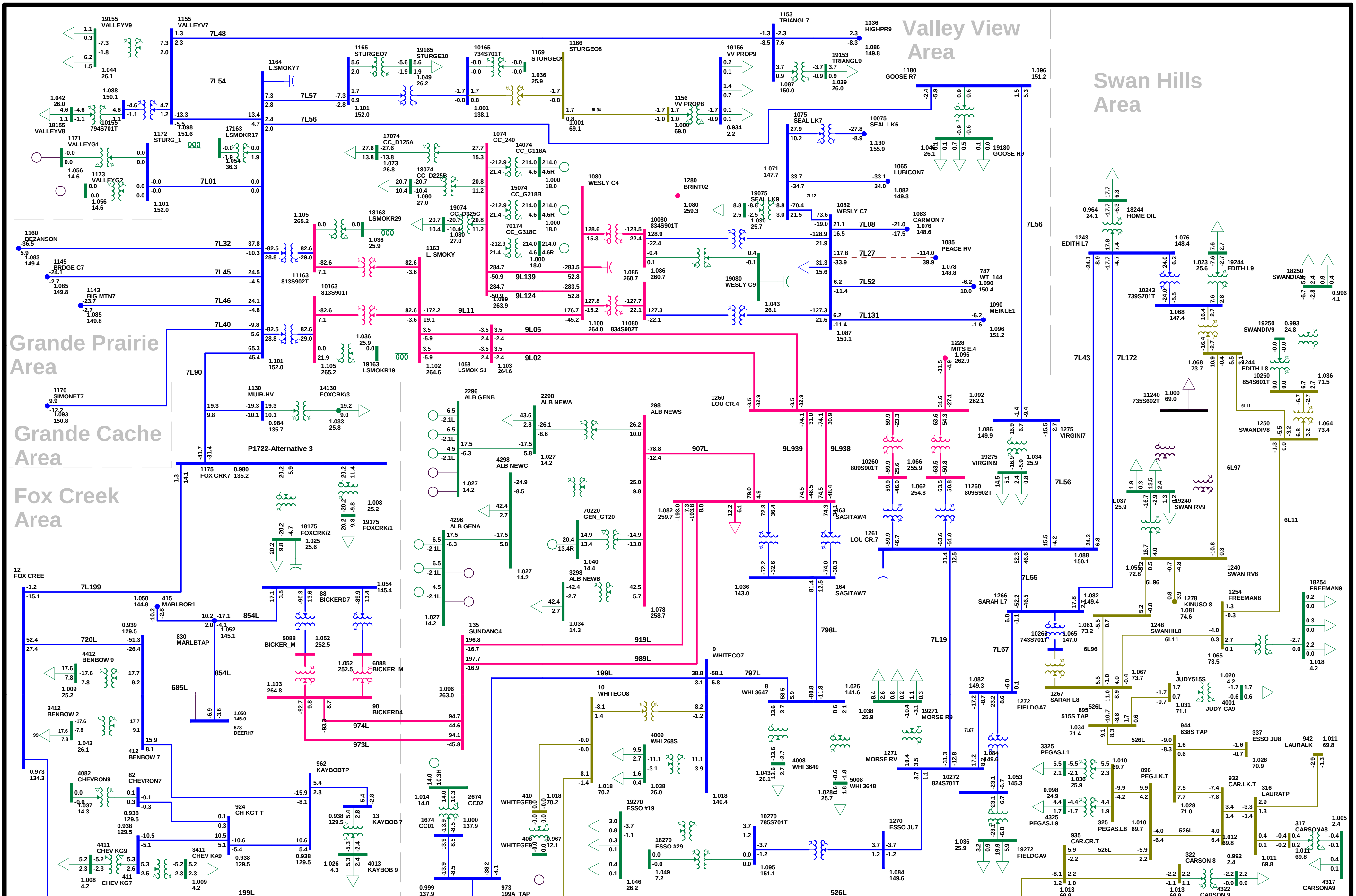
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 854L
2018 WP ALTERNATIVE 3 B-9
WED, APR 05 2017 17:57

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 685L
2018 WP ALTERNATIVE 3 B-10
WED, APR 05 2017 17:54

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar

100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000

ATTACHMENT C

Alternative 3 with a 40 MVAr 138 kV Cap Bank at Benbow 397S

Load Flow Diagrams

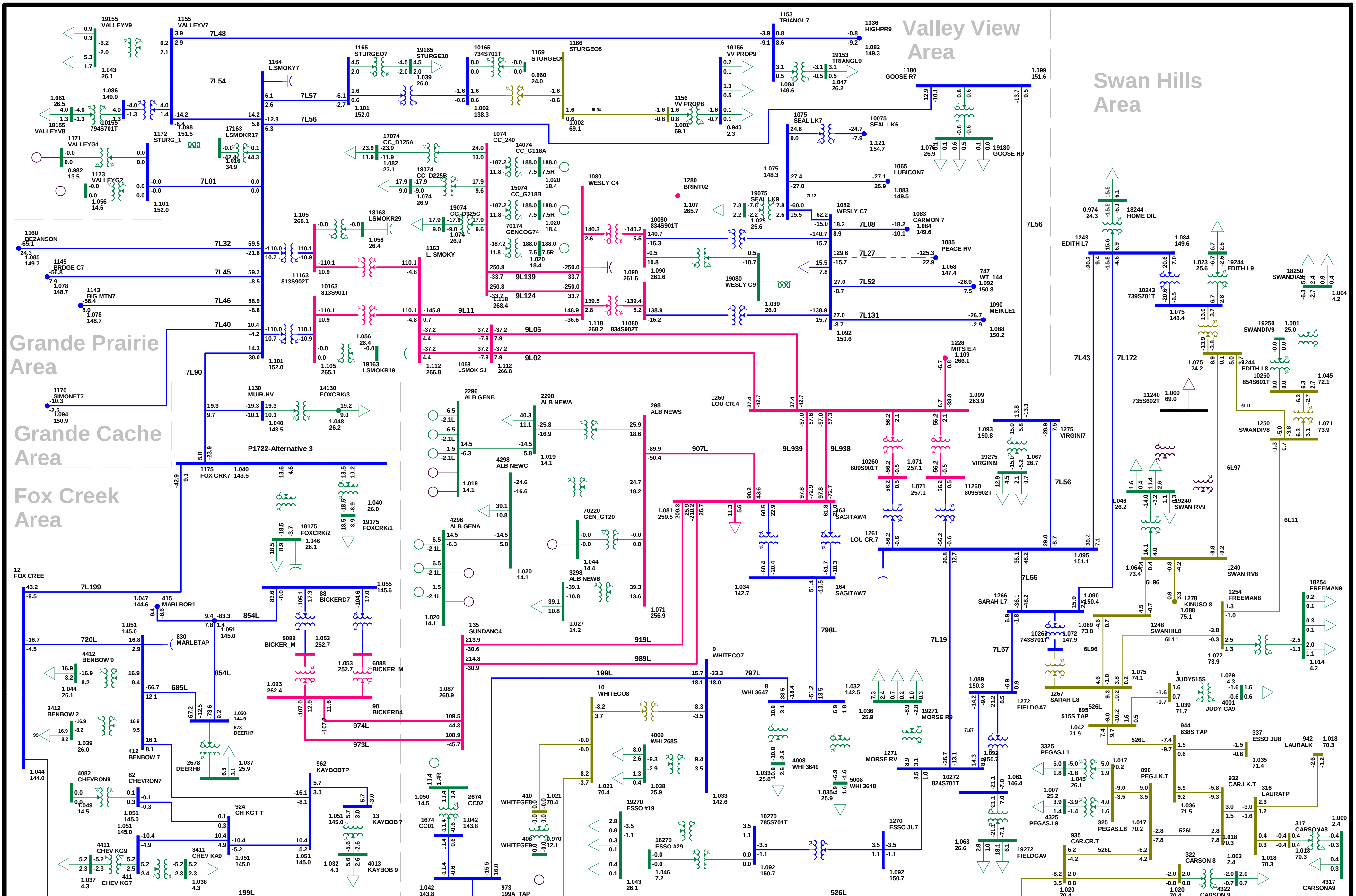
Alternative 3 with a 40 MVAr Cap Bank at Benbow 397S Load Flow Analysis Results

