APPENDIX A CONNECTION ASSESSMENT

ATCO Spirit River New POD
Project Number: 1618

The attached engineering study report has been prepared by a third party as part of the AESO Connection Process. The AESO has reviewed the report and the conclusions that it contains, and finds it acceptable for the purpose of assessing potential impacts of the Project on the transmission system.

After completing the studies for the Project, the ISD of the Project shifted from January 2017 to June 2017; in addition, the AESO corporate forecast has been updated from the 2014 Long-term Outlook to the 2016 Long-term Outlook. The shift in the ISD and the updated forecast do not materially impact the results of this connection assessment, and do not change the conclusions and recommendations contained in this report.

Information regarding the AESO Connection Process can be found at: http://www.aeso.ca/8602.html

Date: June 21, 2016

Function	Name	Company	Signature	Date
Senior Engineer	Liuzhong Shi, P.Eng.	Alberta Electric System Operator	[illegible]	June 21. 2016
Manager, Projects & System Access Studies	Mohamed Kamh, PhD, P.Eng.	Alberta Electric System Operator	[illegible]	June 21, 2016

While the DFO's plans are considered during the transmission planning process, the AESO, in exercising its duties to plan the transmission system, does not oversee distribution planning or the development of specific DFO planning criteria.

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Connection Engineering Study Report for AUC Application

ATCO Spirit River new POD

File No. 1618

Revision: 1

Revision Date: 2016-06-20

	Name	Date	Signature
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APEGA Permit to # Practice P0850

Executive Summary

Project Overview

ATCO Electric Ltd. (ATCO), in its capacity as the legal owner of distribution facilities (DFO), submitted a System Access Service Request (SASR) on November 6, 2014 to the Alberta Electric System Operator (AESO) and has requested a Rate DTS, *Demand Transmission Service* of 21 MW to support the load from industrial and oil field customers in the Spirit River district. In addition, the DFO has indicated that they are currently unable to restore the critical loads in the Rycroft area in accordance with the DFO's distribution planning guidelines (the Project).

The requested in-service date (ISD) for the Project is June 1, 2017.

This report presents the results of the study that assessed the impact of the Project on the Alberta interconnected electric system (AIES).

Existing System

Geographically, the Project is located in the AESO planning area of Grande Prairie (Area 20), which is part of the Northwest Planning Region (NW Region). The Grande Prairie area is bounded by the AESO planning areas of Peace River (Area 19), Valleyview (Area 23), and Grande Cache (Area 22).

From a transmission perspective, the Grande Prairie (Area 20) is served by a 144 kV transmission system and local generation. The area is mainly supplied from the 240/144 kV Little Smoky 813S substation via three 144 kV transmission lines (7L32, 7L45 and 7L46). Also, the 144 kV transmission line 7L20 connects the Grande Prairie (Area 20) to the Grande Cache area (Area 22) and the 144 kV transmission line 7L73 connects the Grande Prairie (Area 20) to the Peace River area (Area 19).

There are existing constraints in the NW Region, which are managed in accordance with 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 the Grande Prairie area (Area 20). All transmission facilities within the Grande Prairie area and the tie lines connecting the Grande Prairie area to the rest of the AIES were studied and monitored for violations of the Reliability Criteria (described in Section 2.1).

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

Power flow analysis was performed for the 2016 winter peak (WP) and 2017 summer peak (SP) pre- and post-Project scenarios.

Voltage stability analysis was performed for the 2016 WP pre- and post-Project scenarios. Transient stability analysis was performed to further investigate the voltage recovery response following connection of the Project.

Results of the pre-Project studies

2016 WP

No Reliability Criteria violations (thermal, voltage range and voltage stability) were observed during Category A and B system conditions.

2017 SP

There were no Reliability Criteria violations (thermal or voltage range) under Category A system condition.

There were no voltage range criteria violations under Category B system conditions. Some thermal overloads – below the short-term ratings of the transmission lines – were observed under some Category B contingencies; namely:

- Subsequent to the loss of 7L197 (Clairmont Lake 811S to Hughes 2030S), line flow above the seasonal rating on 7L03 (Flyingshot Lake 749S to Wapiti 823S tap) was observed.
- Subsequent to the loss of either 7L75 or 7L46 (Little Smoky 813S to Big Mountain 845S), line flow above the seasonal rating on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) was observed.

These thermal overloads will be managed by real time operational practices.

Connection alternatives examined for the Project

This engineering study report examined the following transmission alternatives to serve the Project.

Alternative 1 – Capacity upgrades at Rycroft 730S, Ksituan River 754S, and Saddle Hills 865S substations: This alternative includes relocating Rycroft 730S substation, adding a second 144/25 kV LTC transformer at Ksituan River 754S substation and replacing the existing 144/25 kV transformer-regulator pair at Saddle Hills 865S with a new 144/25 kV LTC transformer.

Alternative 2 – Construction of a new point of delivery (POD): This alternative includes building a new POD designated Mowat 2033S substation, and connecting it to the existing transmission line 7L10 (Rycroft 730S to Ksituan River 754S) via a T-tap connection configuration. Mowat 2033S substation would include one 144/25 kV LTC transformer with a minimum transformation capacity of 23.3 MVA, and associated equipment. Alternative 2 also includes adding one 144 kV breaker at Rycroft 730S on the line 7L68 (Rycroft 730S to Clairmont Lake 811S).

Alternative 3 – Capacity upgrades at Ksituan River 754S and Saddle Hills 865S: Similar to Alternative 1, this alternative includes adding a second 144/25 kV LTC transformer at Ksituan River 754S substation and replacing the existing 144/25 kV transformer-regulator pair at Saddle Hills 865S with a new 144/25 kV LTC transformer.

Connection alternatives selected for further examination

Alternative 2 was selected for further studies. The proposed Mowat 2033S substation would also be used to pick up critical loads from Rycroft 730S substation during transformer outages at Rycroft 730S.

Neither Alternative 1 nor Alternative 3 were selected for further studies because (1) they require greater transmission development, hence higher costs, and (2) they do not meet the DFO's distribution planning guidelines for critical load restoration.

Results of post-Project Studies

The following is a summary of the results of the post-Project studies.

2016 WP

No Reliability Criteria violations (thermal, voltage range and voltage stability) were observed during Category A system condition.

Category B (N-G-1) conditions

- Following the loss of either 7L68, 7L73 or 7L75, thermal flow violations on 7L10 (Rycroft 730S to Mowat 2033S tap) were noted. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Following the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations occur at several substations including the new Mowat 2033S substation.
- Following the loss of 7L73, voltage range criteria violations and POD bus voltage deviations were observed at the Ksituan River 754S 25 kV.
- The PV stability criteria were met for the post-Project scenario, except for the Category B contingency of 7L68. As part of Alternative 2, a 144 kV breaker is added at Rycroft 730S substation on 7L68. Unlike the pre-Project scenarios, the 7L68 contingency in the post-Project scenarios does not lead to tripping the substations along 7L10 line, hence more load remains online subsequent to this contingency.

2017 SP

No Reliability Criteria violations (thermal, voltage range and voltage stability) were observed during Category A system condition.

Category B (N-G-1) conditions

- Similar to the 2016 WP post-Project scenario, following the loss of 7L68, thermal flow violations on 7L10 (Rycroft 730S to Mowat 2033S tap) were noted. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Similar to the 2017 SP pre-Project scenario, subsequent to the loss of either 7L75 or 7L46 (Little Smoky 813S to Big Mountain 845S), line flow above the seasonal rating on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) was identified. This thermal overload will be managed by real time operational practices.
- Similar to the 2016 WP post-Project scenario, following the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations occur at Rycroft 730S, Ksituan River 754S and the new Mowat 2033S substation.

Sensitivity Studies

The sensitivity studies were conducted for 2016 WP and 2017 SP post-Project scenarios with two P1321 Shell Carmon Creek generators in-service. The results indicated that there is only one additional Category B criteria thermal violation attributable to the Shell Carmon Creek generation, a thermal flow violation on 7L75 (Friedenstal 800S to West Peace River 793S) following the loss of 7L32.

No Reliability Criteria violations (thermal and voltage range) were observed during Category A system condition for both scenarios.

Category B (N-G-1) conditions for 2016 WP

- A thermal flow violation on 7L75 (Friedenstal 800S to West Peace River 793S) following the loss of 7L32 was identified. The line rating of 7L75 is limited to 99 MVA by CT ratio and clearance issues. ATCO TFO is undertaking a capital maintenance project (ISD of December 2016) that will restore 7L75 rating to its full thermal capacity (146/187 MVA for summer/winter respectively on a 144 kV base) and mitigate the identified 7L75 thermal violation.
- A thermal flow violation on 7L10 (Rycroft 730S to the proposed Mowat 2033S tap) was identified following the loss of 7L68, 7L75 or 7L73. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Following the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations occur at several substations including the new Mowat 2033S substation.

Category B (N-G-1) conditions for 2017 SP

- Line flow above the normal seasonal ratings on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) following the loss of 7L75 was identified. The flow is below the short-term rating of 7L32, and will be managed by real time operational practices.
- A thermal flow violation on 7L10 (Rycroft 730S to the proposed Mowat 2033S tap) was identified following the loss of 7L68. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Following the loss of 7L68, POD voltage deviations and transmission voltage violations at Rycroft 730S, Ksituan River 754S and Mowat 2033S substations were noted.

Mitigation Measures

From the power flow and voltage stability analyses, Mowat 2033S and Ksituan River 754S have post-contingency transmission voltage violations and thermal overloads on 7L10 under certain Category B conditions. From VQ analysis and switching studies, the optimal 144 kV capacitor bank sizing of 10 MVAr and 15 MVAr were needed at Mowat 2033S. These alleviated both the voltage and thermal violations.

However, with the two proposed 144 kV capacitor banks at Mowat 2033S in-service, a potential marginal thermal violation under Category A conditions was observed on the section of 7L10 between Rycroft 730S and the Mowat 2033S tap in the 2016 WP post-Project scenario. The line rating of 7L10 is currently limited by CT ratio and clearance issues.

ATCO TFO has advised the AESO of plans to increase the rating of this section of 7L10 and to remove the CT limits by April 2017, prior to connection of the Project. This line clearance mitigation will eliminate the potential for the identified 7L10 thermal constraints under Category

A conditions. The Project can be energized to the full 21 MW DTS following completion of the 7L10 clearance mitigation capital maintenance project.

From transient voltage recovery analysis, the following was observed under Category B conditions:

- For 7L68 outage: Voltage recovery problems were identified using the existing far-end fault clearing time of 42 cycles at Rycroft 730S end for faults near Clairmont Lake 811S. The critical fault clearing time for voltage recovery on 7L68 was identified to be 9 cycles. The TFO has confirmed that to achieve this critical fault clearing time, will require establishing a teleprotection-grade telecommunication channel between Rycroft 730S and Clairmont Lake 811S. The TFO has advised that in order to establish this channel, a telecommunications tower and upgrades at Rycroft 730S are required.
- For 7L75 outage: Voltage recovery problems were identified using the existing far-end fault clearing time of 24 cycles at Friedenstal 800S end for faults near West Peace River 793S. The critical fault far-end clearing time for successful voltage recovery on 7L75 was identified to be 18 cycles at Friedenstal 800S for faults near West Peace River 793S.
- For 7L73 outage: Voltage recovery problems were identified using the existing far-end fault clearing time of 24 cycles at Rycroft 730S end for faults near Friedenstal 800S. The critical far-end fault clearing time for successful voltage recovery on 7L73 was identified to be 18 cycles at Rycroft 730S for faults near Friedenstal 800S.

Table E-1 provides analysis of, and conclusions about, the impact of the Project, including mitigations for observed Reliability Criteria violations.

Table E – 1 Project Impact and Mitigation Measures

Identified Reliability Violation		Occur in Pre- or Post-Project	Level of Impact	System Condition	Mitigation Measures/Comments
Contingencies	**Violations**				
Studies (not including Shell Carmon Creek P1321)					
7L197 (Clairmont Lake 811S to Hughes 2030S)	Thermal violation on 7L03 (Flyingshot Lake 749S to Wapiti 823S tap)	Pre-Project Only	Marginal	2017 SP	Real time operational practices.
7L75 (Friedenstal 800S to West Peace River 793S)	Thermal violation on 7L32 (Little Smoky 813S to South Bezanson 862S tap)	Both	Marginal	2017 SP	
7L46 (Little Smoky 813S to Big Mountain 845S)					
7L68 (Clairmont Lake 811S to Rycroft 730S)	Thermal violation on 7L10 (Rycroft 730S to Mowat 2033S tap)	Post-Project Only	Significant	2016 WP, 2017 SP	25 MVAr (10+15 MVAr) capacitor banks at Mowat 2033S was proposed.
7L75 (Friedenstal 800S to West Peace River 793S)				2016 WP	
7L73 (Friedenstal 800S to Rycroft 730S					

Identified Reliability Violation		Occur in Pre- or Post-Project	Level of Impact	System Condition	Mitigation Measures/Comments
Contingencies	Violations				
7L68 (Clairmont Lake 811S to Rycroft 730S	Transmission voltage range criteria violations at Rycroft 730S 144 kV bus, Ksituan River 754S 144 kV bus, Mowat 2033S 144 kV bus; severe POD bus voltage deviations occur at several substations including the new Mowat 2033S substation.			2016 WP, 2017 SP	
7L73 (Friedenstal 800S to Rycroft 730S	Transmission voltage range criteria violations at Ksituan River 754S 144 kV bus; Marginal POD bus voltage deviations occur at Ksituan River 754S.			2016 WP	
7L68 (Clairmont Lake 811S to Rycroft 730S)	Failed in voltage stability analysis			2016 WP	
Sensitivity studies (including two Shell Carmon Creek P1321 units)					
7L32 (South Bezanson 862S to Little Smoky 813S)	Thermal violation on 7L75 (Friedenstal 800S to West Peace River 793S)	Only post-Project scenarios were studied	Significant*	2016 WP	The violation is attributable to the Shell Carmon Creek generation, and will be mitigated by the ATCO TFO's capital maintenance project to restore 7L75 rating.
7L75 (Friedenstal 800S to West Peace River 793S)	Thermal violation on 7L32 (South Bezanson 862S to Little Smoky 813S)		Marginal*	2017 SP	Real time operational practices.
7L68 (Clairmont Lake 811S to Rycroft 730S	Thermal violation on 7L10 (Rycroft 730S to Mowat 2033S tap)			2016 WP, 2017 SP	25 MVAr (10+15 MVAr) capacitor banks at Mowat 2033S was proposed.
7L75 (Friedenstal 800S to West Peace River 793S)				2016 WP	
7L73 (Friedenstal 800S to Rycroft 730S					
7L68 (Clairmont Lake 811S to Rycroft 730S	Transmission voltage range criteria violations at Rycroft 730S 144 kV bus, Ksituan River 754S 144 kV bus, Mowat 2033S 144 kV bus; severe POD bus voltage deviations occur at several substations including the new Mowat 2033S substation.		Significant	2016 WP, 2017 SP	

Identified Reliability Violation		Occur in Pre- or Post-Project	Level of Impact	System Condition	Mitigation Measures/Comments
Contingencies	**Violations**				
7L73 (Friedenstal 800S to Rycroft 730S	Marginal POD bus voltage deviations occur at Ksituan River 754S		Marginal	2016 WP	
Post-Project scenarios with the proposed 25 MVAr capacitor banks at 2033S Mowat					
Category A	Thermal violation on 7L10 of 102.1% (Rycroft 730S to Mowat 2033S tap)	Only post-Project scenarios were studied	Significant	2016 WP	The line rating of 7L10 is currently limited by CT ratio and clearance issues to 49 MVA on a 144 kV base. ATCO TFO plans to increase the rating of this section of 7L10 to 75 MVA on a 144 kV base under an existing TFO capital maintenance project by April 2017, prior to connection of the Project.
Voltage transient recovery analysis (7L68 contingency)	Voltage recovery problems were identified for the existing far-end clearing time of 42 cycles at Rycroft 730S end for faults near Clairmont Lake 811S. The critical fault clearing time for voltage recovery on 7L68 was identified to be 9 cycles.				Upgrade of 7L68 line protection for tele-protection grade communications to achieve the critical clearing time of 9 cycles.
Voltage transient recovery analysis (7L75 contingency)	Voltage recovery problems were identified for the existing far end clearing time of 24 cycles at Friedenstal 800S end for faults near West Peace River 793S.				Reduction of far-end fault clearing speed at Rycroft 730S for faults on 7L73 near Friedenstal 800S from 24 cycles to 18 cycles.
Voltage transient recovery analysis (7L73 contingency)	Voltage recovery problems were identified for the existing far-end clearing time of 24 cycles at Rycroft 730S end for faults near Friedenstal 800S.				Reduction of far-end fault clearing speed at Friedenstal 800S for faults on 7L75 near West Peace River 793S from 24 cycles to 18 cycles.

* The thermal flows violations in the sensitivity studies were compared to thermal flow violations encountered in the post-Project scenarios.

Recommendations

Based on the study results, it is recommended that the Project be connected using Alternative 2 subject to the following:

- The addition of one 10 MVAr capacitor and one 15 MVAr capacitor at Mowat 2033S substation to mitigate potential voltage criteria violations. This will be part of the Project's scope, and
- The completion of the following protection settings changes and upgrades to ensure voltage recovery for the motor loads in the Rycroft area:
    - Accelerate far-end fault clearing speed at Rycroft 730S end for faults near Clairmont Lake 811S to achieve the critical clearing time of 9 cycles, by modifying the protection on 7L68 and adding a telecommunications tower and upgrades at Rycroft 730S. This will be part of the Project's scope.
    - Accelerate far-end fault clearing speed at Friedenstal 800S for faults on 7L75 near West Peace River 793S by reducing the far-end fault clearing time from 24 cycles to 18 cycles. This will be part of the Project's scope.
    - Accelerate far-end fault clearing speed at Rycroft 730S for faults on 7L73 near Friedenstal 800S by reducing the far-end fault clearing time from 24 cycles to 18 cycles. This will be part of the Project's scope.
- The completion of the line clearance mitigation for 7L10, which will be addressed as a Capital Maintenance project.

Contents

Attachments

Figures

Tables

1. Introduction

This Engineering Study Report presents the results of the study that assesses the impact of the Project on the Alberta interconnected electric system (AIES).

1.1. Project

1.1.1. Project Overview

ATCO, in its capacity as the legal owner of distribution facilities (DFO), submitted a System Access Service Request (SASR) on November 6, 2014 to the Alberta Electric System Operator (AESO) and has requested a Rate DTS, *Demand Transmission Service* of 21 MW to support the load from industrial and oil field customers in the Spirit River district.