Load Flow Diagrams

Load flow diagrams for Category A, N-G-0 conditions are provided in this section for the post-Project Alternative 3 with a 40 MVAr 144 kV cap bank at Benbow 397S. The following table presents the list of the load flow diagrams. Please note that Whitecourt generation is turned off for these cases.

Table C-1: List of load flow diagrams for Alternative 3 with a 40 MVAr cap bank at Benbow 397S

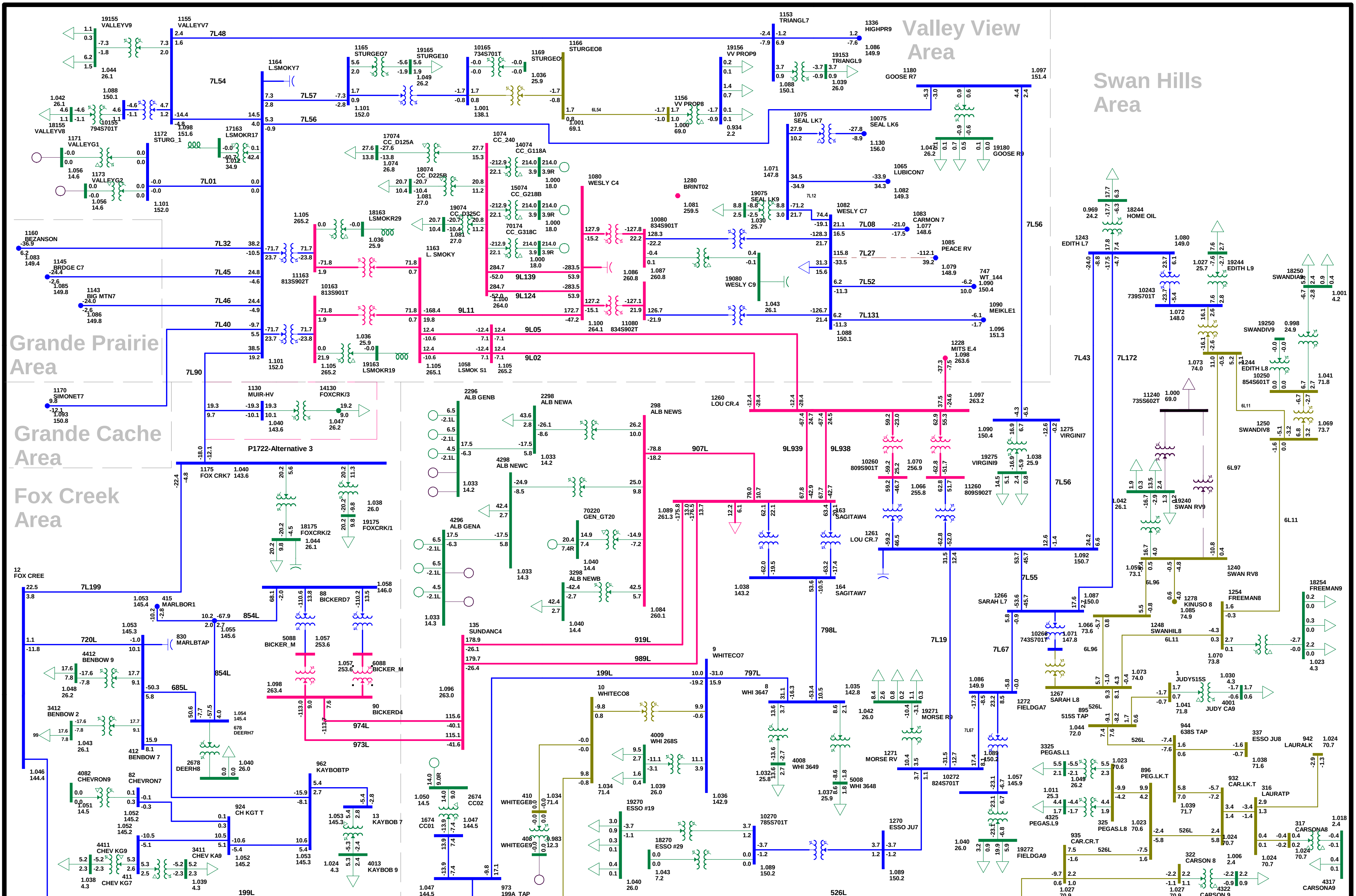
Scenario	Power flow diagram	Page number
2018 SP	N-G, System Normal Condition	C-3
2018 WP	N-G, System Normal Condition	C-4



P1722 - Muir New POD

CATEGORY A, N-0
2018 SP, ALT 3 WITH 38 MVAR CAP AT BENBOW 397S C-3
FRI, APR 07 2017 9:06

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: <=50.000 <=100.000 <=180.000 <=280.000 <=600.000 >600.000



P1722 - Muir New POD

CATEGORY A, N-0
2018 WP ALT 3 WITH 38 MVAR CAP AT BENBOW 397S C-4
FRI, APR 07 2017 9:12

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: <=50.000 <=100.000 <=180.000 <=280.000 <=600.000 >600.000