The requested in-service date (ISD) for the Project is June 1, 2017.

1.1.2. Load Component

The Project includes the requested 21 MW Rate DTS. The requested load will be studied using an expected power factor of 0.90 lagging.

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 study were the following:

1. Assess the impact of the Project connection on the performance of the AIES.
2. Evaluate the Project connection alternatives.
3. Assess any violations of the relevant criteria, standards or requirements of the AESO, both pre- and post-Project.
4. Recommend the Project connection alternative and any mitigation measures to address system performance concerns, if any, to enable the reliable integration of the Project into the AIES.

1.2.2. Study Area

Geographically, the Project is located in the AESO planning area of Grande Prairie (Area 20), which is part of the Northwest Planning Region (NW Region). The Grande Prairie area is bounded by the AESO planning areas of Peace River (Area 19), Valleyview (Area 23), and Grande Cache (Area 22).

From a transmission perspective, the Grande Prairie (Area 20) is served by a 144 kV transmission system and local generation. The area is mainly supplied from the 240/144 kV Little Smoky 813S substation via three 144 kV transmission lines (7L32, 7L45 and 7L46). Also, the 144 kV transmission line 7L20 connects the Grande Prairie (Area 20) to the Grande Cache area (Area 22) and the 144 kV transmission line 7L73 connects the Grande Prairie (Area 20) to the Peace River area (Area 19).

1.2.2.1. Study Area Description

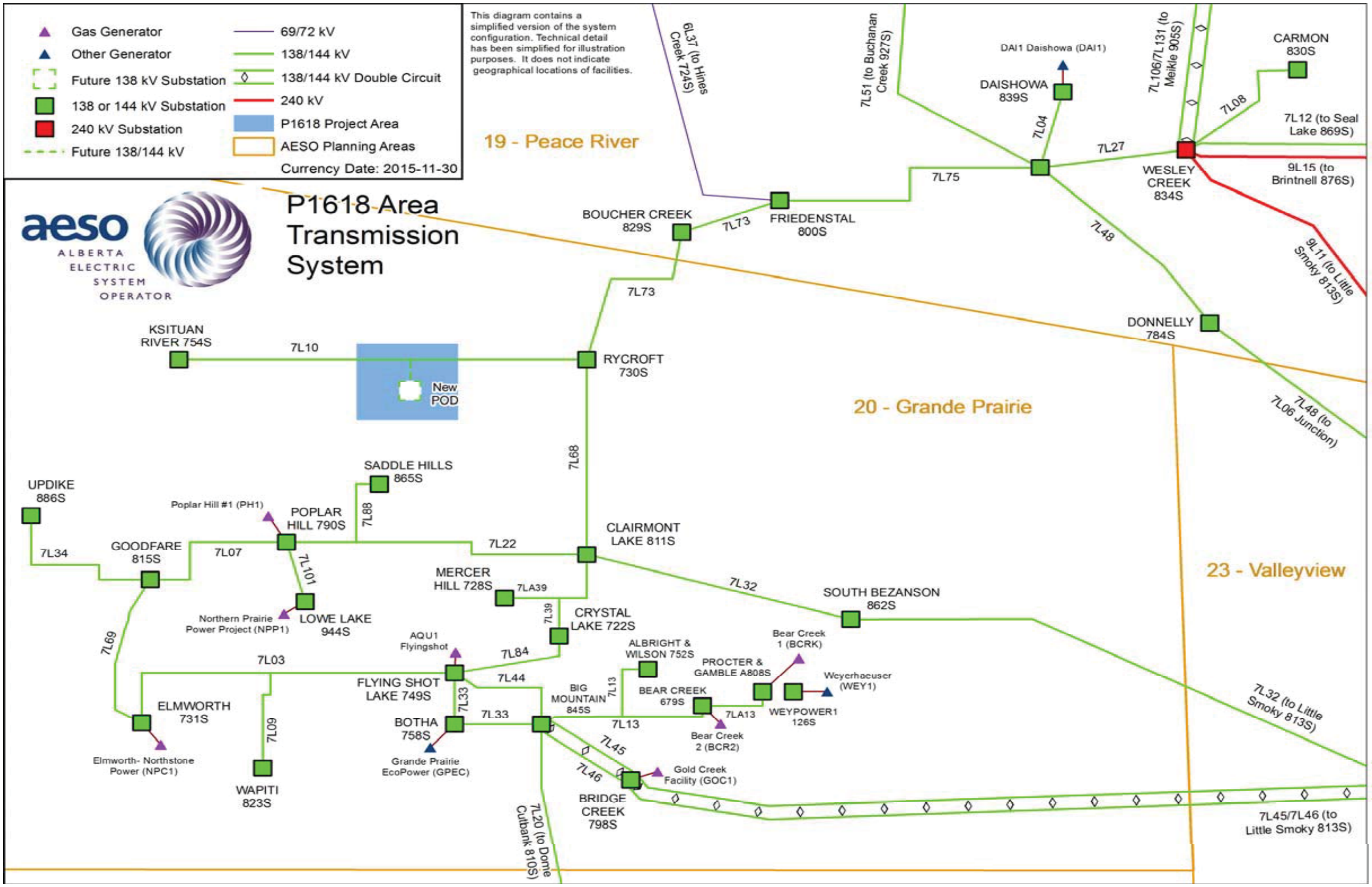
The study area for the Project consists of the Grande Prairie area (Area 20). All transmission facilities within the Grande Prairie area and the tie lines connecting the Grande Prairie area to the rest of the AIES were studied and monitored for violations of the Reliability Criteria (described in Section 2.1)

Figure 1-1 shows the existing transmission system configuration of the study area.

1.2.2.2. Existing Constraints

The existing constraints in the NW Region are managed in accordance with Section 302.1 of the ISO rules, *Real Time Transmission Constraint Management* (TCM Rule Rule).

Figure 1-1: The Transmission System of the Study Area



1.2.2.3. AESO Long-Term Plan

The *AESO 2015 Long-term Transmission Plan* (2015 LTP) includes system reinforcements in the NW Region in the near-term, medium-term and long-term, none of which will be in service prior to the Project ISD. Consequently the Project studies did not include any LTP components.

1.2.3. Studies Performed

The following studies were performed in the connection study:

- Power flow analysis (Category A condition and Category B contingencies);
- Voltage stability analysis (Category A condition and Category B contingencies); and
- Short-Circuit analysis (Category A condition).

1.3. Report Overview

The Executive Summary provides a high-level summary of the report and its conclusions. Section 1 provides an introduction of the Project and describes the scope of the study. Section 2 describes the criteria, system data, and other study assumptions used in this study. Section 3 presents the study methodology used for this study. Section 4 discusses the pre-Project assessment of the system. Section 5 presents the connection alternatives examined. Section 6 provides a technical analysis of the post-Project system assessment for the alternatives selected for further study. Section 7 discusses the project interdependencies. Section 8 presents the conclusions and recommendations of this study.

2. Criteria, System Data, and Study Assumptions

2.1. Criteria, Standards, and Requirements

2.1.1. AESO Transmission 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* [1] (collectively, 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 as well as a summary of Category C5 system conditions.

[1] Filed under separate cover

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-AB-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:

- Seasonal continuous thermal rating of the line’s loading limits.
- Highest specified loading limits for transformers.
- For Category A condition: Voltage range under normal operating condition per AESO Information Document 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*.
- Desired post-contingency voltage change limits for three defined post event timeframes as provided in Table 2-1, below.

Table 2-1: Desired Post-Contingency Voltage Deviations for Low Voltage Busses

Parameter	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 Low Voltage Bus	±10%	±7%	±5%

2.1.2. AESO Information Documents (IDs), Operating Policies and Procedures (OPPs) and Authoritative Documents (ADs)

The AESO Voltage Control Practice ID #2010-007RS will be applied to establish pre-contingency voltage profiles in the study region. The TCM Rule will be followed in setting up the study scenarios and assessment of the impact of the Project connection. In addition, due regard will be given to the AESO Customer Connection Study Requirements Document and the Generation and Load Interconnection Standard.

The Reliability Criteria is the basis for planning the AIES. The transmission system will normally be designed to meet or exceed the Reliability Criteria under credible worst-case loading and generation conditions.

2.2. Load and Generation Assumptions

2.2.1. Load Assumptions

The load forecast used for this connection study is reflected in Table 2-2. The forecast is based on the AESO's 2014 Long-term Outlook (2014 LTO). The active to reactive power ratio in the study scenarios was maintained when scaling loads.

Table 2-2: Load Forecast (2014 LTO at AIL Peak)

2014 LTO at AIL Peak				**Forecast Peak Load (MW)**	
Planning Area	**Description**			**2016**	**2017**
20	**Grande Prairie**	Summer	Max		373.8
		Winter	Max	404.0	
19	**Peace River**	Summer	Max		202.1
		Winter	Max	224.9	
NW Region	**Northwest**	Summer	Max		1271.2
		Winter	Max	1368.6	
AIL	**AIL w/o Losses**	Summer	Max		11440.3
		Winter	Max	12154.2	

2.2.2. Generation Assumptions

Table 2-3 provides the generation dispatch used for the connection study. Lowe Lake generator (NPP1) is considered as the N-G generator for all power flow and voltage stability analyses.

Table 2-3: Summary of Local Non-Wind Generator Dispatch in the Study Scenarios

Existing/Future	Plant Name	Bus Number	Area	Capacity (MW)	2016 WP	2017 SP
Existing	BCR2	19142_2	20	15	12	12
Existing	BCRK	18142_1	20	79	OFF	OFF
Existing	DAI1	1087_1, 1087_1a	19	52	36	36
Existing	GOC1	19145_1	20	5	OFF	OFF
Existing	GPEC	17101_2	20	27	18	11
Existing	HRM	1148_1	22	144	80	60
Existing	NPC1	17134_5, 17134_6, 18134_7, 18134_8, 21134_10	20	12	OFF	OFF
Existing	NPP1	17120_1	20	93	OFF	OFF
Existing	PH1	16118_1	20	48	0 (sync-condenser)*	0 (sync-condenser)*
Existing	WEY1	1146_1A	20	48	41	34
Future	Whitetail Peaking (P1290)	1747_G1, 3747_G2, 5747_G4 4747_G3	19	200	OFF	OFF
Future	Carmon Creek (P1321)	14074_G1, 15074_G2, 16074_G3	19	600	428**	377**
Existing	Genalta Cadotte (P1523)	19083	19	28	26	24

Note:

*The Poplar Hill (bus 16118) generation dispatch was originally set at zero (off line). Further pre-Project studies identified voltage collapse or low voltage under Category B contingency of 7L197 for 2016 WP and 2017 SP. Poplar Hill was therefore switched on-line as TMR in synch-condenser mode in order to provide voltage support and meet voltage stability criteria.

**Sensitivity studies were completed for the post-Project 2016 WP and 2017 SP with two Carmon Creek generators.

2.2.3. Intertie Flow and HVDC Power Orders

The intertie points are deemed to be too far away to have an effect on the assessment of the proposed connection. The flows in the study area are not influenced by the AIES HVDC facilities. As a result, the intertie and HVDC assumptions are kept consistent with that in the AESO planning base cases and not adjusted for this study.

2.3. System Projects

No system projects were included in the study.

2.4. Customer Connection Projects

Table 2-4 lists the customer projects included in the study scenarios that have earlier positions in the AESO Connection Queue. Project ISDs are subject to change.

Table 2-4: List of projects included in the system models

Project Number	Project Description	Projected ISD
P1290	Whitetail Peaking Station	01-Jan-17
P1321*	Shell Carmon Creek Cogen	2 phases: Sept-17 (units 1 & 2) 01-Mar-18 (unit 3)
P1505**	ATCO City of Grande Prairie New POD	Dec.1, 2018

* P1321 with two units in service is included in the sensitivity studies.

** P1505 is included in all of the study scenarios for this Project as they are ahead in the AESO connection queue. As there are no additional transmission system developments planned in Area 20 or Area 22 during the time period from the ISD of the Project to the ISD of P1505, the 2016 WP and 2017 WP study scenarios used in this report which include P1505 provide a valid assessment of the impact of the Project on the AIES.

2.5. Facility Ratings and Shunt Elements

The ratings for the existing transmission lines in the study area are shown in Table 2-5.

Table 2-6 lists the shunt elements (capacitors, reactors and SVCs) in the study area.

Table 2-5: Summary of line ratings in the study Area (MVA on a 138 kV base)

Transmission Line	Summer (MVA)	Winter (MVA)
7L84 Flyingshot 749S – Crystal 722S	142.8	142.8
7L03 Flyingshot 749S – Elmworth 731S	109.3	139.0
7L33 Flyingshot 749S – Big Mountain 845S	140.9	142.8
7L20 Big Mountain 845S – Dome Cutbank 810S	143.8	143.8
7L45 Big Mountain 845S – Little Smoky 813S	140.9	179.2
7L68 Clairmont Lake 811S – Rycroft 730S	94.9	94.9
7L32 Clairmont Lake 811S – Little Smoky 813S	109.3	139.9
7L22 Clairmont Lake 811S – Poplar Hill 790S	109.3	139.9

Transmission Line	Summer (MVA)	Winter (MVA)
7L07 Goodfare 815S – Poplar Hill 790S	109.3	139.9
7L69 Elmworth 731S – Goodfare 815S	109.3	139.9
7L39 Clairmont Lake 730S – Crystal Lake 722S	109.3	139.9
7L44 Flyingshot 749S – Big Mountain 845S	139.9	142.8
7L13 Big Mountain 845S – Procter & Gamble 808S	140.9	179.2
7L46 Big Mountain 845S – Little Smoky 813S	140.9	179.2
7L73 Rycroft 730S – Boucher Creek 829S Tap	94.9	94.9
7L73 Boucher Creek 829S Tap – Friedenstal 800S	94.9	94.9
7L75 Friedenstal 800S – West Peace A793S	94.9	94.9
7L27 Wesley Creek 834S – West Peace A793S	109.3	139.9
7L10 Rycroft 730S – Ksituan River 754S	47.0	47.0
7L101 Poplar Hill 790S – Lowe Lake 944S	109.3	139.9

Table 2-6: Summary of shunt elements in the study area

Station Name and Number	Voltage (kV)	Capacitor (MVAr)	Reactor (MVAr)	SVC (MVAr)
Big Mountain 845S	144	1 x 30	-	-
Clairmont Lake 811S	144	1 x 25	-	-
Crystal Lake 722S	144	1 x 29.6	-	-
Goodfare 815S	144	2 x 15	-	-
HR Milner 740S	25	1 x 5.4	-	-
Ksituan River 754S	144	1 x 15	-	-
P&G	13.8	1 x 6 1 x 11		
Little Smoky 813S	144	3 x 30	-	-
	34.5	-	-	+/- 100
	25	-	2x 20	
Poplar Hill 790S	144	1 x 24.7	-	-
	25	2 x 1.2	-	-
		2 x 2.4		
		1 x 5.4		
West Peace A793S	144	2 x 15	-	-
Friedenstal 800S	144	1 x 15	-	-
	25	1 x 4.8	-	-

2.6. Voltage Profile Assumptions

Study area bus voltages in the base cases were set according to the desired ranges in the AESO Voltage Control Practice ID #2010-007RS prior to power flow analysis. Table 2-7 provides the voltages at the key buses for the study area and vicinity.

Table 2-7: Summary of voltage at key buses in the study region

Substation	Nominal Voltage (kV)	ID# 2010-007RS			Voltage in the Study Scenarios (kV) N-G-0			
					Pre-Project		Post-Project Alternative 2	
		Minimum Operating Limit (kV)	Desire Range (kV)	Maximum Operating Limit (kV)	2016 WP	2017 SP	2016 WP	2017 SP
Rycroft 730S	144	136.8	142.6-154.1	155	147.7	147.5	144.9	146.5
H.R. Milner 740S	144	144	146-150	151	147.8	148.7	147.9	149.0
Crystal Lake 722S	144	144	147-151	155	147.7	148.4	147.9	149.1
Flyingshot Lake 749S	144	144	147-151	155	147.1	147.9	147.5	148.7
Poplar Hill 790S	144	142	144-151	155	146.7	148.5	147.8	149.5
Clairmont Lake 811S	144	144	147-151	155	147.8	148.5	147.6	149.0
Little Smoky 813S	240	255	257-268	275	259.5	259.3	259.2	259.3
	144	146	148-152	155	151.0	151.0	151.0	151.0
Goodfare 815S	144	142	144-151	155	146.8	148.5	148.0	149.8
Big Mountain 845S	144	145	147-151	155	147.2	147.9	147.6	148.7
West Peace River 793S	144	148	148-151	155	149.1	149.4	149.8	150.1
Friedenstal 800S	144	142	145-149	155	150.8	149.0	149.6	150.7
Wesley Creek 834S	240	257	257-268	275	262.9	262.6	261.3	262.4
	144	148	148-151	155	150.1	149.4	150.4	149.9

3. Study Methodology

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

3.1. Study Objectives

The objectives of the study discussed in this report were the following:

- Assess the impact of the Project connection on the AIES.
- Evaluate the Project connection alternatives.
- Recommend the Project connection alternative and any mitigation measures to address system performance concerns, if any, to enable the reliable integration of the Project into the AIES.

3.2. Study Scenarios

The requested Project ISD is June 1, 2017. Hence, the study was conducted using the 2016-2017WP and 2017SP scenarios. The 2025WP scenario is only considered to determine the short-circuit levels for the future system. Please note that in the study scenarios, the Lowe Lake Generator (NPP1) is considered as the N-G generator for all power flow and voltage stability analysis. Table 3-1 lists the scenarios considered for the Project study. A power factor of 0.9 lagging was used for the new Project load.

Table 3-1: Study Scenarios

Scenario	Year / Season Load	Condition	Project Load (MW)	System Generation Dispatch Conditions
1	2016 WP	Pre-Project	0	Economic
2	2017 SP		0	Economic
3	2016 WP	Post-Project	21	Economic
4	2017 SP		21	Economic

3.3. Connection Studies Carried Out

The studies completed for this connection project are shown in Table 3-2.

Table 3-2: Summary of Studies Performed

Study Scenarios	Studies Performed	Contingencies Included
1, 2, 3, 4	Power flow	Category A and B
1, 3	Voltage stability	Category A and B
1, 3 and 2025WP	Short-circuit	Category A

3.4. Power flow Analysis

Power flow analysis was completed on all study scenarios to identify any thermal rating or transmission voltage violations as per the Reliability Criteria.

POD low voltage bus deviations were also assessed by first locking all tap changers and area capacitors to identify any post transient voltage deviations above 10%. Tap changers were then allowed to move while capacitors remained locked to determine if any voltage deviations above 7% were found in the area. Once all taps and capacitor controls were allowed to adjust, POD bus voltage deviations above 5% were reported for both the pre-Project and post-Project networks.