ATTACHMENT D

Alternative 3 with a 40 MVAr 144 kV Cap Bank at Fox Creek 741S

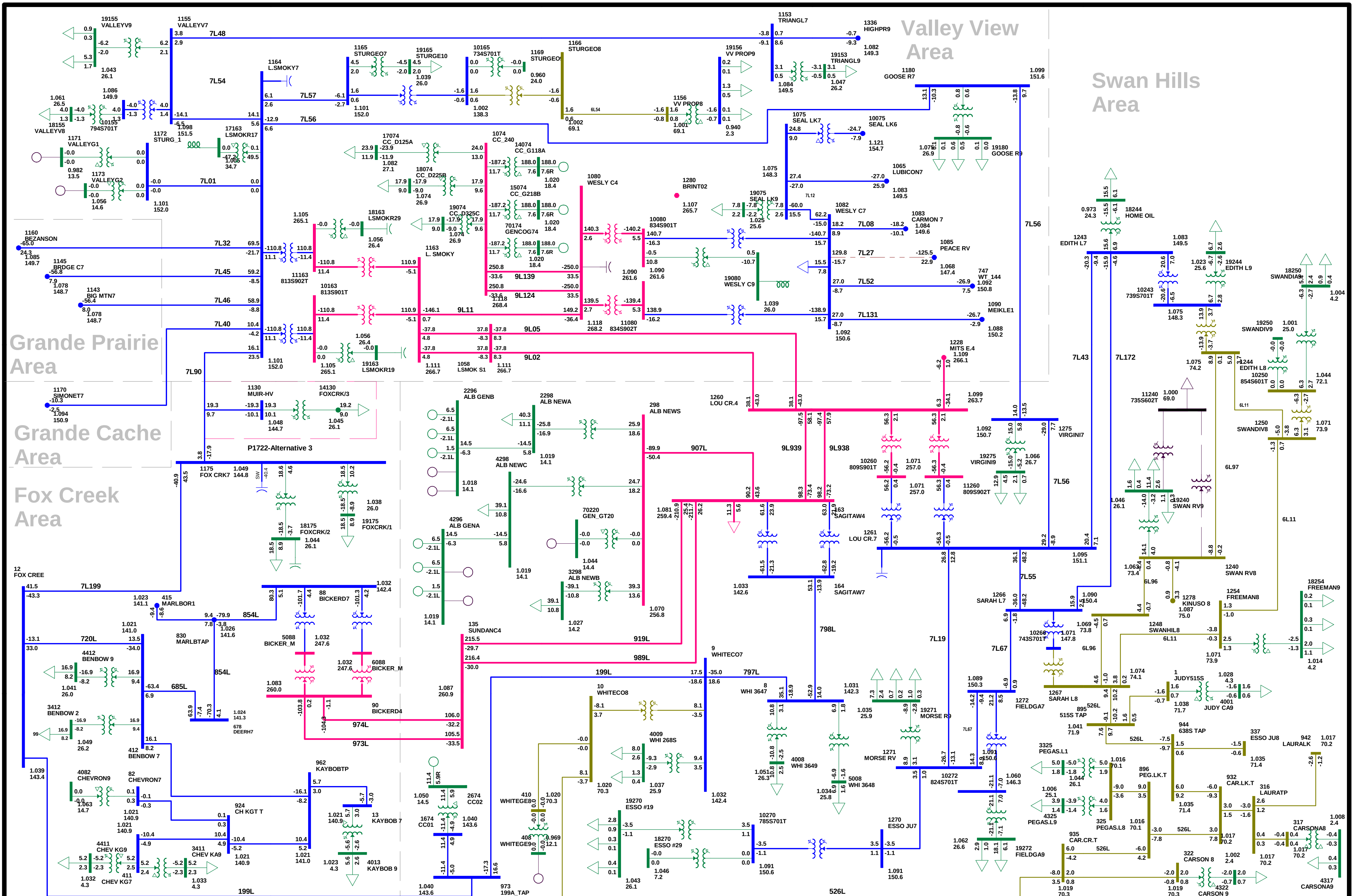
Load Flow Diagrams (Scenarios 3 and 4)

Alternative 3 with a 40 MVAr Cap Bank at Fox Creek 741S Load Flow Analysis Results (Scenarios 3 and 4)

Load Flow Diagrams

Load flow diagrams for Category A and selected Category B contingencies are provided in this section for the post-Projec Alternative 3 with a 40 MVAr 144 kV cap bank at Fox Creek 741S. The following table presents the list of the load flow diagrams. Please note that Whitecourt generation is turned off for these cases.

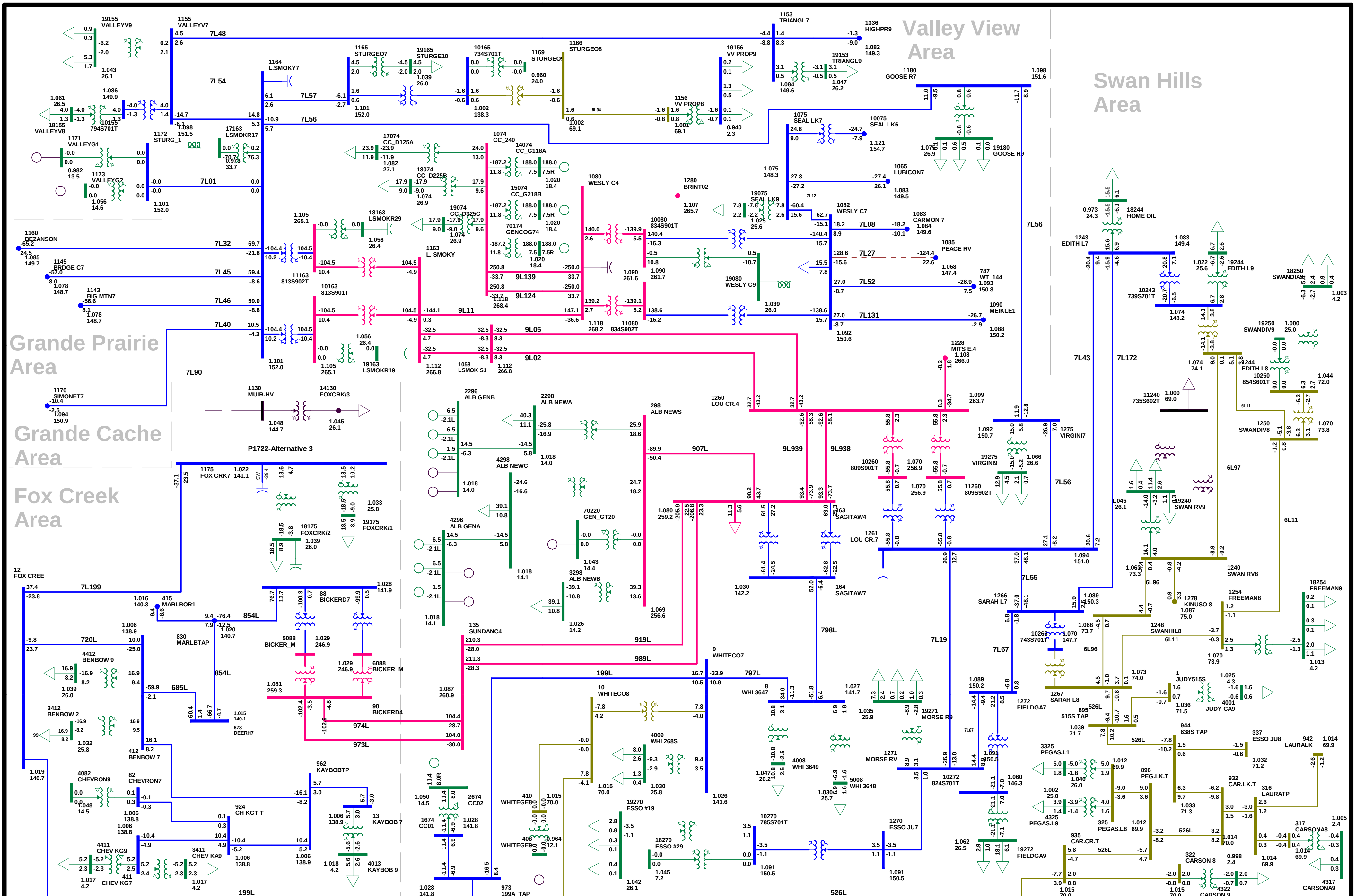
Table D-1: List of load flow diagrams for Alternative 3 with a 40 MVAr cap bank at Fox Creek 741S



P1722 - Muir New POD

CATEGORY A, N-0
2018 SP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-3
WED, APR 05 2017 18:00

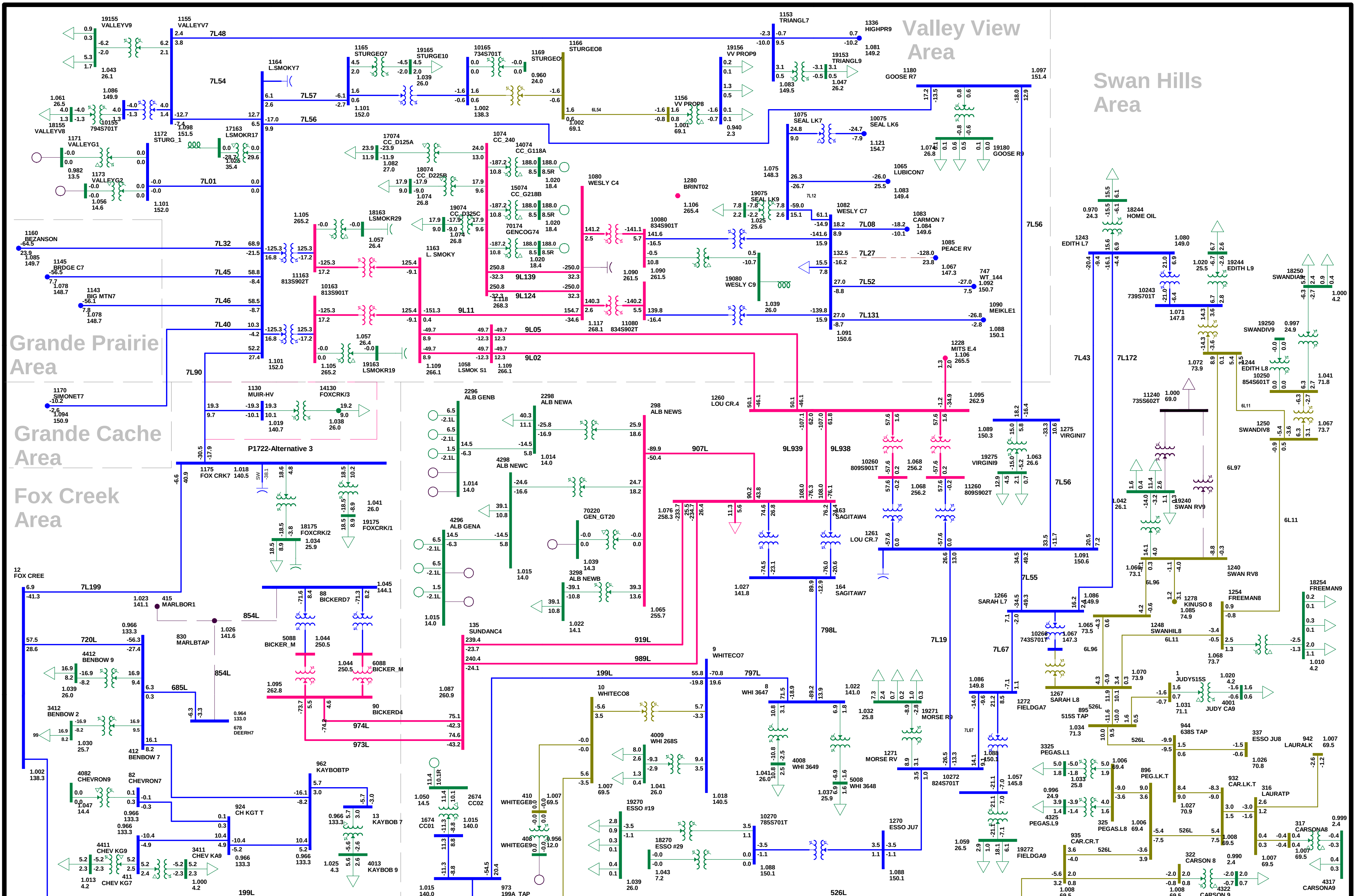
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 7L90
2018 SP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-4
WED, APR 05 2017 18:02

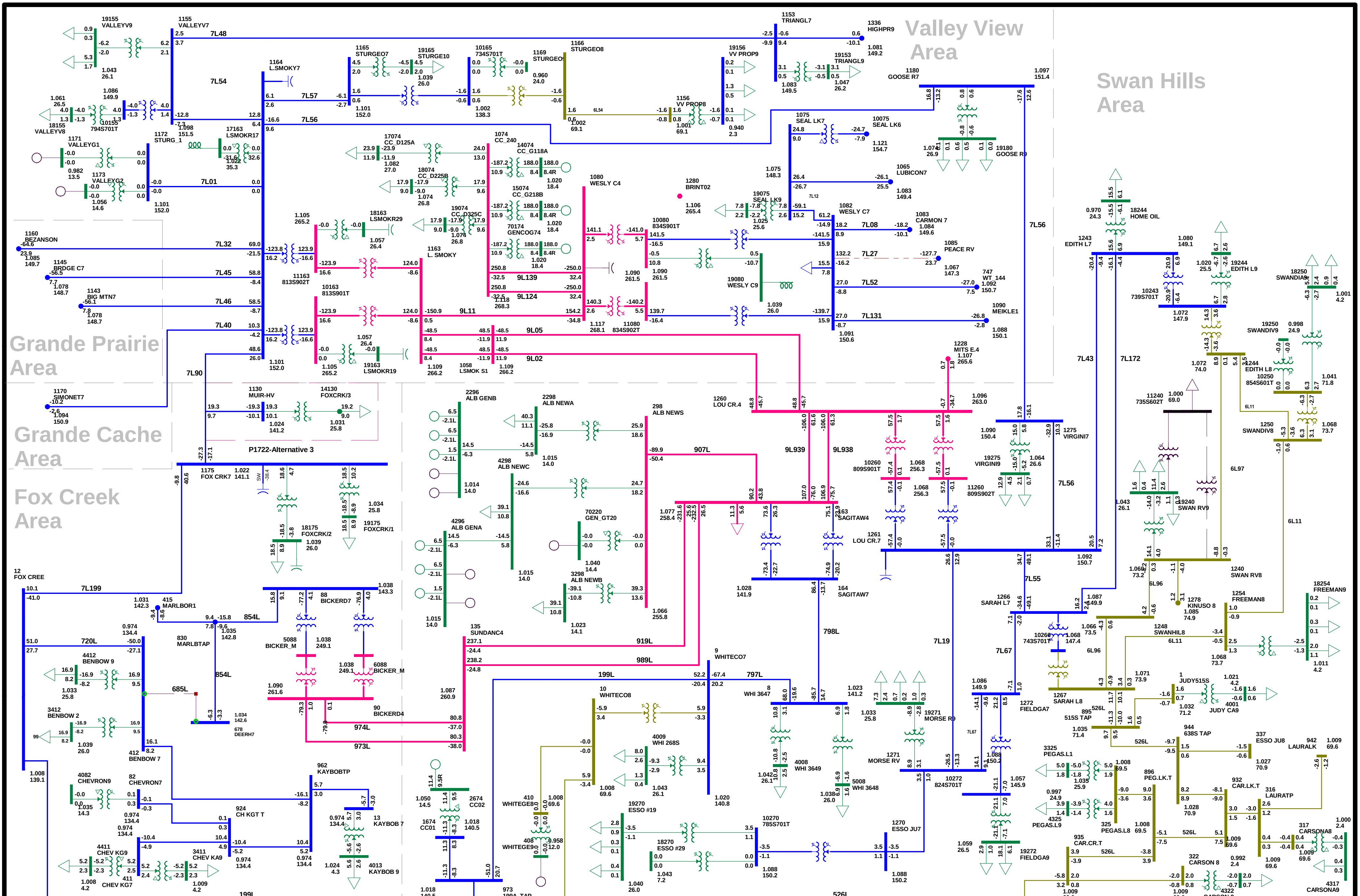
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 854L
2018 SP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-5
WED, APR 05 2017 18:04