3.4.1. Contingencies Studied

Power flow analysis was performed for the Category A and all Category B contingencies in the Grande Prairie area, the tie lines connecting the Grande Prairie area to the Grande Cache area and the Valleyview area, and the tie lines connecting the Grande Prairie area to the Peace River area up to Wesley Creek 834S 240kV substation for all pre- and post-Project scenarios.

3.5. Voltage Stability Analysis

Voltage stability analysis was performed as described in the Reliability Criteria. Both PV (Power Voltage) and VQ (Voltage Reactive Power) curves were performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology. The voltage stability criteria states that for load areas, post-transient voltage stability is required for the area modeled at a minimum of 105% of the reference load level for system normal conditions (Category A) and for single contingencies (Category B). For this standard, the reference load level is the maximum established planned load.

The PV analysis was performed by increasing load in the Grande Prairie Area (Area 20) and increasing the generation in the following AESO planning areas:

- Calgary (Area 6);
- Northeast Region Generators (Area 33);
- Central and Edmonton Region Generators (Areas 30, 35, 40, and 60);
- South Region Generation (Areas 43, 53, 54, 55, and 57).

The objective of the PV curve is to determine the ability of the network to maintain voltage stability at all the busses in the system under normal and abnormal system conditions. The PV curve is a representation of voltage change as a result of increased power transfer between the Grande Prairie area and the rest of the AIES. The reported incremental transfers will be to the collapse point. As per the AESO requirements, no assessment based upon other criteria such as minimum voltage will be made at the PV minimum transfer.

As per the voltage stability criteria, post transient techniques (all tap changers, all discrete capacitors locked, but SVCs will be allowed to adjust) will used in applying the criteria and this information is reflected in all tables and graphs. Also for this analysis, no limits will be selected for the generation sources, non-negative active power constant MVA loads will be enforced and the existing power factor for the reference will be maintained.

VQ curves with the criteria minimum 5% load increase for the critical Category B contingencies in the study area are provided to confirm the results of the PV analysis and to ensure there is sufficient reactive power margin at the weakest bus identified in the power flow. VQ curves were used in this assessment to help determine the reactive power injection required at a specific bus to increase the bus voltage to the extreme minimum criteria limit accounting for a future 5% load growth as per criteria. It should be noted that when new VAr support facilities are required and the voltage deviation at the bus can support the size, engineering judgment will be used to recommend capacitor sizes to establish bus voltages above the extreme minimum voltage at the most reactive deficient bus for the worst Category B contingency with the 5% forecast load increase to better account for the typical 30-50 year life cycle of a substation.

3.5.1. Contingencies Studied

Voltage stability analysis was performed for the Category A and all Category B contingencies in the Grande Prairie area, the tie lines connecting the Grande Prairie area to the Grande Cache area and the Valleyview area, and the tie lines connecting the Grande Prairie area to the Peace River area up to Wesley Creek 834S 240kV substation for the 2016 WP post-Project scenario to determine the system voltage stability margin in this winter peaking area.

3.6. Sensitivity Analysis

Sensitivity studies were conducted using the 2016 WP and 2017 SP post-Project (Scenarios 3 and 4) assuming the P1321 Shell Carmon Creek two generation units are in-service.

3.7. Transient Stability Analysis for Voltage Recovery

Transient stability analysis was performed to further investigate the voltage recovery response for 2016 WP scenario using the worst three contingencies identified during voltage stability analysis to ensure the effectiveness of proposed mitigation measures. The focus of this voltage recovery response analysis will be to ensure that the area voltages recover to prevent cascading load loss when the mitigation measures proposed from the load flow analysis is included.

The transient stability analysis was performed based on the following:

- Use the scenario(s) which identified voltage collapse or area voltage problems;
- Include proposed mitigation;
- Model the study area motor load using the CLOD model;
- Apply a three phase to ground fault using the worst three contingencies identified during voltage stability analysis, these contingencies indicated area voltage criteria violations in the load flow analysis.

The actual fault clearing times from the area Transmission Facility Owner (TFO) were used in these studies. For north regions of the AIES, including Northwest and Northeast, typically 70% of the load is assumed to be motors of which 40% are large motors and 30% are small motors except for the substations where detailed load information was available. For these substations, the motor composition applied was based upon information from the DFO to more accurately reflect the load. Refer to Attachment F for the motor composition used in this study.

4. Pre-Project System Assessment

Currently there is no breaker at Rycroft 730S on 7L68, and therefore a fault on 7L68 would be cleared by the 144 kV line breaker at Rycroft 730S on 7L73, resulting in loss of Ksituan River 754S and Rycroft 730S substations. For the pre-Project analysis, this existing protection scheme for Category B contingency of 7L68 was implemented.

4.1. Pre-Project Power flow Analysis

Power flow diagrams for the Category A condition and selected Category B contingencies are included in Attachment A.

4.1.1. Scenario 1: 2016 WP Pre-Project

No Reliability Criteria violations (thermal, voltage range and voltage stability) were observed during Category A and B system conditions.

4.1.2. Scenario 2: 2017 SP Pre-Project

There were no Reliability Criteria Violations (thermal and voltage range) under Category A system condition. Moreover, there were no voltage range criteria violations during Category B system conditions. Some thermal overloads – below the short-term ratings of the transmission lines – were noticed subsequent to some Category B contingencies; namely:

- Subsequent to the loss of 7L197 (Clairmont Lake 811S to Hughes 2030S), line flow above the seasonal rating on 7L03 (Flyingshot Lake 749S to Wapiti 823S tap) was noted.
- Subsequent to the loss of either 7L75 or 7L46 (Little Smoky 813S to Big Mountain 845S), line flow above the seasonal rating on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) was identified. Please refer to Table 4-1.

Table 4-1: Scenario 2: 2017 SP N-G-1 Thermal Flows Above the Seasonal Rating

Contingency	Branch	Line Rating Normal/ Short-term (MVA)*	Pre-Contingency		Post- Contingency		% Loading Differ-ence
			Power Flow (MVA)*	% Loading	Power Flow (MVA)*	% Loading	
7L197 (Clairmont Lake 811S to Hughes 2030S)	7L03 (Flyingshot Lake 749S to Wapiti 823S tap)	109.3/ 124.6	51.2	46.8	114.0	104.3	57.5
7L75 (Friedenstal 800S to West Peace River 793S)	7L32 (Little Smoky 813S to South Bezanson 862S tap)	109.3/ 124.6	86.6	79.2	110.2	100.8	21.6
7L46 (Little Smoky 813S to Big Mountain 845S)		109.3/ 124.6	86.6	79.2	111.9	102.4	23.2

*MVA on a 138 kV base

4.2. Voltage Stability Analysis

The PV margin criterion was met for the pre-Project 2016 WP scenario.

4.2.1. Scenario 1: 2016 WP Pre-Project

For this pre-Project scenario, the reference load level for the study area (Area 20) is 404.0 MW. The minimum incremental load transfer for the Category B contingencies is 5% or 20.2 MW (0.05 x 404.0 MW = 20.2 MW) to meet the voltage stability criteria. Table 4-2 summarizes the five worst Category B contingencies PV margin in the Project study area.

Table 4-2: Scenario 1: 2016 WP – PV Analysis Results

Contingency	From	To	Maximum incremental transfer (MW)	Meets 105% PV margin?
Category A	System Normal		72.5	Yes
7L197	Clairmont Lake 811S	Hughes 2030S	25.0	Yes
7L75	West Peace River 793S	Friedenstal 800S	35.6	Yes
7L46	Big Mountain 845S	Little Smoky 813S	39.4	Yes
7L73	Friedenstal 800S	Rycroft 730S	41.9	Yes
7L20	Big Mountain 845S	H.R. Milner 740S	42.5	Yes

5. Connection Alternatives

5.1. Overview

This engineering study report will examine the following transmission alternatives to serve the Project.

5.2. Connection Alternatives Identified

Alternative 1:

Capacity upgrades at Rycroft 730S, Ksituan River 754S, and Saddle Hills 865S. The TFO has confirmed that this alternative would require to relocate Rycroft 730S as the existing substation cannot be expanded at the current location. In addition, this alternative would require (a) site expansion to Ksituan River 754S substation to accommodate a second 144/25 kV LTC transformer and (b) salvage of the existing 144/25 kV transformer-regulator pair at Saddle Hills 865S substation and replacing it with a new 144/25 kV LTC transformer.

Alternative 2:

This alternative involves the construction of a new point of delivery (POD) substation in the vicinity of NW10-78-7-W6M and connect the new POD to the existing transmission line 7L10 (Rycroft substation 730S to Ksituan River 754S) via a T-tap connection configuration. The new POD will be designated Mowat 2033S and would include one 144/25 kV LTC transformer with a minimum transformation capacity of 23.3 MVA. For this alternative, a transformer size of 30/40/50 MVA would be recommended based on good electric industry practice and under advisement from the legal owner of transmission facilities (TFO) regarding their asset management and inventory practices.

With this Alternative 2, it is proposed to add one (1) 144 kV breaker at Rycroft 730S on the line 7L68 (Rycroft 730S to Clairmont Lake 811S substation. This would eliminate having to drop three substations (Ksituan River 754S, the new POD) subsequent to a fault on the line 7L68.

Alternative 3:

Capacity upgrades at Ksituan River 754S and Saddle Hills 865S. Similar to Alternative 1, this alternative would require (a) site expansion to Ksituan River 754S substation to accommodate a second 144/25 kV LTC transformer and (b) salvage of the existing 144/25 kV transformer-regulator pair at Saddle Hills 865S substation and replacing it with a new 144/25 kV LTC transformer.

5.2.1. Connection Alternatives Selected for Further Studies

Alternative 2 was selected for further studies. The new Mowat 2033S substation proposed by Alternative 2 would also be used to pick up critical loads from Rycroft 730S substation during transformer outages.

5.2.2. Connection Alternatives Not Selected for Further Studies

Alternative 1 and Alternative 3 were not selected for further studies because they:

- require greater transmission development for no incremental benefit,
- as per ATCO DFO's DDR, of the PODs in this area, Rycroft 730S has the highest component of critical loads. Currently during an extended POD transformer outage at Rycroft 730S, the DFO is unable to restore these critical loads in the four hour window as recommended in DFO's distribution planning guideline. These two alternatives do not address the four hour restoration window.

6. Technical Analysis of the Connection Alternatives

6.1. Alternative 2

6.1.1. Power flow Analysis

6.1.1.1. Scenario 3: 2016 WP Post-Project

No Reliability Criteria violations (thermal, voltage range and voltage stability) were observed during Category A system condition.

<u>Category B (N-G-1) conditions</u>

- Following the loss of either 7L68, 7L73 or 7L75, thermal flow violations on 7L10 (Rycroft 730S to Mowat 2033S tap) were noted. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Following the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations occur at several substations including the new Mowat 2033S substation.
- Following the loss of 7L73, voltage range criteria violations and marginal POD bus voltage deviations were observed at the Ksituan River 754S 25 kV.

Please refer to Table 6-1 and Table 6-2.

Table 6-1: Scenario 3 Alternative 2: 2016 WP N-G-1 Thermal Flows Above the Seasonal Rating

Contingency	Branch	Line Rating	Pre-Project		Post-Project		% Loading Differ-ence
		Normal/ Short-term (MVA)*	Power Flow (MVA)*	% Loading	Power Flow (MVA)*	% Loading	
7L68 (Clairmont Lake 811S to Rycroft 730S	7L10 (Rycroft 730S to Mowat 2033S tap)	47 / 47	26.3	55.9	56.5	120.2	63.3
7L75 (Friedenstal 800S to West Peace River 793S)			26.4	56.2	48.2	102.6	46.4

Contingency	Branch	Line Rating Normal/ Short-term (MVA)*	Pre-Project		Post-Project		% Loading Differ-ence
			Power Flow (MVA)*	% Loading	Power Flow (MVA)*	% Loading	
7L73 (Friedenstal 800S to Rycroft 730S			26.9	57.3	49.6	105.6	48.3

*MVA on a 138 kV base

Table 6-2: Scenario 3 Alternative 2: 2016 WP N-G-1 Voltage Violations and POD Bus Deviations

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for Non-Transmission Busses Only				Post Manual (kV)	% Change for POD buses only
					Post Tran-sient (kV)	% Change	Post Auto (kV)	% Change		
7L68 (Clairmont Lake 811S to Rycroft 730S)	Rycroft 730S	1100	138	144.9	N/A				120.7	—
		19100	25	25.9	20.9	20.0	22.7	25.9	20.9	20.0
	Ksituan River 754S	1104	138	142.2	N/A				115.9	—
		19104	25	25.9	20.1	23.1	21.5	25.9	20.1	23.1
	Mowat 2033S	1116	138	142.6	N/A				117.2	—
		19116	25	25.9	20.5	21.9	22.3	25.9	20.5	21.9
	Friedenstal 800S	19105	25	25.9	22.8	12.6	—	25.9	22.8	12.6
	Hines Creek 724S	19107	25	25.9	22.6	13.0	—	25.9	22.6	13.0
	Boucher Creek 829S	19102	13.8	14.0	12.0	13.9	—	14.0	12.0	13.9
	Eureka River 861S	19108	25	25.9	22.5	13.6	—	25.9	22.5	13.6
7L73 (Friedenstal 800S to Rycroft 730S	Ksituan River 754S	1104	138	142.2	N/A				129.7	—
		19104	25	25.9	23.4	10.2	—	—	24.4	6.3

6.1.1.2. Scenario 4: 2017 SP Post-Project

No Reliability Criteria violations (thermal, voltage range and voltage stability) were observed during Category A system condition.

<u>Category B (N-G-1) conditions</u>

- Similar to the 2016 WP post-Project scenario, following the loss of 7L68, thermal flow violations on 7L10 (Rycroft 730S to Mowat 2033S tap) were noted. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.

- Similar to the 2017 SP pre-Project scenario, subsequent to the loss of either 7L75 or 7L46 (Little Smoky 813S to Big Mountain 845S), line flow above the seasonal rating on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) was identified. This thermal overload will be managed by real time operational practices.
- Similar to the 2016 WP post-Project scenario, following the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations occur at Rycroft 730S, Ksituan River 754S and the new Mowat 2033S substation.

Please refer to Table 6-3 and Table 6-4.

Table 6-3: Scenario 4 Alternative 2: 2017 SP N-G-1 Thermal Flows Above the Seasonal Rating

Contingency	Branch	Line Rating	Pre-Project		Post-Project		% Loading Difference
		Normal/ Short-term (MVA)*	Power Flow (MVA)*	% Loading	Power Flow (MVA)*	% Loading	
7L75 (Friedenstal 800S to West Peace River 793S)	7L32 (Little Smoky 813S to South Bezanson 862S tap)	109.3/ 124.6	110.2	100.8	111.0	101.6	0.8
7L46 (Little Smoky 813S to Big Mountain 845S)		109.3/ 124.6	111.9	102.4	110.9	101.5	–0.9
7L68 (Clairmont Lake 811S to Rycroft 730S	7L10 (Rycroft 730S to Mowat 2033S tap)	47 / 47	25.1	53.4	50.4	107.2	53.8

*MVA on a 138 kV base

Table 6-4: Scenario 4 Alternative 2: 2017 SP N-G-1 Voltage Violations and POD Bus Deviations

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for Non-Transmission Busses Only				Post Manual (kV)	% Change for POD buses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
7L68 (Clairmont Lake 811S to Rycroft 730S)	Rycroft 730S	1100	138	146.5	N/A				128.0	—
		19100	25	25.9	22.3	14.4	—	25.9	22.3	14.4
	Ksituan River 754S	1104	138	143.9	N/A				124.0	—
		19104	25	25.9	21.8	16.5	23.2	25.9	21.8	16.5
	Mowat 2033S	1116	138	144.3	N/A				124.9	—
		19116	25	25.9	22.0	15.6	23.9	25.9	22.0	15.6

6.1.2. Voltage Stability Analysis

The PV margin criterion was met for the post-Project 2016 WP scenario, expect for the Category B contingency of 7L68.

6.1.2.1. Scenario 3: 2016 WP Post-Project

For this post-Project scenario, the reference load level for the study area (Area 20) is 404.0 MW. The minimum incremental load transfer for the Category B contingencies is 5% or 20.2 MW (0.05 x 404.0 MW = 20.2 MW) to meet the voltage stability criteria. Table 6-5 summarizes the five worst Category B contingencies PV margin in the Project study area.

Figure 6-1 and Figure 6-2 depict the PV curves for those worst contingencies at Mowat 2033S and Ksituan River. It should be noted that Ksituan River 754S presented the lowest post-contingency voltage from the power flow and voltage stability analyses.

PV margin criterion was met for this scenario, expect for the Category B contingency of 7L68.

Table 6-5: Scenario 3: 2016 WP – PV Analysis Results

Contingency	From	To	Maximum incremental transfer (MW)	Meets 105% PV margin?
Category A	System Normal		75.0	Yes
7L68	Clairmont Lake	Rycroft 730S	11.0	No
7L75	West Peace River 793S	Friedenstal 800S	28.0	Yes
7L73	Friedenstal 800S	Rycroft 730S	34.0	Yes
7L197	Clairmont Lake 811S	Hughes 2030S	38.0	Yes
7L46	Big Mountain 845S	Little Smoky 813S	43.0	Yes

Figure 6-1: PV Curves at Mowat 2033S substation for the five worst Category B contingencies.