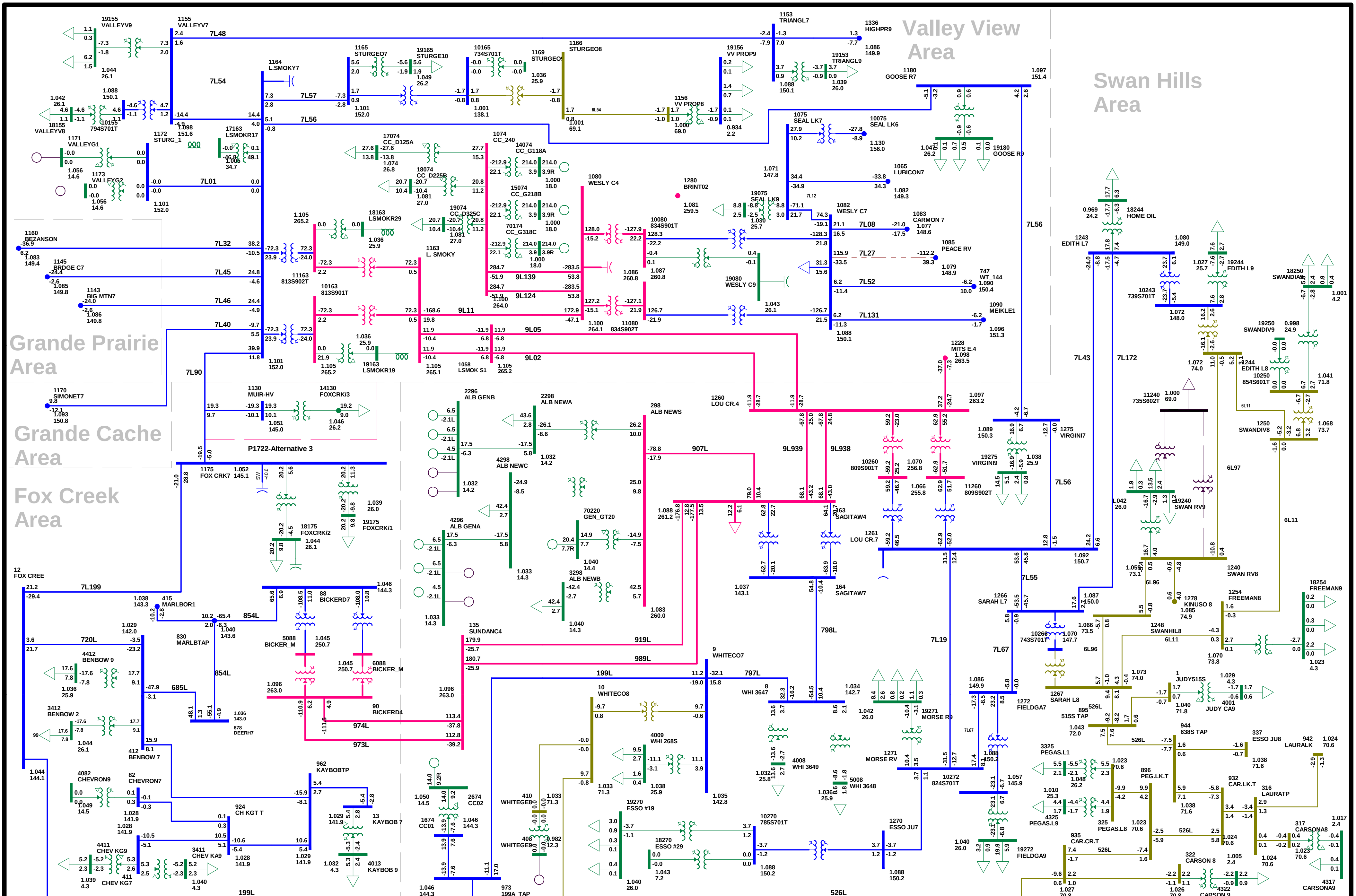
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 685L
2018 SP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-6
WED, APR 05 2017 18:05