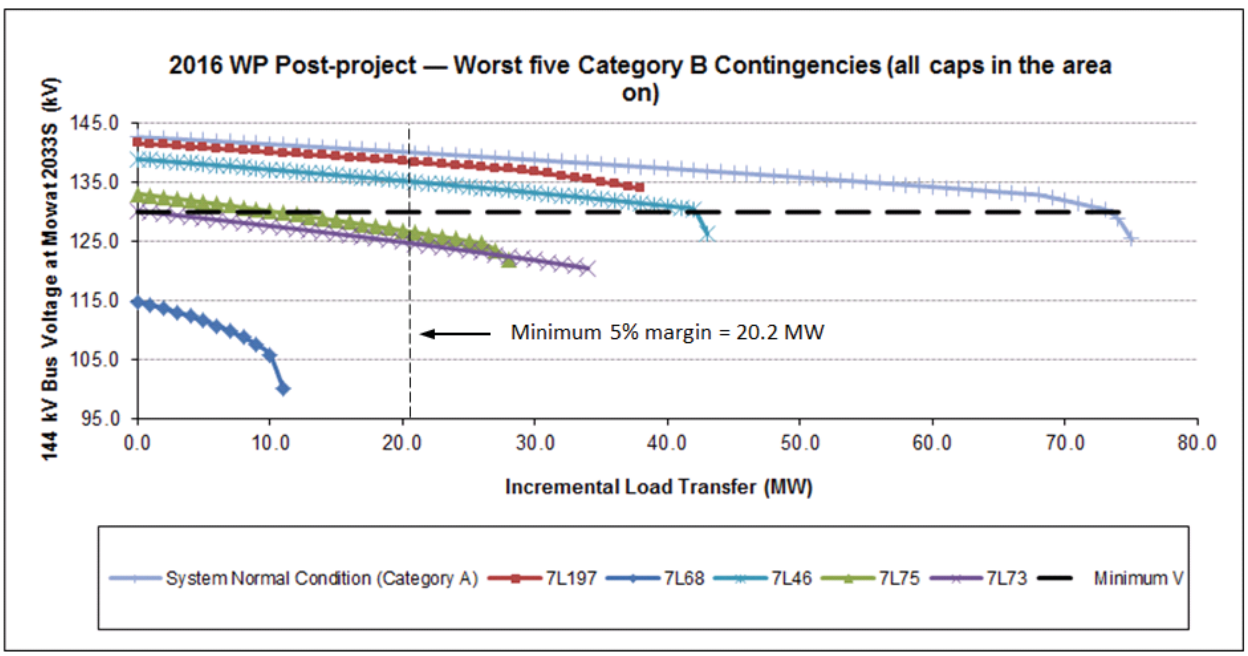
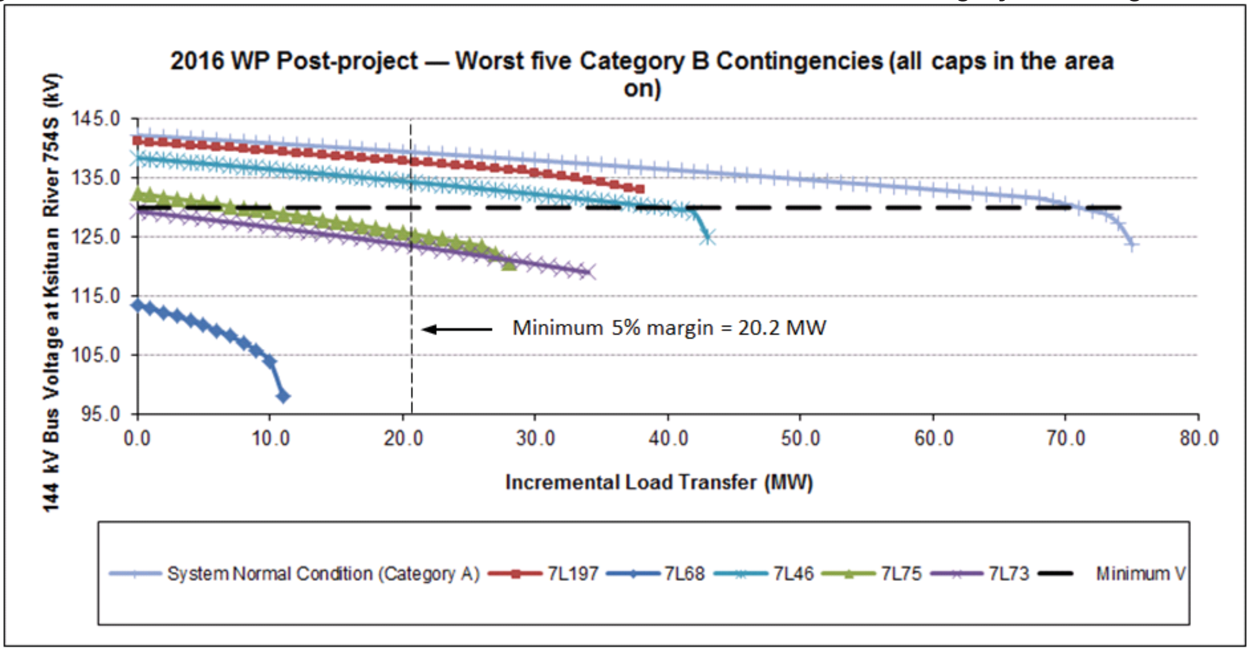


Figure 6-2: PV Curves at Ksituan River 754S substation for the five worst Category B contingencies.



6.1.3. Sensitivity Studies (Alternative 2 with Carmon Creek Generators)

The sensitivity studies were conducted in the post-Project 2016 WP and 2017 SP scenarios with two Carmon Creek generators.

The results were compared to the Scenario 3 and 4 and showed that there were no additional Category B criteria voltage violations different from those previously identified except for the thermal flow violation on 7L75 (Friedenstal 800S to West Peace River 793S) following the loss of 7L32, which is attributable to the Shell Carom Creek generation.

The following is a summary of the power flow analysis:

No Reliability Criteria violations (thermal and voltage range) were observed during Category A system condition for both scenarios.

<u>Category B (N-G-1) conditions for 2016 WP</u>

- A thermal flow violation on 7L75 (Friedenstal 800S to West Peace River 793S) following the loss of 7L32 was identified. The line rating of 7L75 is limited to 99 MVA by CT ratio and clearance issues. ATCO TFO has a capital maintenance project in progress with an ISD of December 2016. This project will restore 7L75 rating to its full thermal capacity (146/187 MVA for summer/winter respectively on a 144 kV base) which upon completion will mitigate the thermal violations noted.
- A thermal flow violation on 7L10 (Rycroft 730S to the proposed Mowat 2033S tap) was identified following the loss of 7L68, 7L75 or 7L73. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Following the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations occur at several substations including the new Mowat 2033S substation.

<u>Category B (N-G-1) conditions for 2017 SP</u>

- Line flow above the normal seasonal ratings on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) following the loss of 7L75 was identified. The flow is below the short-term rating of 7L32, and will be managed by real time operational practices.
- A thermal flow violation on 7L10 (Rycroft 730S to the proposed Mowat 2033S tap) was identified following the loss of 7L68. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues.
- Following the loss of 7L68, POD voltage deviations and transmission voltage violations at Rycroft 730S, Ksituan River 754S and the new Mowat 2033S substation were noted.

Please refer to Table 6-6 through Table 6-9. Power flow diagrams for the Category A condition and selected Category B contingencies are included in Attachment D.

Table 6-6: 2016 WP Alternative 2 – Sensitivity Studies: N-G-1 Thermal Flows Above the Seasonal Rating

Contingency	Branch	Line Rating Normal/ Short-term (MVA)*	Post-Project Scenario 3		Post-Project – Sensitivity Studies		% Loading Difference
			Power Flow (MVA)*	% Loading	Power Flow (MVA)*	% Loading	
7L68 (Clairmont Lake 811S to Rycroft 730S	7L10 (Rycroft 730S to Mowat 2033S tap)	47 / 47	56.5	120.2	54.5	116.0	–4.2
7L75 (Friedenstal 800S to West Peace River 793S)			48.2	102.6	47.7	101.4	–1.2
7L73 (Friedenstal 800S to Rycroft 730S			49.6	105.6	49.1	104.5	–1.1
7L32 (South Bezanson 862S to Little Smoky 813S)	7L75 (Friedenstal 800S to West Peace River 793S)	94.9 / 94.9	78.8	83.0	99.7	105.1	22.1

*MVA on a 138 kV base

Table 6-7: 2016 WP Alternative 2 – Sensitivity Studies: 2016 WP N-G-1 Voltage Violations and POD Bus Deviations

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for Non-Transmission Busses Only				Post Manual (kV)	% Change for POD buses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
7L68 (Clairmont Lake 811S to Rycroft 730S)	Rycroft 730S	1100	138		N/A				124.0	—
		19100	25	25.9	21.7	16.6	23.4	9.9	23.4	9.9
	Ksituan River 754S	1104	138		N/A				119.5	—
		19104	25	25.9	21.1	19.1	22.2	14.5	22.2	14.5
	Mowat 2033S	1116	138		N/A				120.6	—

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for Non-Transmission Busses Only				Post Manual (kV)	% Change for POD buses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
		19116	25	25.9	21.4	18.1	23.0	11.7	23.0	11.7
	Hines Creek 724S	19107	25		23.5	10.2	—	—	—	—
	Boucher Creek 829S	19102	13.8		12.5	11.0	—	—	—	—
	Eureka River 861S	19108	25		23.4	10.7	—	—	—	—
7L73 (Friedenstal 800S to Rycroft 730S	Ksituan River 754S	19104	25		—	—	—	—	24.6	5.2

Table 6-8: 2017 SP Alternative 2 – Sensitivity Studies: N-G-1 Thermal Flows Above the Seasonal Rating

Contingency	Branch	Line Rating Normal/ Short-term (MVA)*	Post-Project Scenario 4		Post-Project – Sensitivity Studies		% Loading Difference
			Power Flow (MVA)*	% Loading	Power Flow (MVA)*	% Loading	
7L75 (Friedenstal 800S to West Peace River 793S)	7L32 (South Bezanson 862S to Little Smoky 813S)	109.3 / 124.6	111.0	101.6	111.0	101.6	0.0
7L68 (Clairmont Lake 811S to Rycroft 730S)	7L10 (Rycroft 730S to 7LA10 tap)	47 / 47	50.4	107.2	48.8	103.9	–3.3

*MVA using 138 kV base

Table 6-9: 2017 SP Alternative 2 – Sensitivity Studies: N-G-1 Voltage Violations and POD Bus Deviations

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for Non-Transmission Busses Only				Post Manual (kV)	% Change for POD buses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
7L68 (Clairmont Lake 811S to Rycroft 730S)	Rycroft 730S	19100	25	25.9	23.0	11.8	—	—	—	—
	Ksituan River 754S	1104	138	143.6	N/A				127.4	—
		19104	25	25.9	22.6	13.4	23.9	8.1	23.9	8.1
	Mowat 2033S	1116	138	144.0	N/A				128.2	—
		19116	25	25.9	22.7	12.8	—	—	24.6	5.5

6.1.4. Mitigation Measures for Identified Issues

Post-Project power flow analysis has shown that subsequent to the loss of 7L68, voltage range criteria violations and severe POD bus voltage deviations were noted at several substations including the new Mowat 2033S substation. In addition, subsequent to the loss of 7L68, voltage stability margin violation was observed. In addition in the 2016 WP, subsequent to the loss of 7L73 a transmission voltage criteria violation and POD bus deviations were noted at Ksituan River 754S. Additional VAr support is necessary in order to mitigate the identified transmission voltage criteria violations, POD voltage deviations, as well as voltage stability issues with the Category B contingencies.

6.1.4.1. Capacitor Bank Location Selection

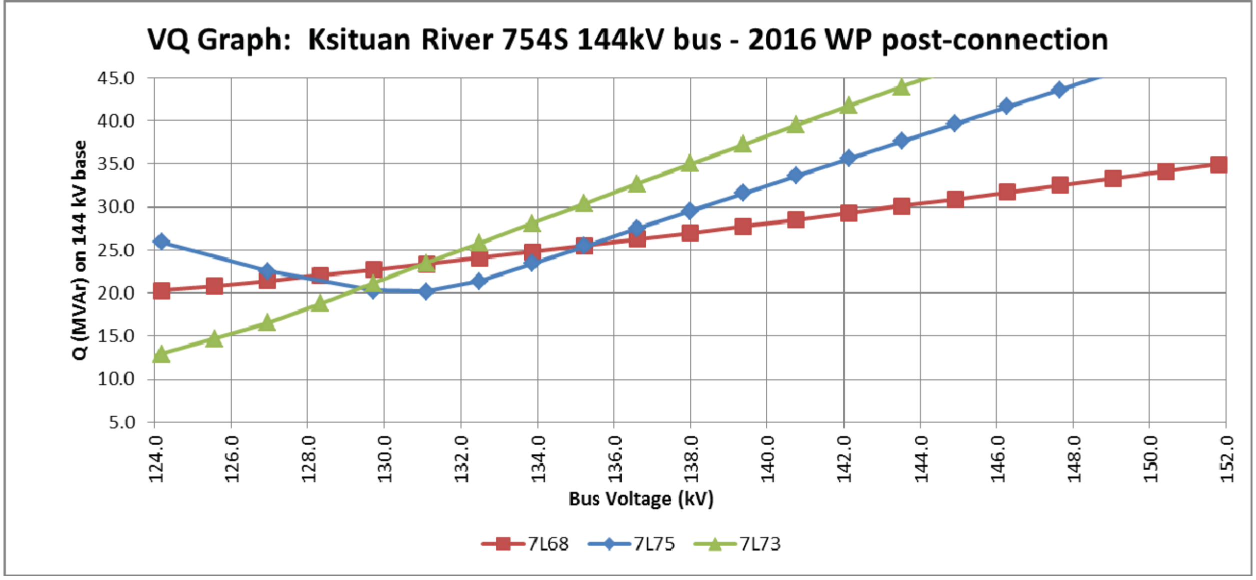
From the power flow and voltage stability analyses, Mowat 2033S and Ksituan River 754S have presented post-contingency transmission voltage violations. The TFO has confirmed that Ksituan River 754S substation has no physical room for such capacitor bank addition without major fence expansion. Moreover, the transmission voltage profiles at Mowat 2033S and Ksituan River 754S decay at very similar rate as the load transfer increases. Hence, the new Mowat 2033S POD can be readily designed to include the new capacitor bank without space limitation.

6.1.4.2. Capacitor Bank Sizing using VQ Analysis

The V-Q analysis was performed to determine the amount of reactive power required at Mowat 2033S to maintain the transmission voltage above the minimum voltage range criteria (130 kV) at Ksituan River 754S and Mowat 2033S substations under any Category B contingency. The Western Electricity Coordinating Council (WECC) recommends that the minimum amount of reactive power resources be based on increasing the base load by a minimum of 5% of the reference load level for system normal conditions (Category A) and for single contingencies (Category B). The rate of load increase in this area is expected to be higher than 5%, so 10% above the reference load level was used for the V-Q analysis.

Figure 6-3 shows the VQ graph for the three worst Category B contingencies (7L68, 7L75, and 7L73) identified during power flow and voltage stability analyses. To meet the minimum transmission voltage with the 110% load level increase in the study area, the VQ analysis performed at the Ksituan River 754S 144 kV bus indicates the need for an additional 23 MVAr of reactive support (on a 144 kV base) at Ksituan River 754S. Based on ATCO TFO's sparing policy, a capacitor bank rated at 25 MVAr on a 144 kV base is recommended.

Figure 6-3: VQ Curves for the three worst Category B contingencies (determining VAr support at Mowat 2033S to maintain the acceptable transmission voltage at Ksituan River 754S)



6.1.4.3. Capacitor Switching Step Testing

Steady-state capacitor bank switching study was conducted to identify the magnitude of the voltage step change using both the 2016 WP and 2017 SP post-Project scenarios.

The voltage step changes at the 144 kV and 25 kV buses with a single 25 MVAr capacitor bank installed at Mowat 2033S are shown in Table 6-10. The switching steps are not within the ATCO DFO criteria. It is recommended to split the 25 MVAr in two capacitor banks (10 and 15 MVAr) at Mowat 2033S.

Table 6-10: 144 kV 25 MVAr Capacitor Bank at Mowat 2033S Switching Step Change for N-G-0

Scenario	Substation Name and Number	Bus No.	kV Base	Pre-Cap Switching p.u.	Post-Cap Switching p.u.	Step Change (%)
Scenario 3: 2016 WP	Mowat 2033S	1116	138	1.03066	1.08874	5.81
		19116	25	1.03753	1.09625	5.87
	Ksituan River 754S	1104	138	1.02729	1.08443	5.71
		19104	25	1.03128	1.08915	5.79
	Rycroft 730S	1100	138	1.04742	1.08943	4.20
		19100	25	1.03124	1.07294	4.17
	Clairmont Lake 811S	1117	144	1.07158	1.09112	1.95
	Boucher Creek 829S	1102	144	1.06800	1.09913	3.11
		19102	13.8	1.01112	1.04061	2.95
Scenario 4: 2017 SP	Mowat 2033S	1116	138	1.03959	1.09836	5.88
		19116	25	1.02909	1.08752	5.84

Scenario	Substation Name and Number	Bus No.	kV Base	Pre-Cap Switching p.u.	Post-Cap Switching p.u.	Step Change (%)
	Ksituan River 754S	1104	138	1.03681	1.09461	5.78
		19104	25	1.03622	1.09446	5.82
	Rycroft 730S	1100	138	1.05565	1.09820	4.26
		19100	25	1.02937	1.07112	4.18
	Clairmont Lake 811S	1117	144	1.07653	1.09649	2.00
	Boucher Creek 829S	1102	144	1.07569	1.10714	3.15
		19102	13.8	1.00613	1.03556	2.94

The steady-state switching studies are repeated first with a 15 MVAr capacitor bank and second with additional 10 MVAr capacitor bank assuming the first capacitor bank in-service. The voltage step change at the 144 kV and 25 kV buses with the 15 MVAr and 10 MVAr capacitor banks at Mowat 2033S are shown in Table 6-11 and Table 6-12, respectively.

Table 6-11: 1st proposed 144 kV 15 MVAr Capacitor Bank at Mowat 2033S Switching Step Change for N-G-0

Scenario	Substation Name and Number	Bus No.	kV Base	Pre-Cap Switching p.u.	Post-Cap Switching p.u.	Step Change (%)
Scenario 3: 2016 WP	Mowat 2033S	1116	138	1.03066	1.06483	3.42
		19116	25	1.03753	1.07208	3.45
	Ksituan River 754S	1104	138	1.02729	1.06091	3.36
		19104	25	1.03128	1.06531	3.40
	Rycroft 730S	1100	138	1.04742	1.07216	2.47
		19100	25	1.03124	1.05580	2.46
	Clairmont Lake 811S	1117	144	1.07158	1.08310	1.15
	Boucher Creek 829S	1102	144	1.06800	1.08634	1.83
		19102	13.8	1.01112	1.02850	1.74
Scenario 4: 2017 SP	Mowat 2033S	1116	138	1.03959	1.07418	3.46
		19116	25	1.02909	1.06348	3.44
	Ksituan River 754S	1104	138	1.03681	1.07083	3.40
		19104	25	1.03622	1.07049	3.43
	Rycroft 730S	1100	138	1.05565	1.08071	2.51
		19100	25	1.02937	1.05396	2.46
	Clairmont Lake 811S	1117	144	1.07653	1.08830	1.18
	Boucher Creek 829S	1102	144	1.07569	1.09422	1.85
		19102	13.8	1.00613	1.02348	1.74

Table 6-12: 2nd proposed 144 kV 10 MVAr Capacitor Bank at Mowat 2033S* Switching Step Change for N-G-0

Scenario	Substation Name and Number	Bus No.	kV Base	Pre-Cap Switching p.u.	Post-Cap Switching p.u.	Step Change (%)
Scenario 3: 2016 WP	Mowat 2033S	1116	138	1.06728	1.09133	2.40
		19116	25	1.03009	1.05340	2.33
	Ksituan River 754S	1104	138	1.06407	1.08774	2.37
		19104	25	1.03247	1.05563	2.32
	Rycroft 730S	1100	138	1.07320	1.09058	1.74
		19100	25	1.03375	1.05063	1.69
	Clairmont Lake 811S	1117	144	1.08132	1.08939	0.81
	Boucher Creek 829S	1102	144	1.08659	1.09946	1.29
		19102	13.8	1.01568	1.02772	1.20
Scenario 4: 2017 SP	Mowat 2033S	1116	138	1.06429	1.08822	2.39
		19116	25	1.03602	1.05941	2.34
	Ksituan River 754S	1104	138	1.06135	1.08489	2.35
		19104	25	1.03636	1.05952	2.32
	Rycroft 730S	1100	138	1.06998	1.08727	1.73
		19100	25	1.03114	1.04790	1.68
	Clairmont Lake 811S	1117	144	1.08063	1.08872	0.81
	Boucher Creek 829S	1102	144	1.07901	1.09172	1.27
		19102	13.8	1.00927	1.02117	1.19

* It is assumed the first proposed 15 MVAr capacitor bank installed at Mowat 2033S substation.