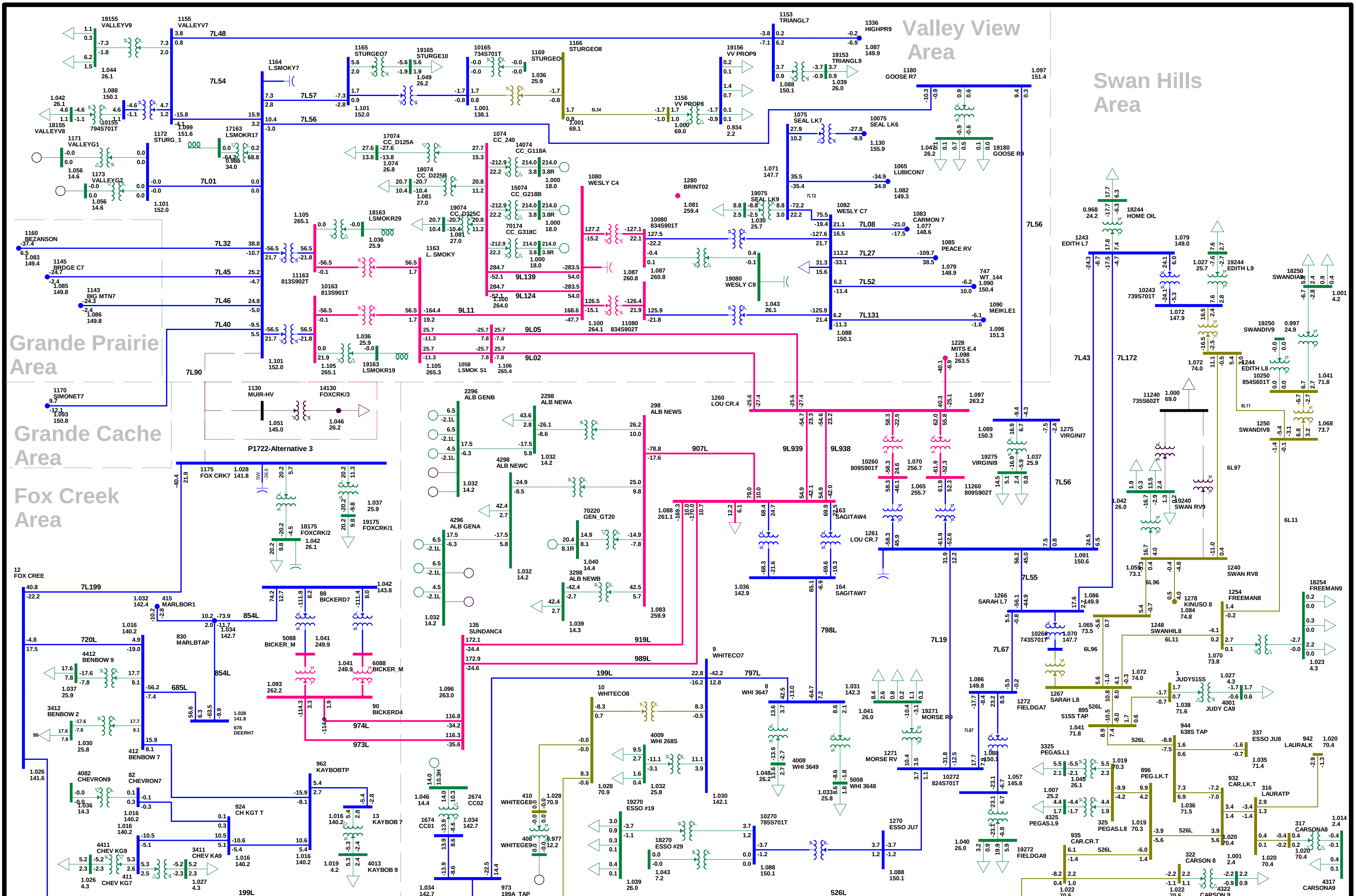
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY A, N-0
2018 WP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-7
WED, APR 05 2017 18:07

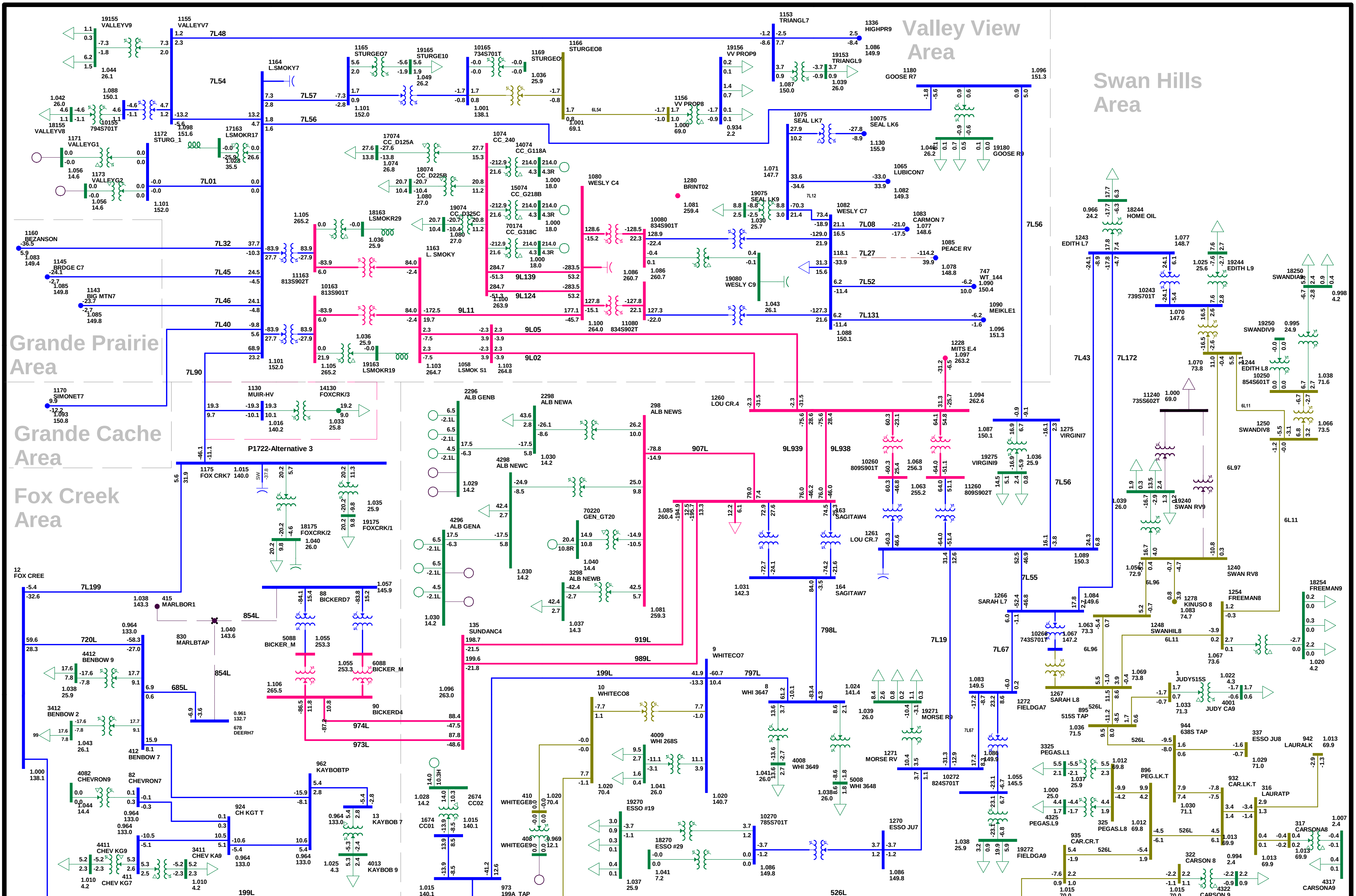
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 7L90
2018 WP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-8
WED, APR 05 2017 18:08

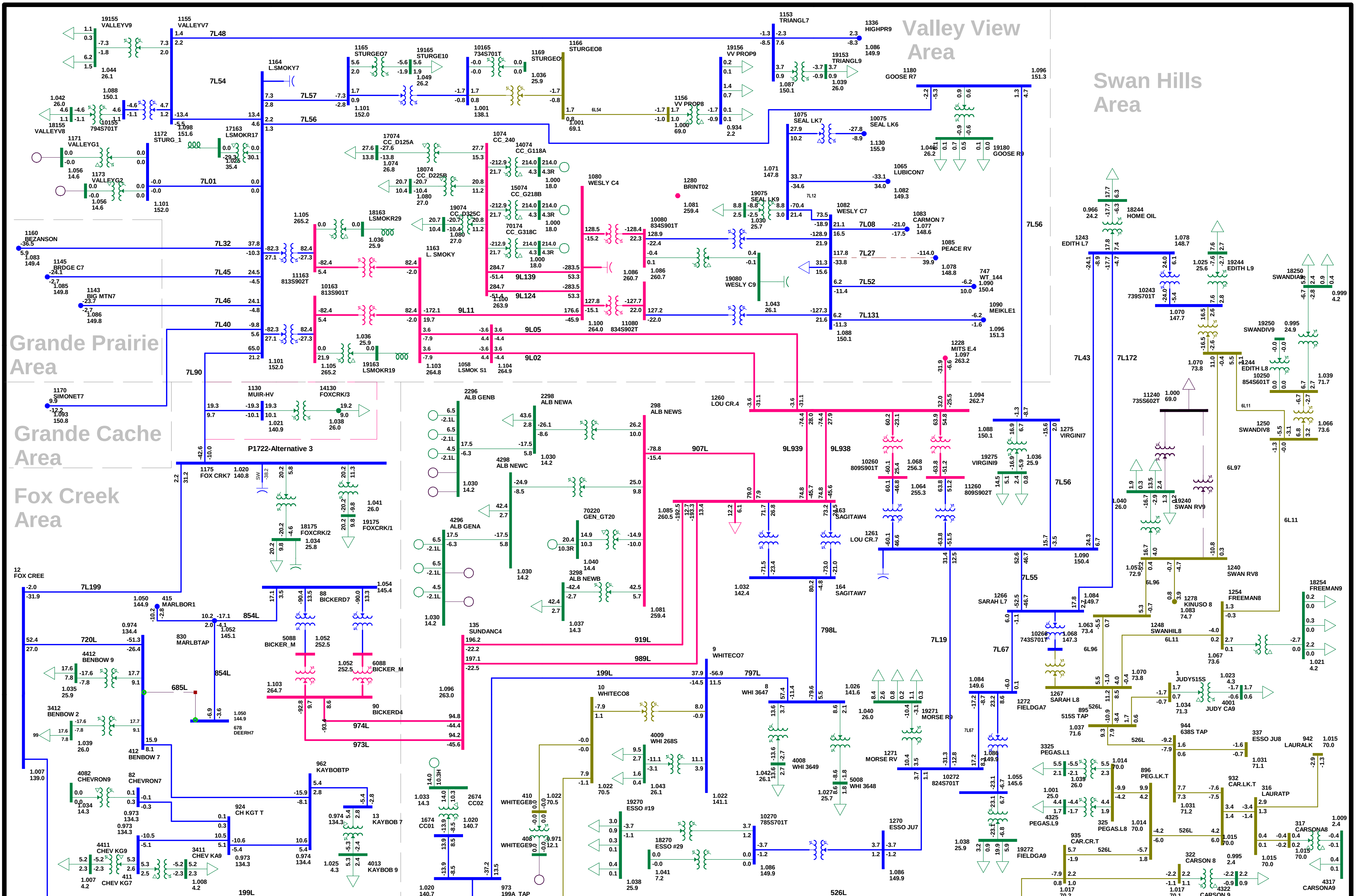
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 854L
2018 WP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-9
WED, APR 05 2017 18:10

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000



P1722 - Muir New POD

CATEGORY B, LOSS OF 685L
2018 WP, ALT 3 WITH 40 MVAR CAP AT FOX CREEK 741S D-10
WED, APR 05 2017 18:11

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.140OV 0.950UV
kV: >0.000 <=25.000 <=72.000 <=144.000 <=240.000

ATTACHMENT E

Post-Project Voltage Stability Curves with a 40 MVAr capacitor bank at Fox Creek 741S (Scenario 4)

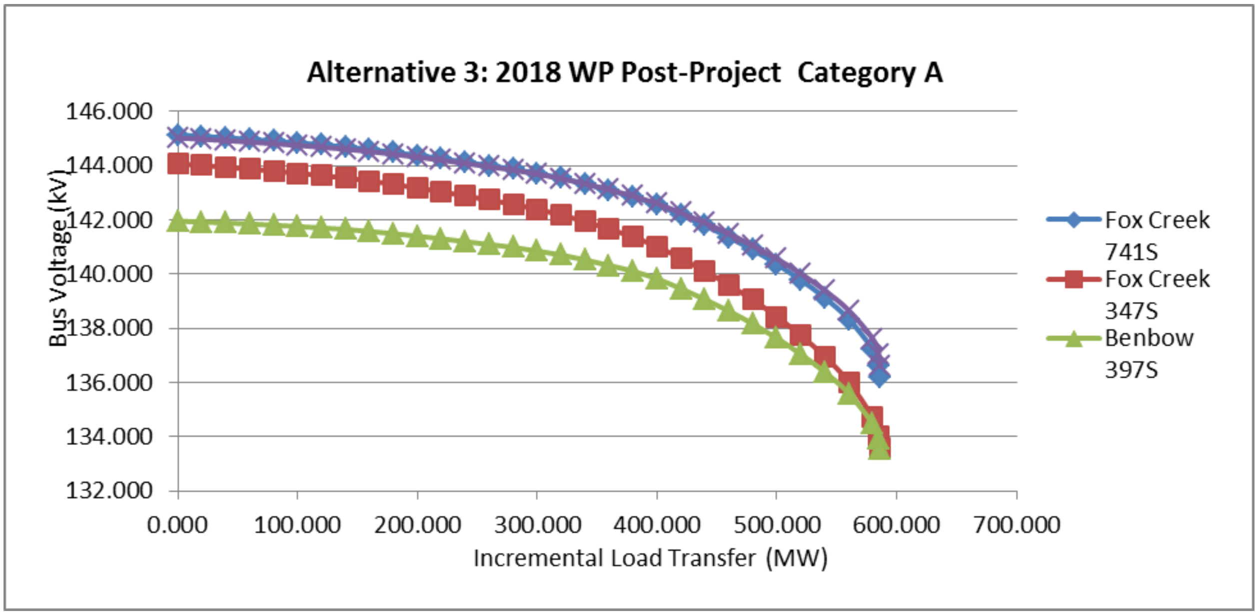
Alternative 3 Voltage Stability Analysis Results (Scenarios 4)