The switching step changes for the 10 and 15 MVAr capacitor banks at Mowat 2033S, Ksituan River 754S and Rycroft 730S are within ATCO DFO criteria. It is noted that the switching step change at adjacent substations upstream of Rycroft 730S is less than 2%.

6.1.4.4. System Performance with the Proposed Mitigation Measure

Power flow and voltage stability analyses was repeated for 2016 WP and 2017 SP scenarios including the two proposed capacitor banks at Mowat 2033S (10 and 15 MVAr). There were no transmission voltage violations, POD bus voltage deviations or voltage stability concerns identified. The power flow plots for the Category A condition and selected Category B contingencies with the two capacitor banks are provided in Attachment C. Voltage stability results (MW margin for the five worst contingencies and PV curves) for the post-Project 2016 WP with the two capacitor banks at Mowat 2033S are provided in Attachment E.

It should be noted that in the post-Project scenarios, subsequent to the loss of 7L68, 7L73 or 7L75, thermal flow violations on 7L10 (Rycroft 730S to Mowat 2033S tap) were noted. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues. This thermal flow violation on 7L10 is due to low voltage during Category B contingencies and will no longer exist with the voltage support required to mitigate the voltage criteria violations identified.

With the two proposed 144 kV capacitor banks at Mowat 2033S in-service, a potential thermal violation of 102.1% under Category A conditions was observed on the section of 7L10 between Rycroft 730S and the Mowat 2033S tap in the 2016 WP post-Project scenario. The line rating of 7L10 is currently limited by CT ratio and clearance issues to 49 MVA on a 144 kV base. ATCO TFO plans to increase the rating of this section of 7L10 to 75 MVA on a 144 kV base under an existing TFO capital maintenance project by April 2017, prior to connection of the Project. This TFO line clearance mitigation will eliminate the potential for the identified 7L10 thermal constraints under Category A conditions. The Project can be energized to the full 21 MW DTS following completion of the TFO 7L10 capital maintenance project.

6.1.4.5. Voltage Recovery using Transient Stability Analysis with the Motor Load Model (CLOD)

In addition to the power flow and voltage stability analyses, transient stability analysis was performed to further investigate the voltage recovery response using the 2016 WP scenario including the two proposed 144 kV capacitor banks at Mowat 2033S (10 and 15 MVAr). The voltage recovery response analysis was conducted for the worst three contingencies identified in the power flow and voltage stability analyses, namely 7L68, 7L73, and 7L75. The focus of this analysis was to test the key contingencies with the proposed mitigation to ensure that the area voltages recover fast enough to prevent cascading load loss.

This analysis was completed using the dynamic motor model (CLOD). In the Northeast and most of the Northwest, the mix of 30% small and 40% large motors was applied whereas for the Edmonton, Central and South regions of the AIES a mix of 10% small and 10% large motors was applied. For the Grande Prairie area and key busses in the Northwest, ATCO DFO provided the Customer load composition per substation which was used to determine the mix of small and large motor loads for this analysis. Please refer to Attachment F for further details.

Please refer to Attachment F for the detailed transient stability analysis. A summary of the findings is provided below:

- For 7L68: Voltage recovery problems were identified for the existing Zone 2 clearing time of 42 cycles at Rycroft 730S end for faults near Clairmont Lake 811S. The critical fault clearing time for voltage recovery on 7L68 was identified to be 9 cycles. The TFO has confirmed that to achieve this fault clearing time will require utilizing teleprotection grade telecommunications between Rycroft 730S and Clairmont Lake 811S. Along with modifying the protection on 7L68 to ensure the critical clearing time is achieved, a telecommunications tower and upgrades will be required at Rycroft 730S.
- For 7L75: Voltage recovery problems were identified for the existing Zone 2 clearing time of 24 cycles at Friedenstal 800S end for faults near West Peace River 793S. To successfully recover the voltage, critical far-end fault clearing time of 18 cycles was identified. It is recommended to accelerate the zone 2 clearing time for 7L75 at Friedenstal 800S to achieve a total clearing time of 18 cycles and resolve the voltage recovery issues.
- For 7L73: Voltage recovery problems were identified for existing Zone 2 clearing time of 24 cycles at Rycroft 730S end for faults near Friedenstal 800S. To successfully recover the voltage, critical far-end fault clearing time of 18 cycles was identified. It is

recommended to accelerate the zone 2 clearing time for 7L73 at Rycroft 730S to achieve a total clearing time of 18 cycles and resolve the voltage recovery issues.

6.2. Conclusions

For the post-Project 2016 WP and 2017 SP scenarios with Alternative 2, no Category A condition violations were identified.

Alternative 2 proposes a 144 kV breaker addition at Rycroft 730S on 7L68 to eliminate de-energizing Rycroft 730S, Ksituan River 754S and the proposed new Mowat 2033S with the loss of 7L68 as per the current configuration. However, following the loss of 7L68, transmission voltage violations at Rycroft 730S, Ksituan River 754S and Mowat 2033S as well as voltage deviations at several substations in the Spirit River area were noticed. The power flow and voltage stability analyses showed that this configuration requires additional reactive power support in order to meet the minimum voltage criteria. Following the loss of 7L73, POD bus voltage deviations and low POD voltages were also noted at the adjacent Ksituan River 754S substation.

The sensitivity studies indicated that with P1321 Shell Carmon Creek generation addition, there were no Category A condition violations noted nor additional Category B criteria voltage violations from those identified on post-Project scenarios except for the thermal flow violation on 7L75 (Friedenstal 800S to West Peace River 793S) following the loss of 7L32, which is attributable to the Shell Carom Creek generation.

V-Q analysis was subsequently carried out to quantify the additional reactive support requirements. The two proposed 144 kV capacitor banks will be installed at the proposed Mowat 2033S (10 and 15 MVAr) given Ksituan River 754S would require a fence expansion to accommodate the additional equipment. Subsequent testing proved this to be sufficient to alleviate the voltage criteria violations and POD bus deviations for the worst contingencies at both Ksituan River 754S and Mowat 2033S.

Subsequent to the loss of either 7L75 or 7L46 (Little Smoky 813S to Big Mountain 845S) in the 2017 SP pre- and post- Project scenarios, line flow above the seasonal rating on 7L32 (Little Smoky 813S to the South Bezanson 862S tap) was identified. This thermal overload will be managed by real time operational practices.

Following the loss of either 7L68, 7L73 or 7L75 in the 2016 WP scenario, or the loss of 7L68 in the 2017 SP scenario, thermal flow violations on 7L10 (from Rycroft 730S to proposed Mowat 2033S tap) was noted. The line rating of 7L10 is limited to 49 MVA on a 144 kV base by CT ratio and clearance issues. This thermal flow violation on 7L10 is due to low voltage during Category B contingencies and will no longer exist with the voltage support required to mitigate the voltage criteria violations identified.

With the two proposed 144 kV capacitor banks at Mowat 2033S in-service, a potential thermal violation of 102.1% under Category A conditions was observed on the section of 7L10 between Rycroft 730S and the Mowat 2033S tap in the 2016 WP post-Project scenario. The line rating of 7L10 is currently limited by CT ratio and clearance issues to 49 MVA on a 144 kV base. ATCO TFO plans to increase the rating of this section of 7L10 to 75 MVA on a 144 kV base under an existing TFO capital maintenance project by April 2017, prior to connection of the Project. This TFO line clearance mitigation will eliminate the potential for the identified 7L10 thermal constraints under Category A conditions. The Project can be energized to the full 21 MW DTS following completion of the TFO 7L10 capital maintenance project.

Transient stability analysis was performed to ensure successful post-contingency voltage recovery under the critical contingencies (7L68, 7L73 and 7L75). To ensure voltage recovery for the motor loads in the Rycroft area after critical area faults, the protection review and modification on 7L68, 7L75 and 7L73 is required.

7. Project Interdependencies

A section of the transmission line 7L10 needs to be restored, through line clearance mitigation work and CT limits being removed, prior to the Project being energized. ATCO TFO has advised the AESO of plans to restore the rating of the section of 7L10 and to remove the CT limits by April 2017, prior to connection of the Project. This will be addressed as a Capital Maintenance project.

8. Recommendations

Based on the study results, it is recommended that the Project be connected using Alternative 2 subject to the following:

- The addition of one 10 MVAr capacitor and one 15 MVAr capacitor at Mowat 2033S substation to mitigate potential voltage criteria violations. This will be part of the Project's scope, and
- The completion of the following protection settings changes and upgrades to ensure voltage recovery for the motor loads in the Rycroft area:
    - Accelerate far-end fault clearing speed at Rycroft 730S end for faults near Clairmont Lake 811S to achieve the critical clearing time of 9 cycles, by modifying the protection on 7L68 and adding a telecommunications tower and upgrades at Rycroft 730S. This will be part of the Project's scope.
    - Accelerate far-end fault clearing speed at Friedenstal 800S for faults on 7L75 near West Peace River 793S by reducing the far-end fault clearing time from 24 cycles to 18 cycles. This will be part of the Project's scope.
    - Accelerate far-end fault clearing speed at Rycroft 730S for faults on 7L73 near Friedenstal 800S by reducing the far-end fault clearing time from 24 cycles to 18 cycles. This will be part of the Project's scope.
- The completion of the line clearance mitigation for 7L10, which will be addressed as a Capital Maintenance project.

ATTACHMENT A
Pre-Project System Power Flow Plots

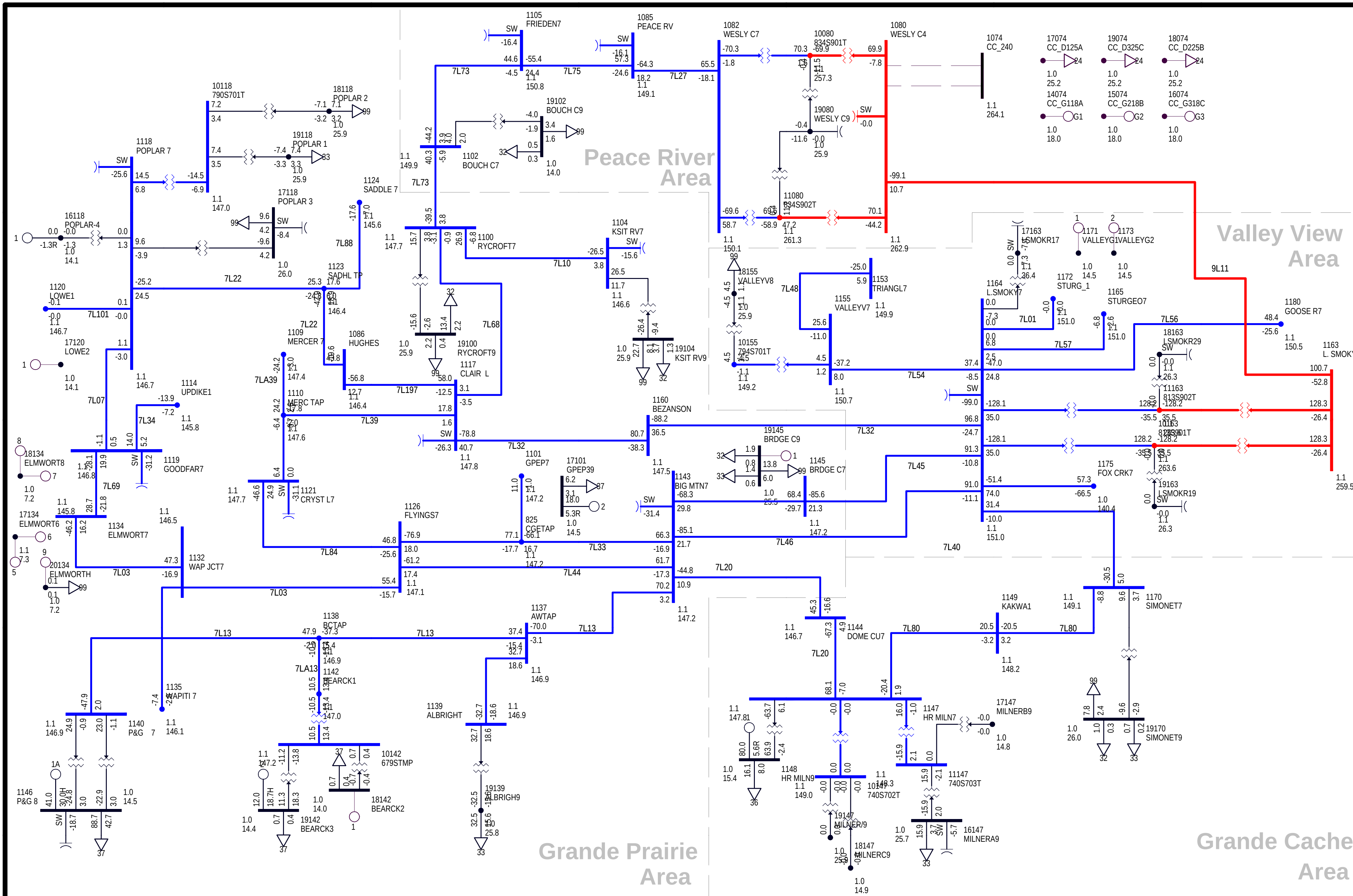
Existing System Power Flow Results

Power Flow Diagrams

The pre-Project power flow diagrams for Category A and selected B contingencies are provided in this section. The following table presents the list of the power flow diagrams. Please note that Lowe Lake generator is turned off for the analyzed case.

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

Scenario	Power flow diagram	Page number
2016 WP	N-G-0, System Normal Condition	A-3
	N-G-1, Loss of 7L73	A-4
	N-G-1, Loss of 7L68	A-5
	N-G-1, Loss of 7L32	A-6
	N-G-1, Loss of 7L46	A-7
	N-G-1, Loss of 7L75	A-8
	N-G-1, Loss of 7L197	A-9
2017 SP	N-G-0, System Normal Condition	A-10
	N-G-1, Loss of 7L73	A-11
	N-G-1, Loss of 7L68	A-12
	N-G-1, Loss of 7L32	A-13
	N-G-1, Loss of 7L46	A-14
	N-G-1, Loss of 7L75	A-15
	N-G-1, Loss of 7L197	A-16

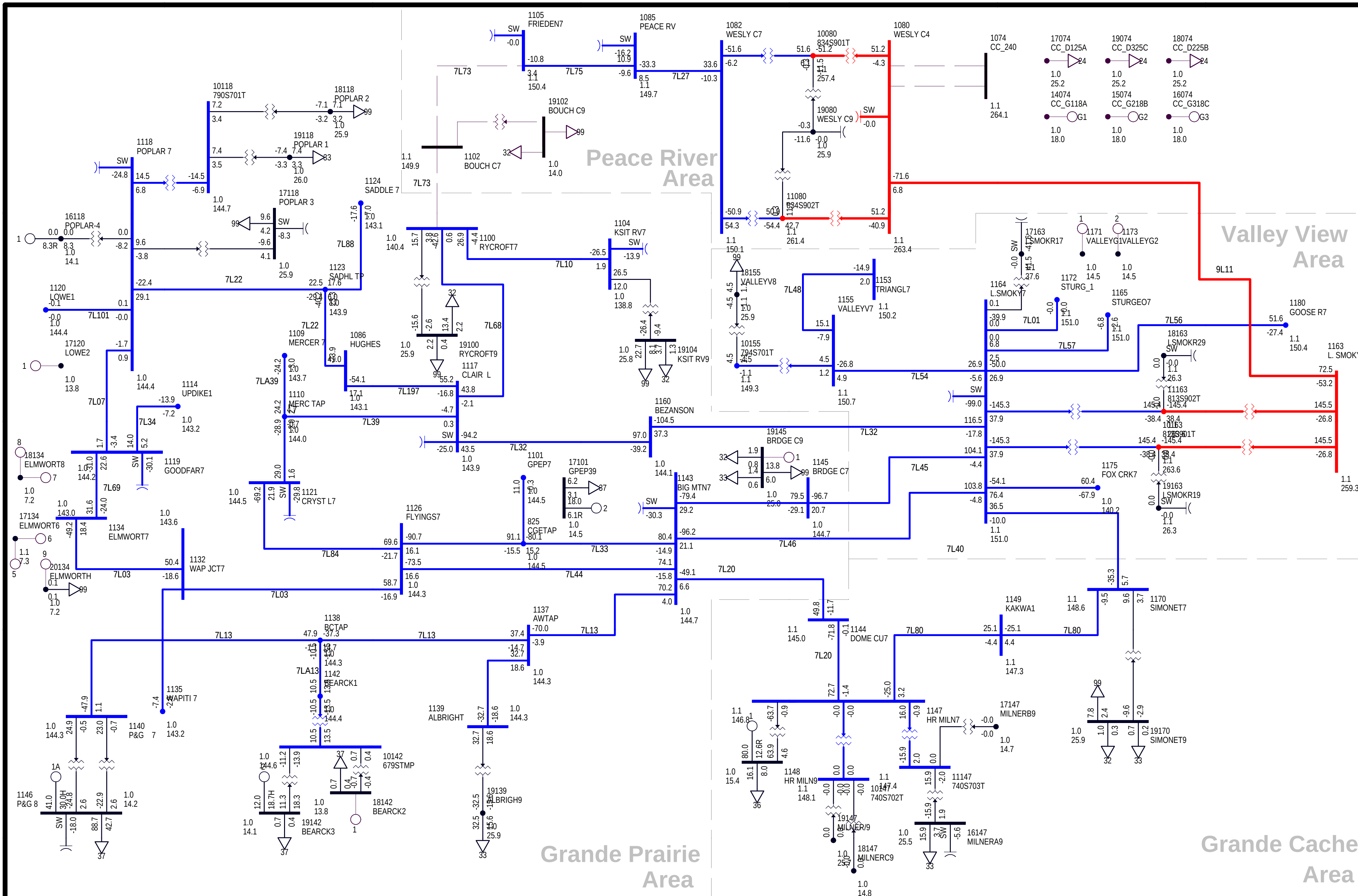


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY A, N-G-0
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Page A- 3