P-V Curves

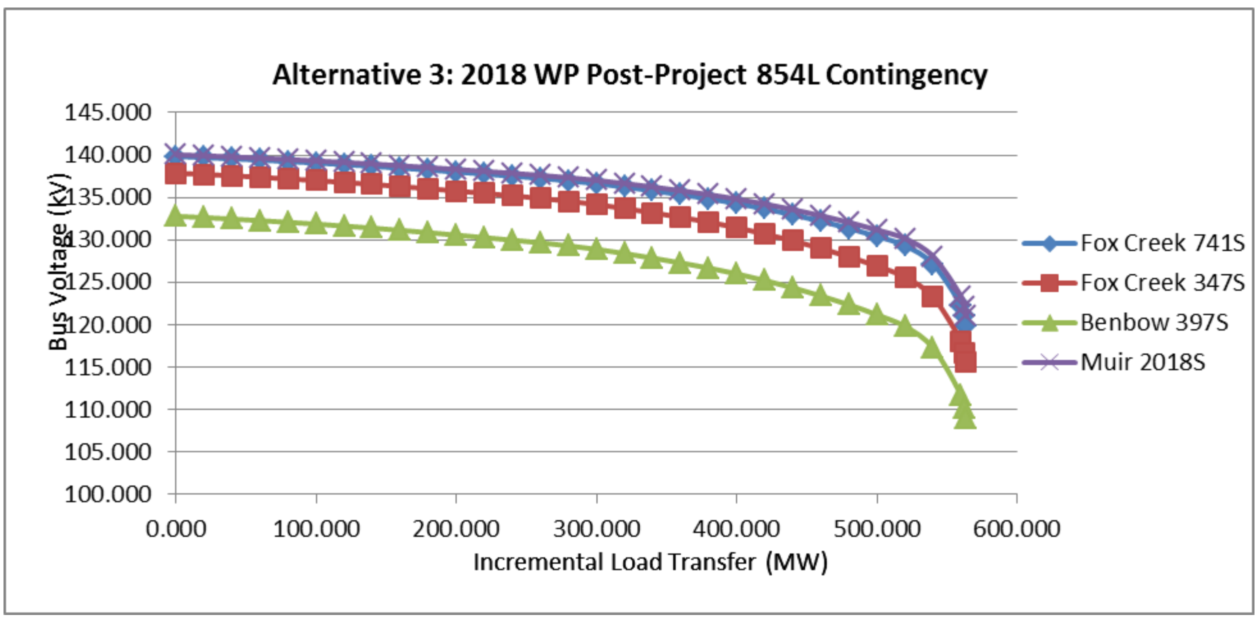
The voltage stability analysis was completed for the post-Project Alternative 3 winter peak scenario (2018WP). The P-V curves for the worst contingencies are provided below.

Figure E-1 shows the P-V curves for Category A and Category B 854L, 685L and 798L contingencies in the post-Project for Scenario 4 in 2018WP.

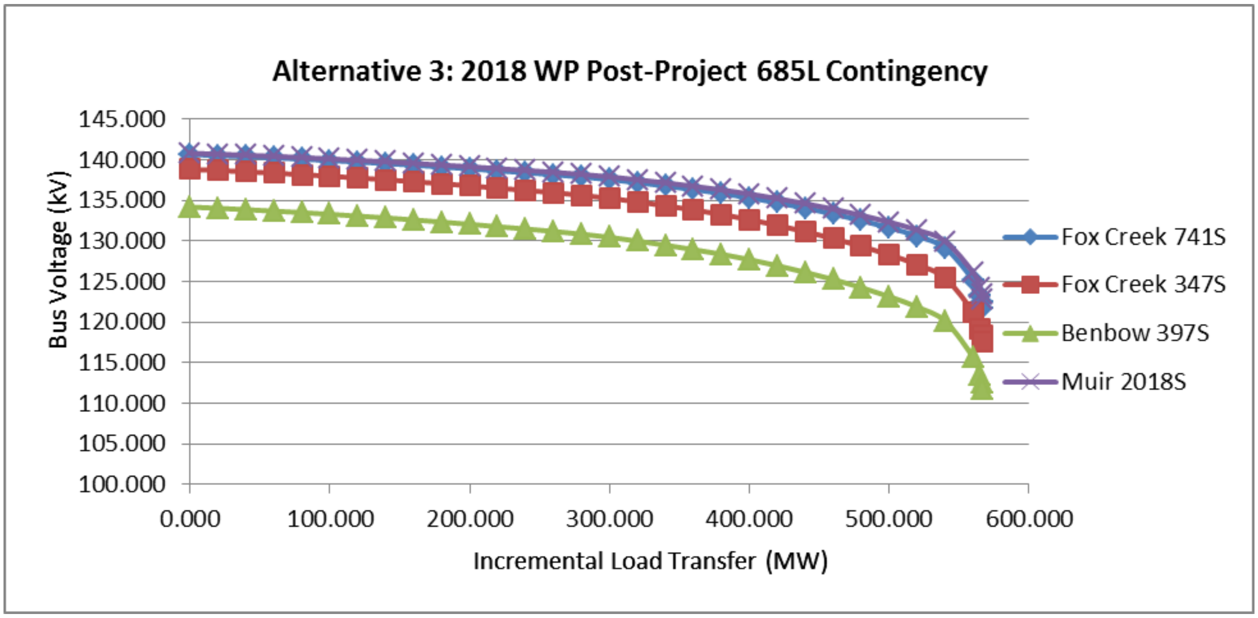
Figure E-1: P-V Curves for Scenario 4 – 2018WP Post-Project Alternative 3



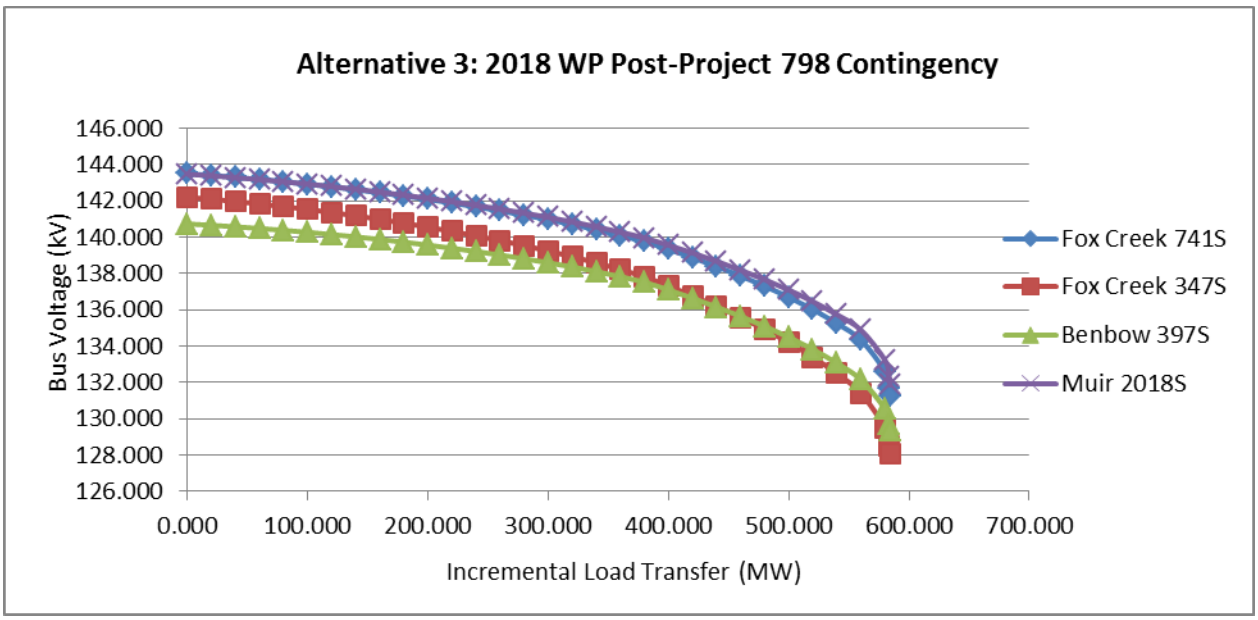
(a) Category A



(b) 854L Contingency



(c) 685L Contingency



(d) 798L Contingency