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

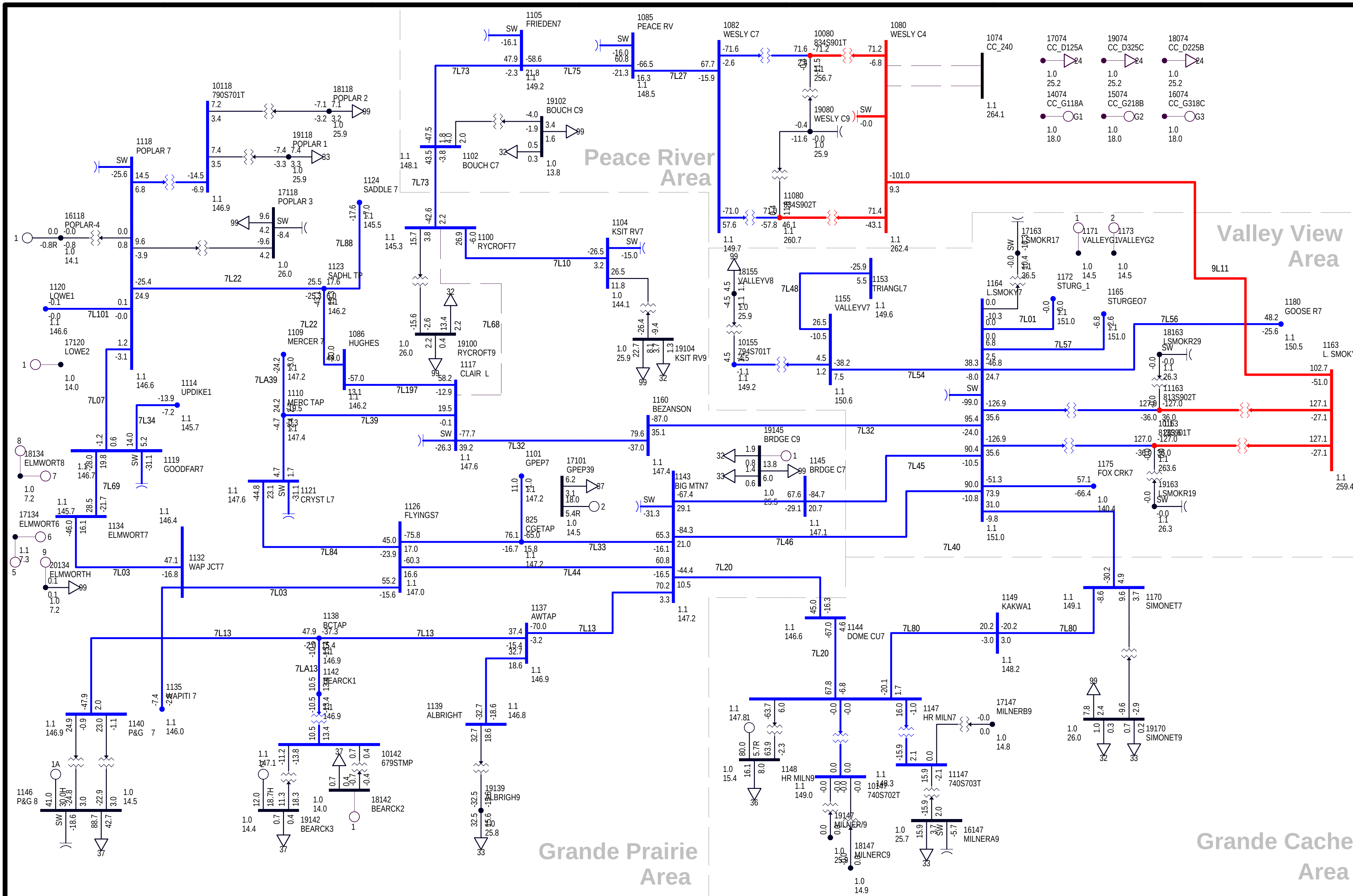


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Page A- 4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

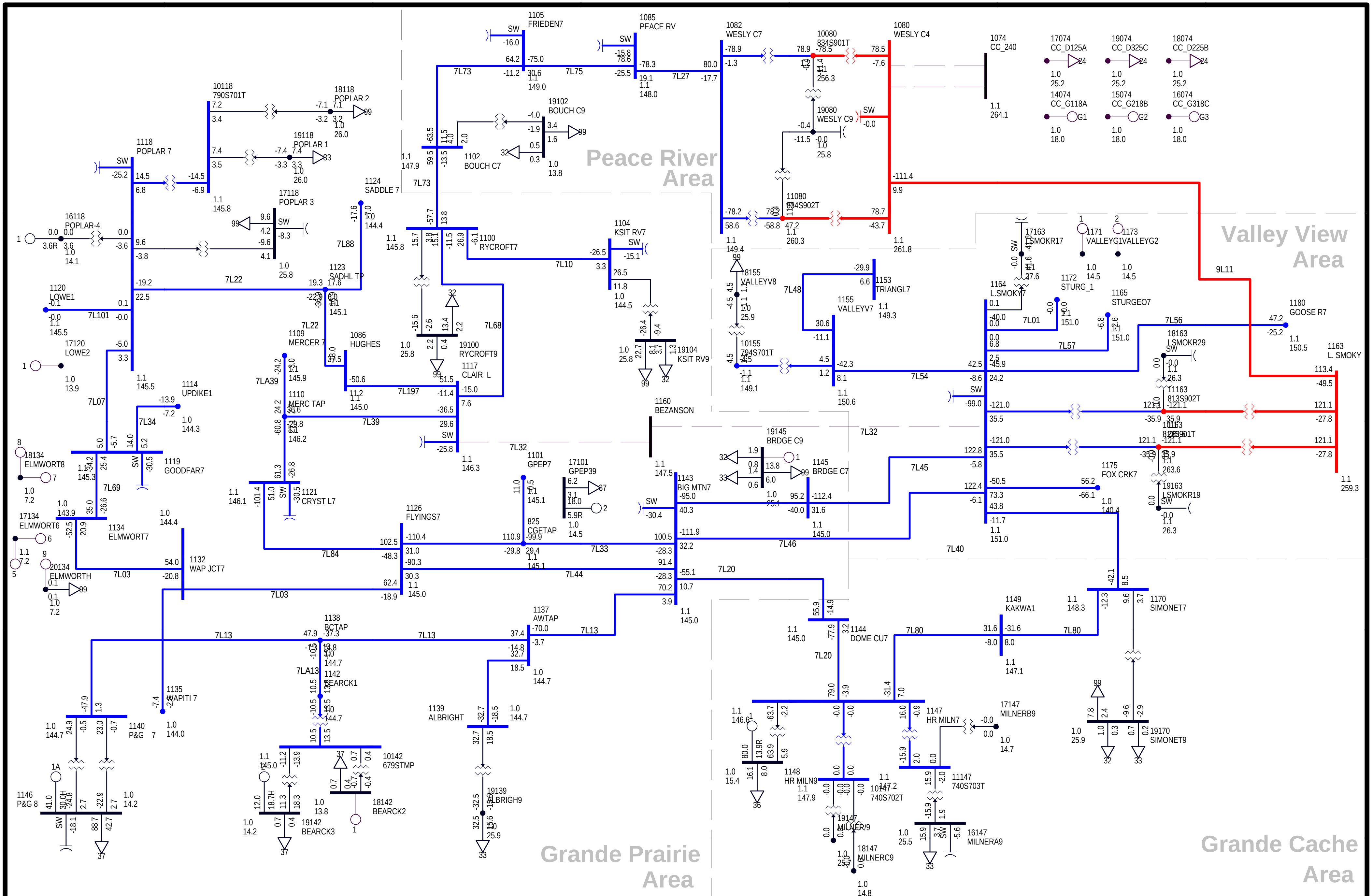


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Page A- 5

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

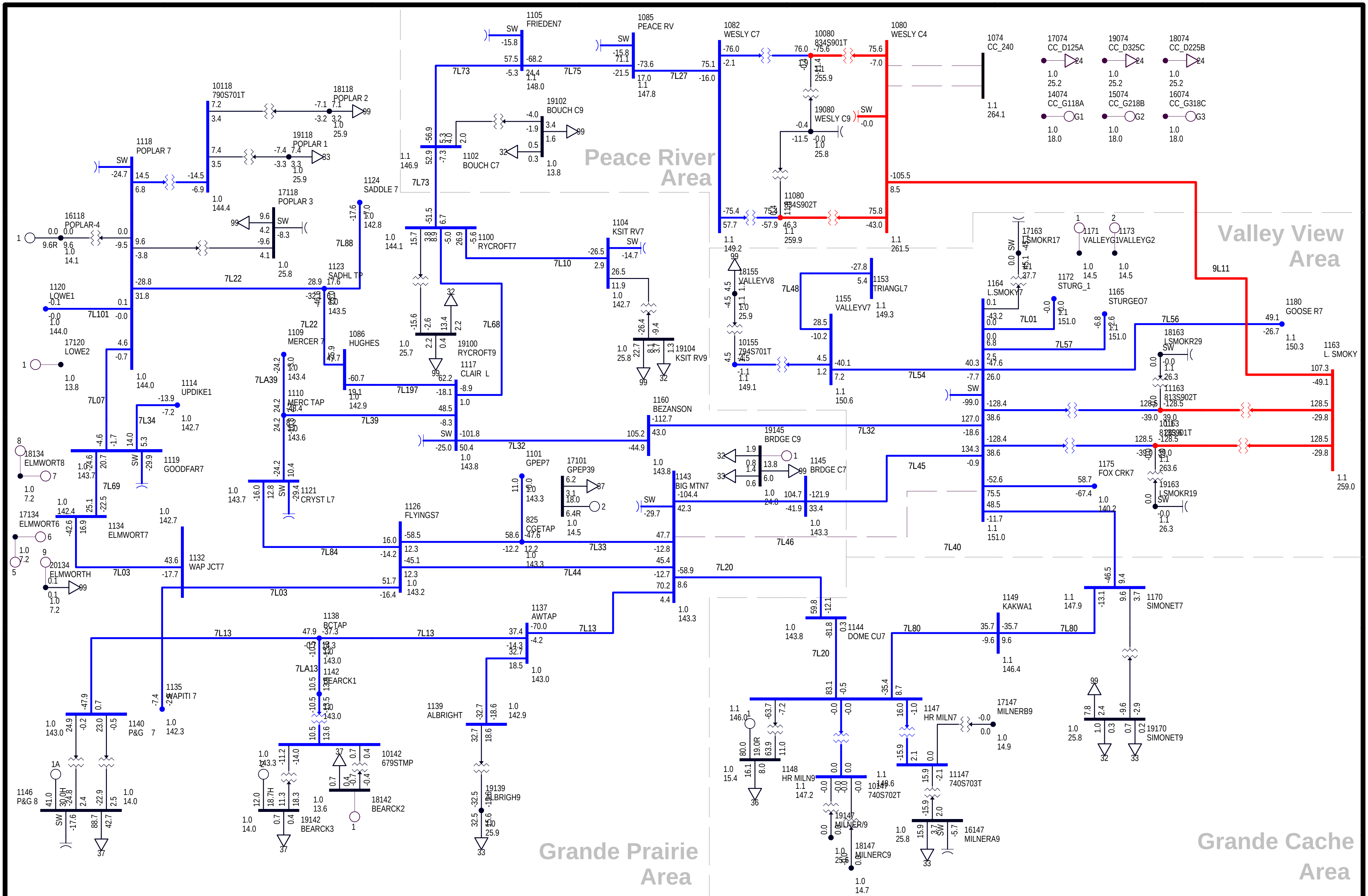


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Page A- 6

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

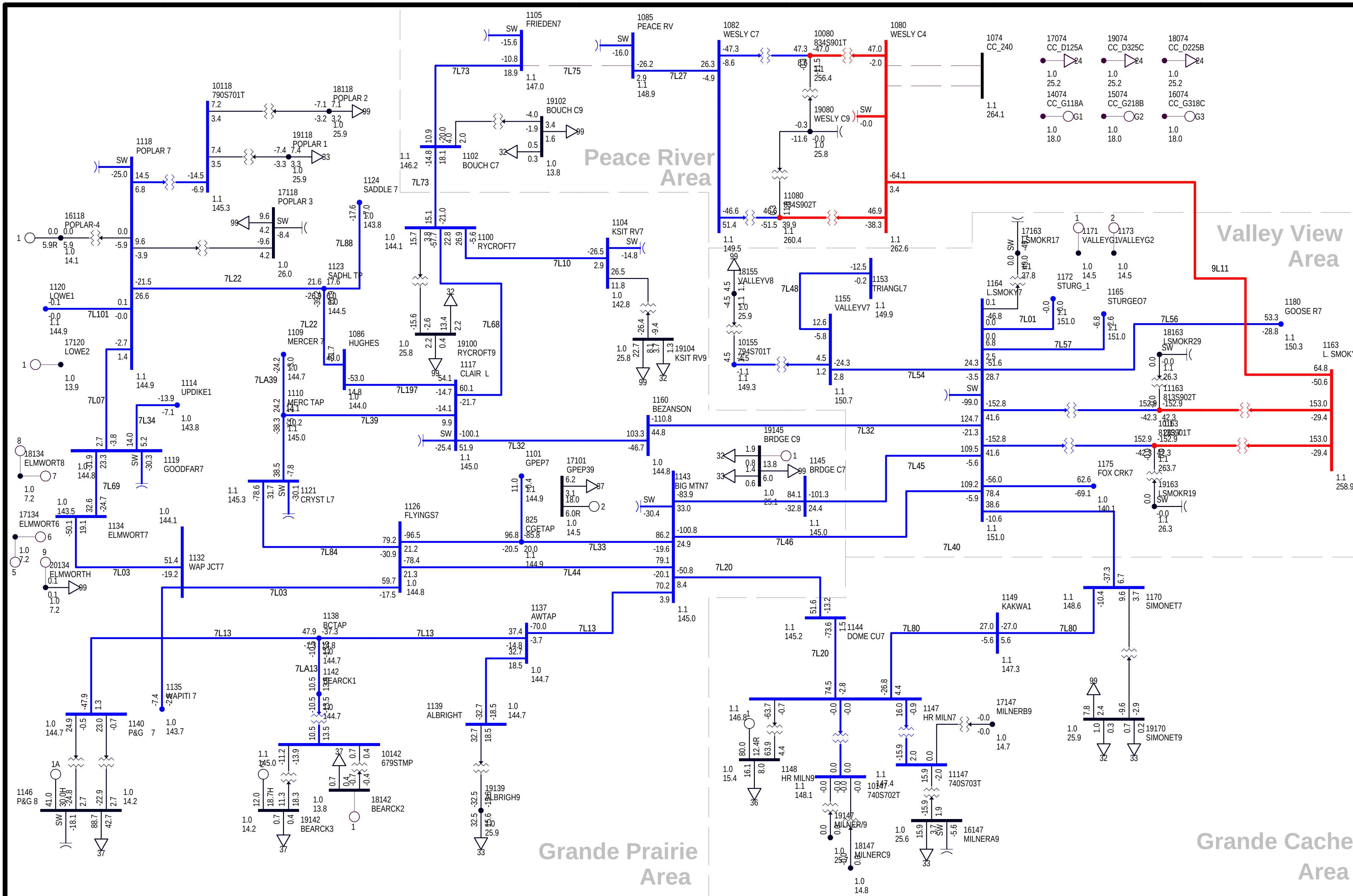


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Page A- 7

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

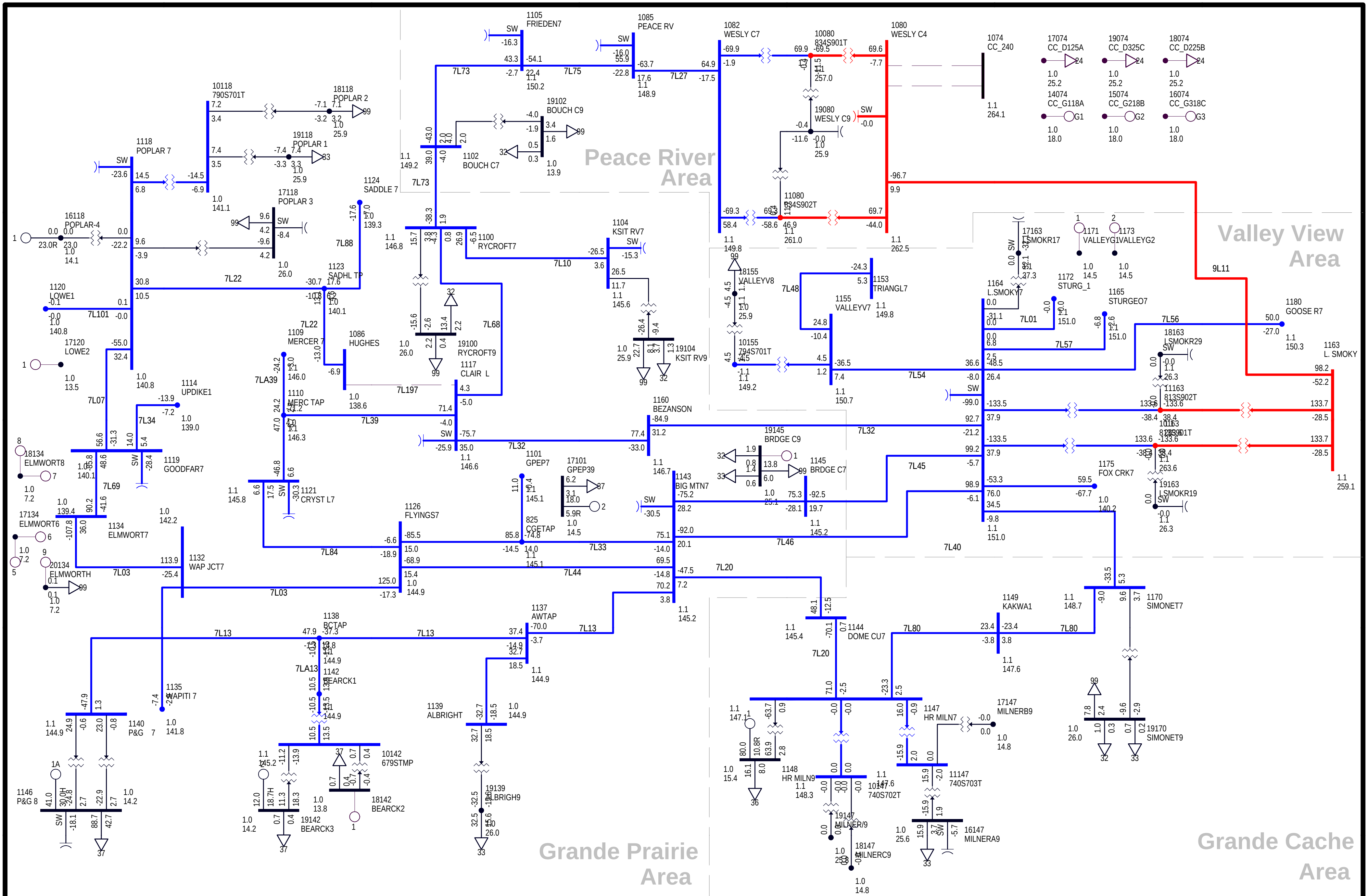


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Page A- 8

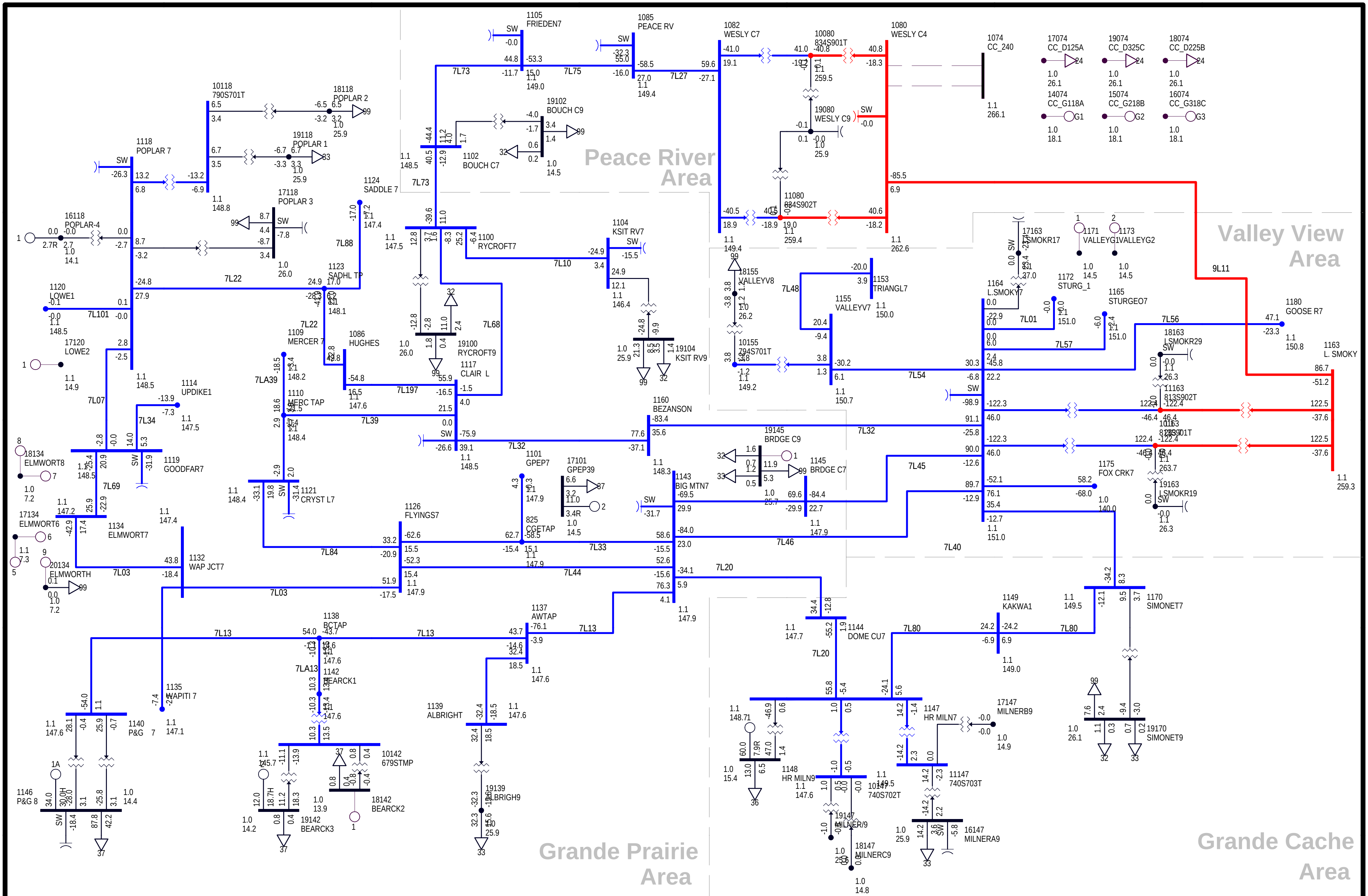
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2016 WP WITHOUT PROJECT
WED, FEB 10 2016 14:09

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

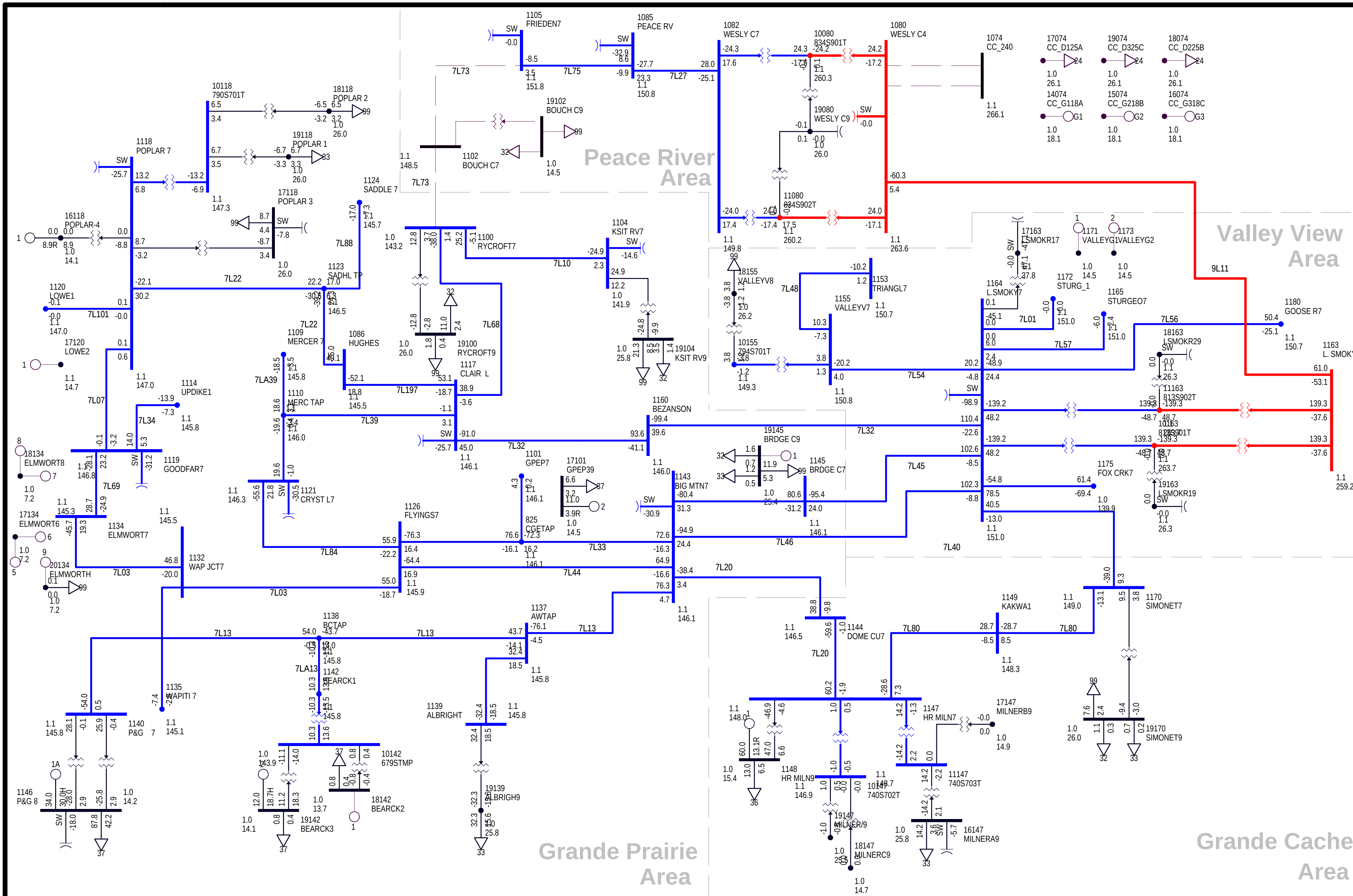


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY A, N-G-0
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Page A- 10

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

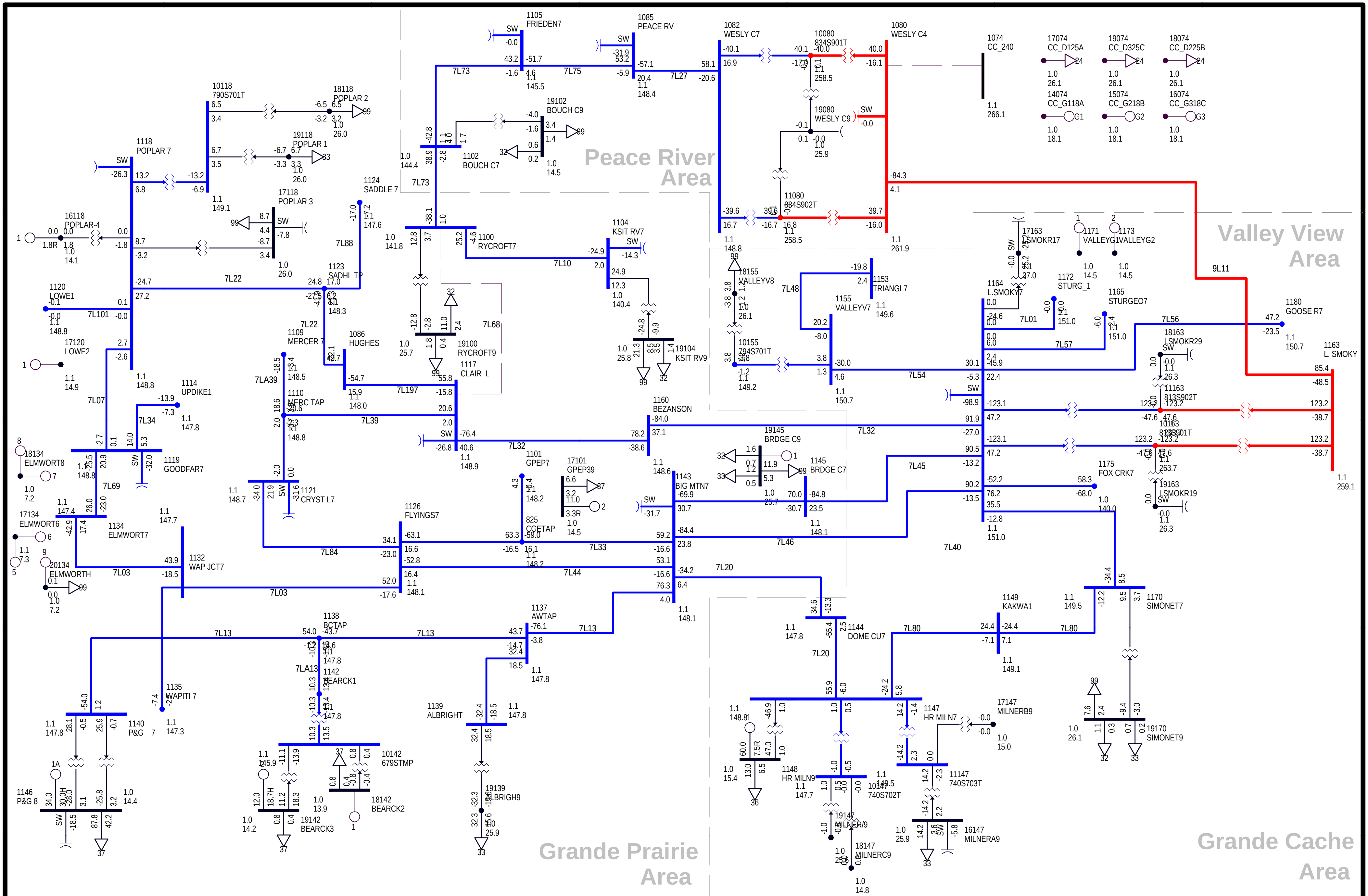


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Page A- 11

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

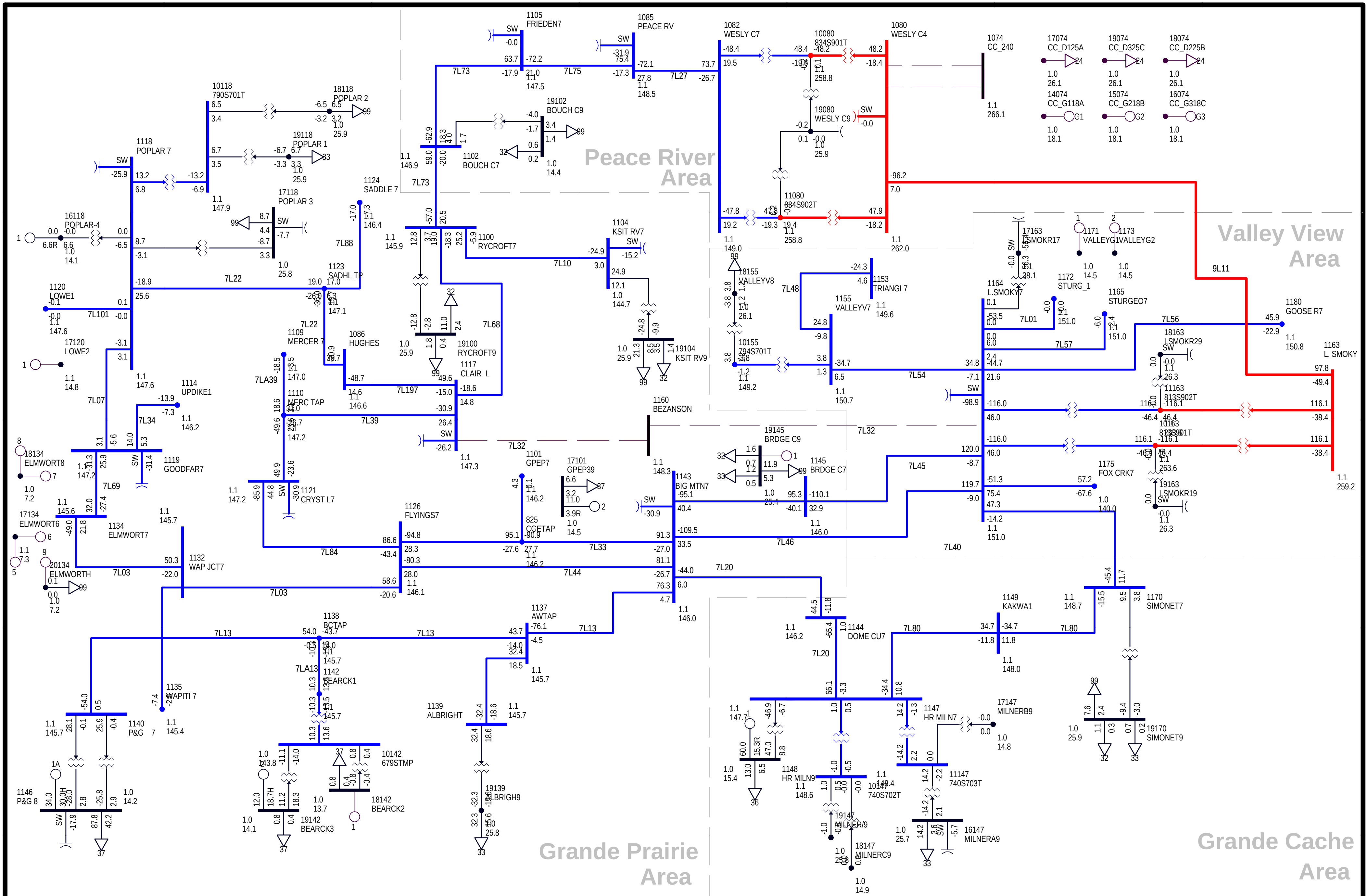


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Page A- 12

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

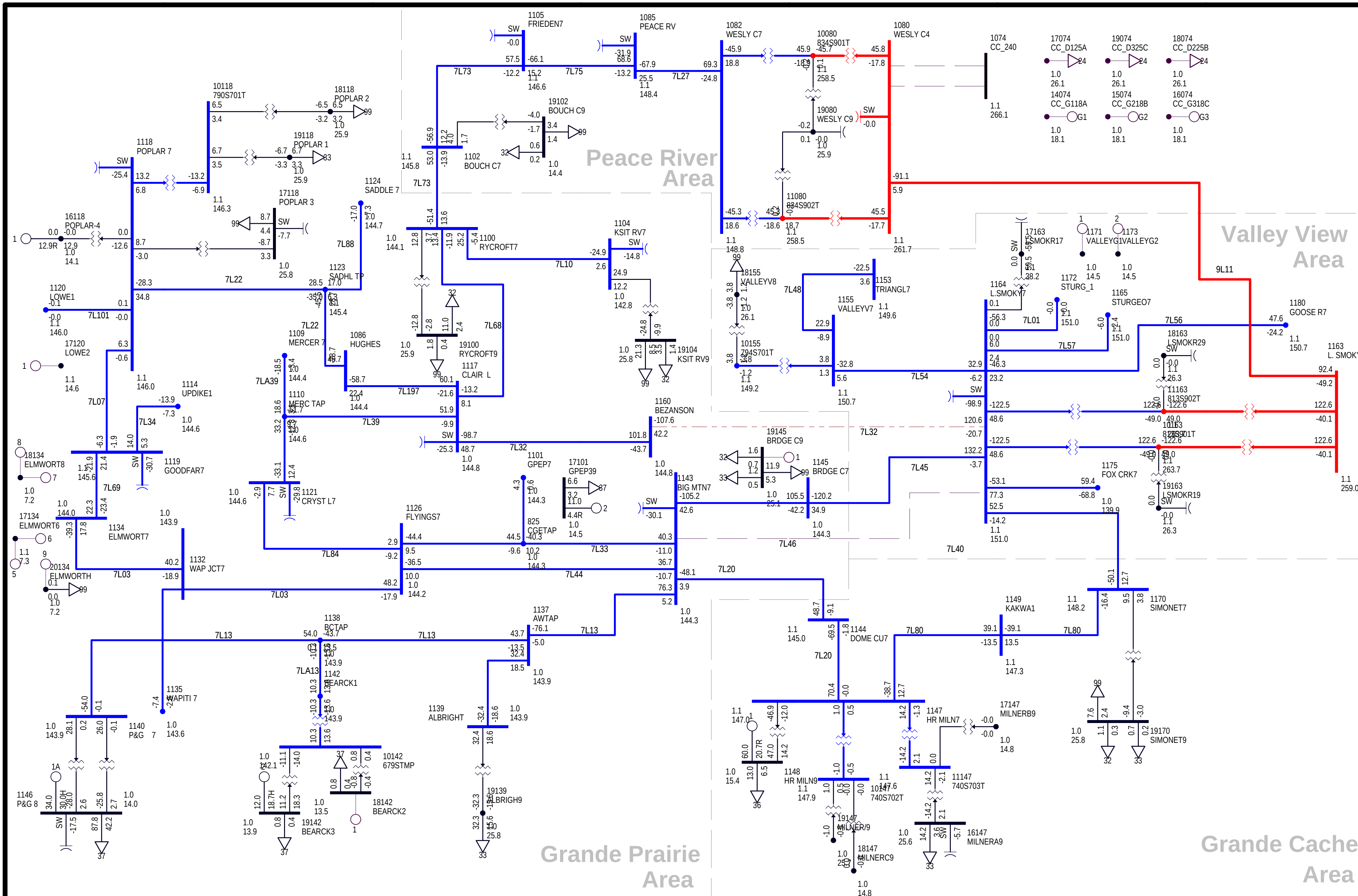


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Page A- 13

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

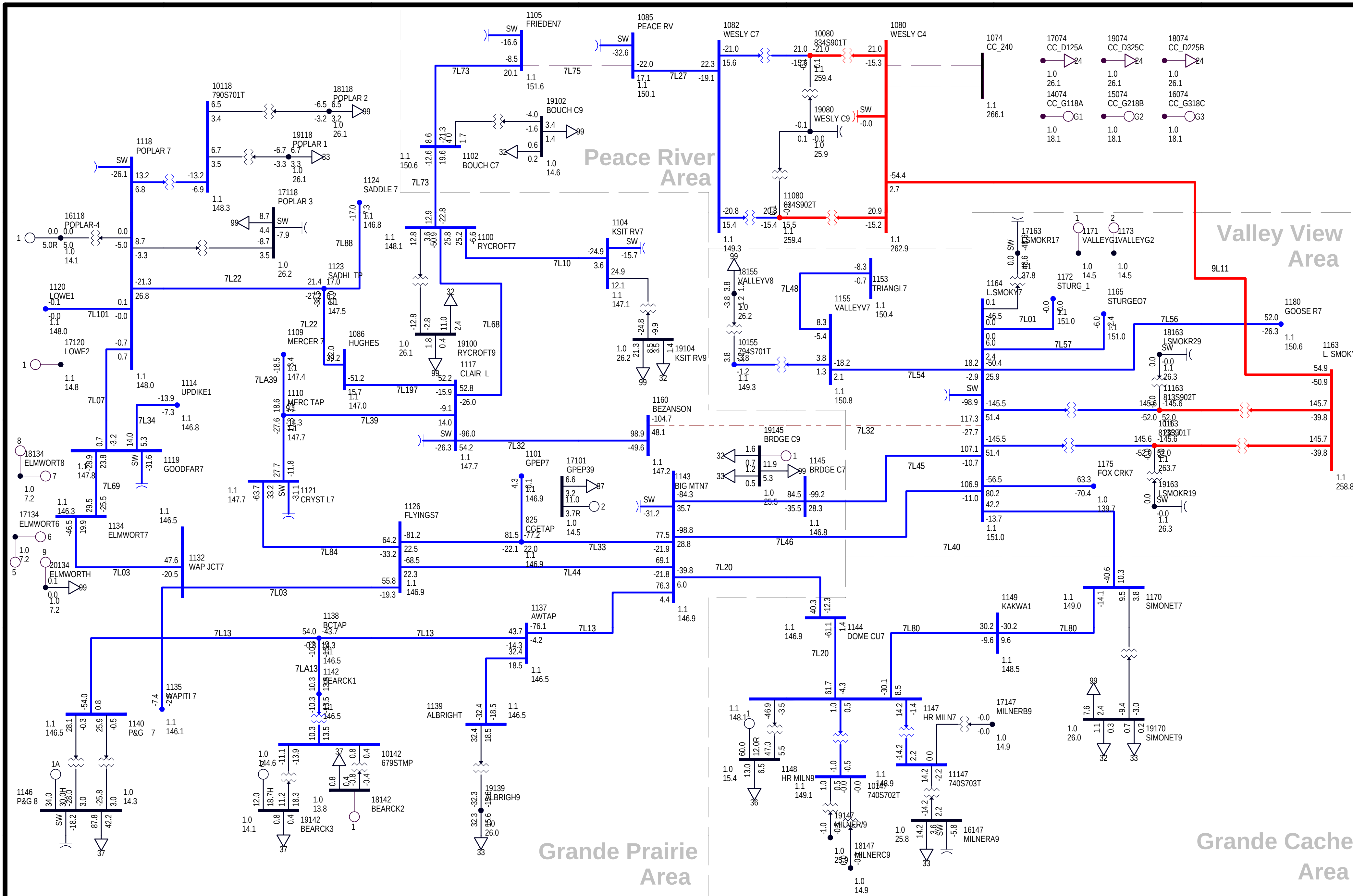


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Page A- 14

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

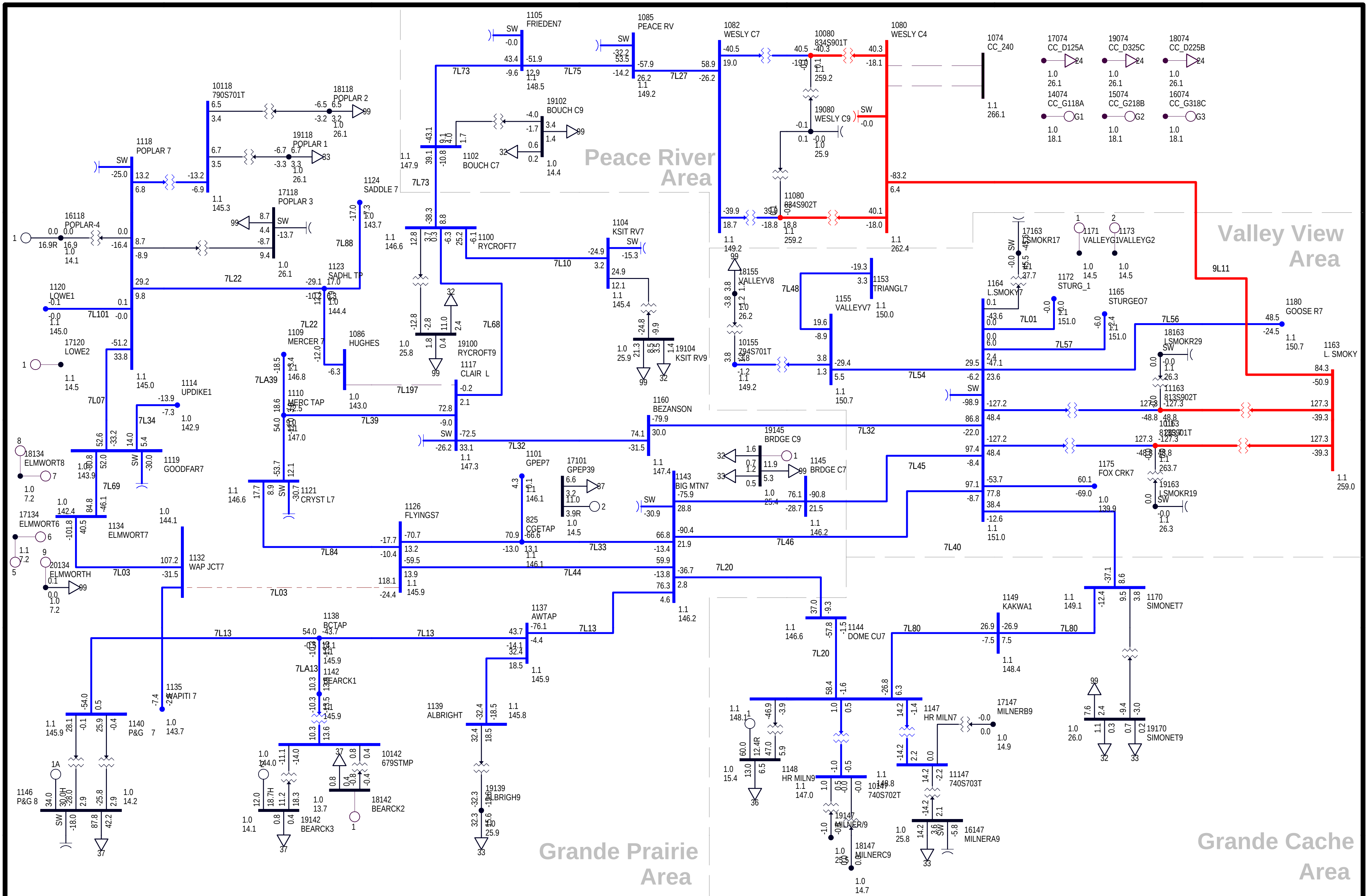


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Page A- 15

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2017 SP WITHOUT PROJECT
WED, FEB 10 2016 14:08

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

ATTACHMENT B

Post-Project Alternative 2: System Power Flow Plots

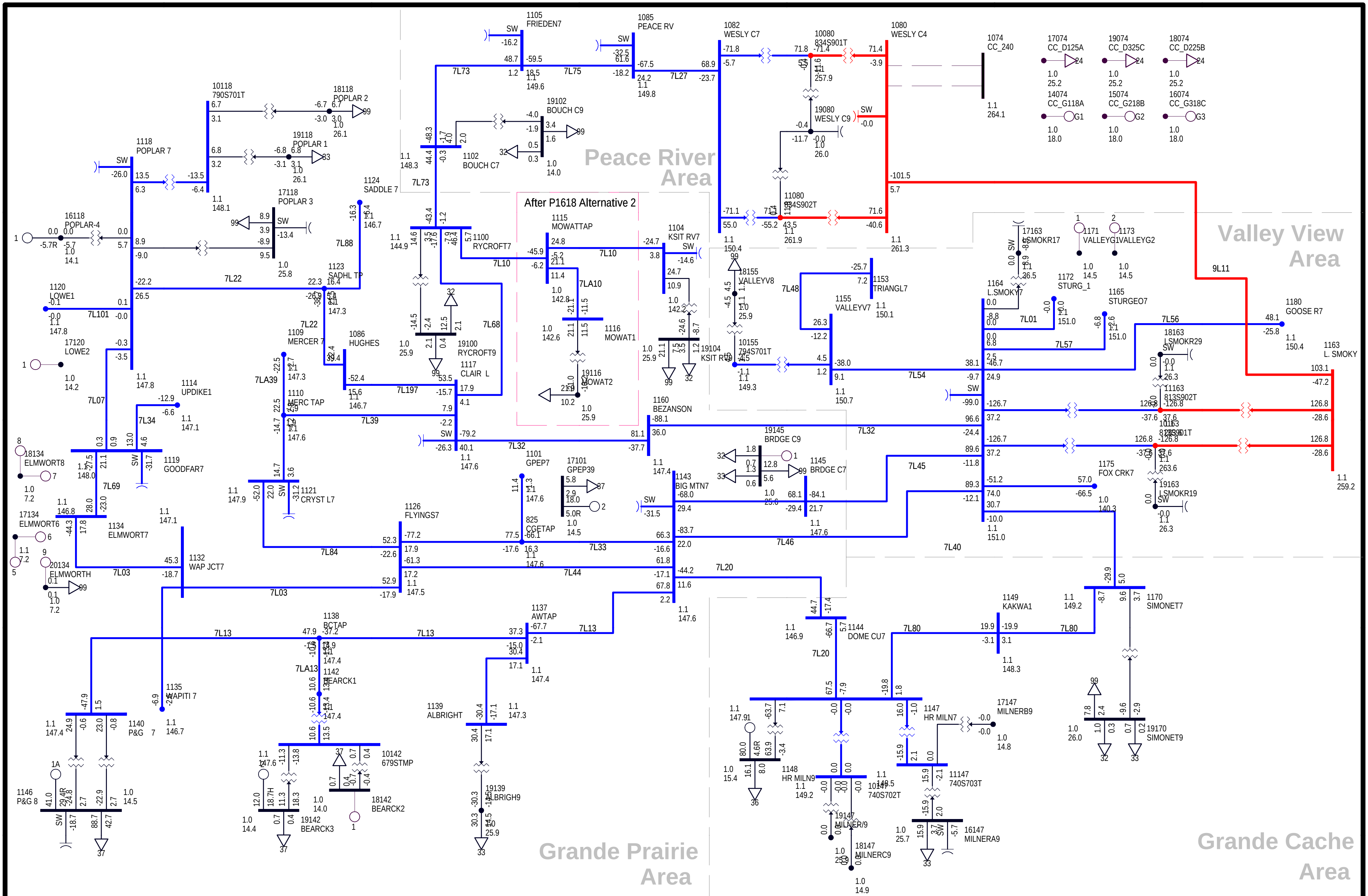
System Power Flow Results

Power Flow Diagrams

The post-Project alternative 2 power flow diagrams for Category A and selected B contingencies are provided in this section. The following table presents the list of the power flow diagrams. Please note that Lowe Lake generator is turned off for the analyzed case.

Table B-1: List of post-Project power flow diagrams

Scenario	Power flow diagram	Page number
2016 WP	N-G-0, System Normal Condition	B-3
	N-G-1, Loss of 7L73	B-4
	N-G-1, Loss of 7L68	B-5
	N-G-1, Loss of 7L32	B-6
	N-G-1, Loss of 7L46	B-7
	N-G-1, Loss of 7L75	B-8
	N-G-1, Loss of 7L197	B-9
2017 SP	N-G-0, System Normal Condition	B-10
	N-G-1, Loss of 7L73	B-11
	N-G-1, Loss of 7L68	B-12
	N-G-1, Loss of 7L32	B-13
	N-G-1, Loss of 7L46	B-14
	N-G-1, Loss of 7L75	B-15
	N-G-1, Loss of 7L197	B-16

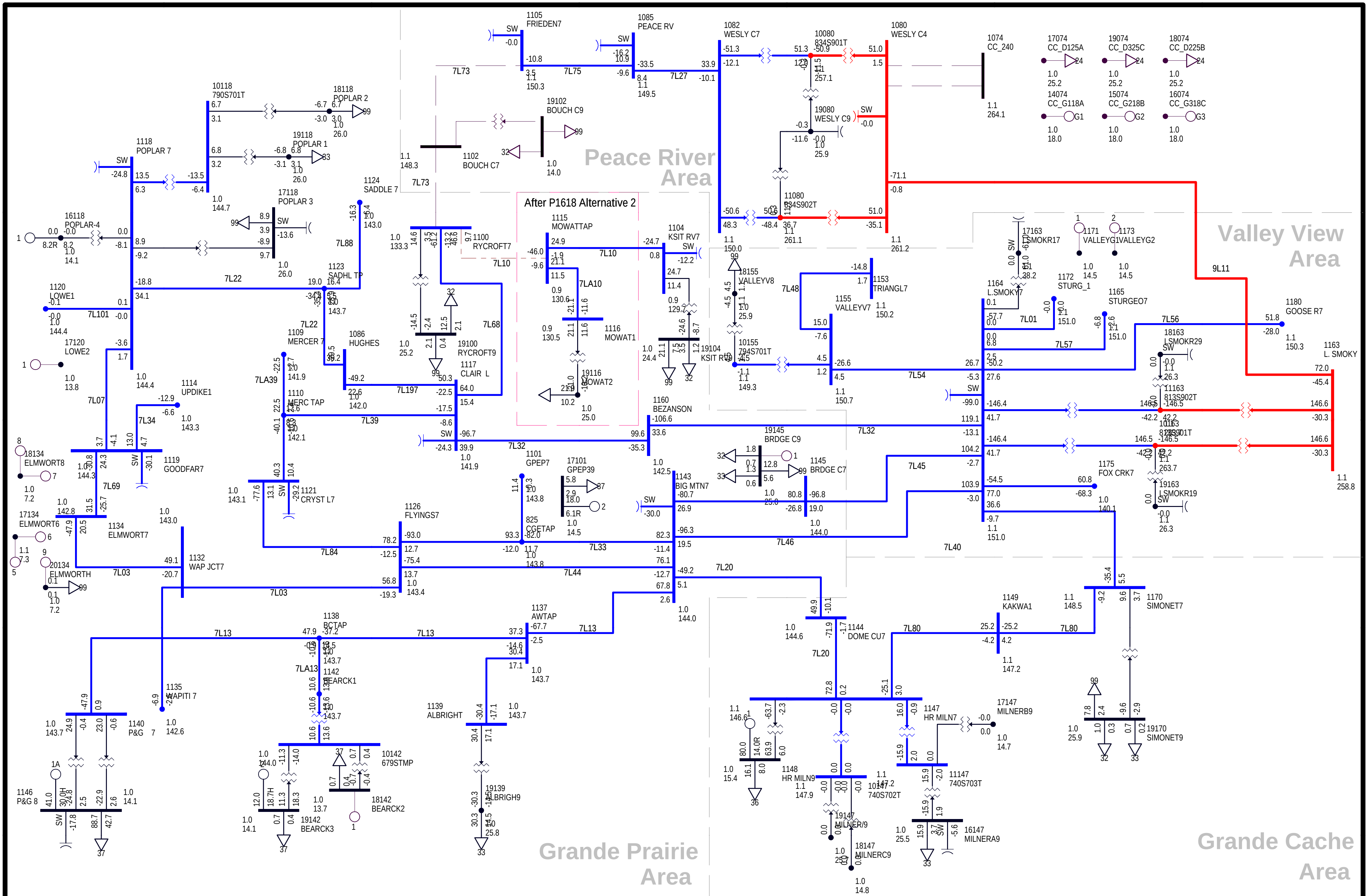


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY A, N-G-0
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

Page B- 3

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

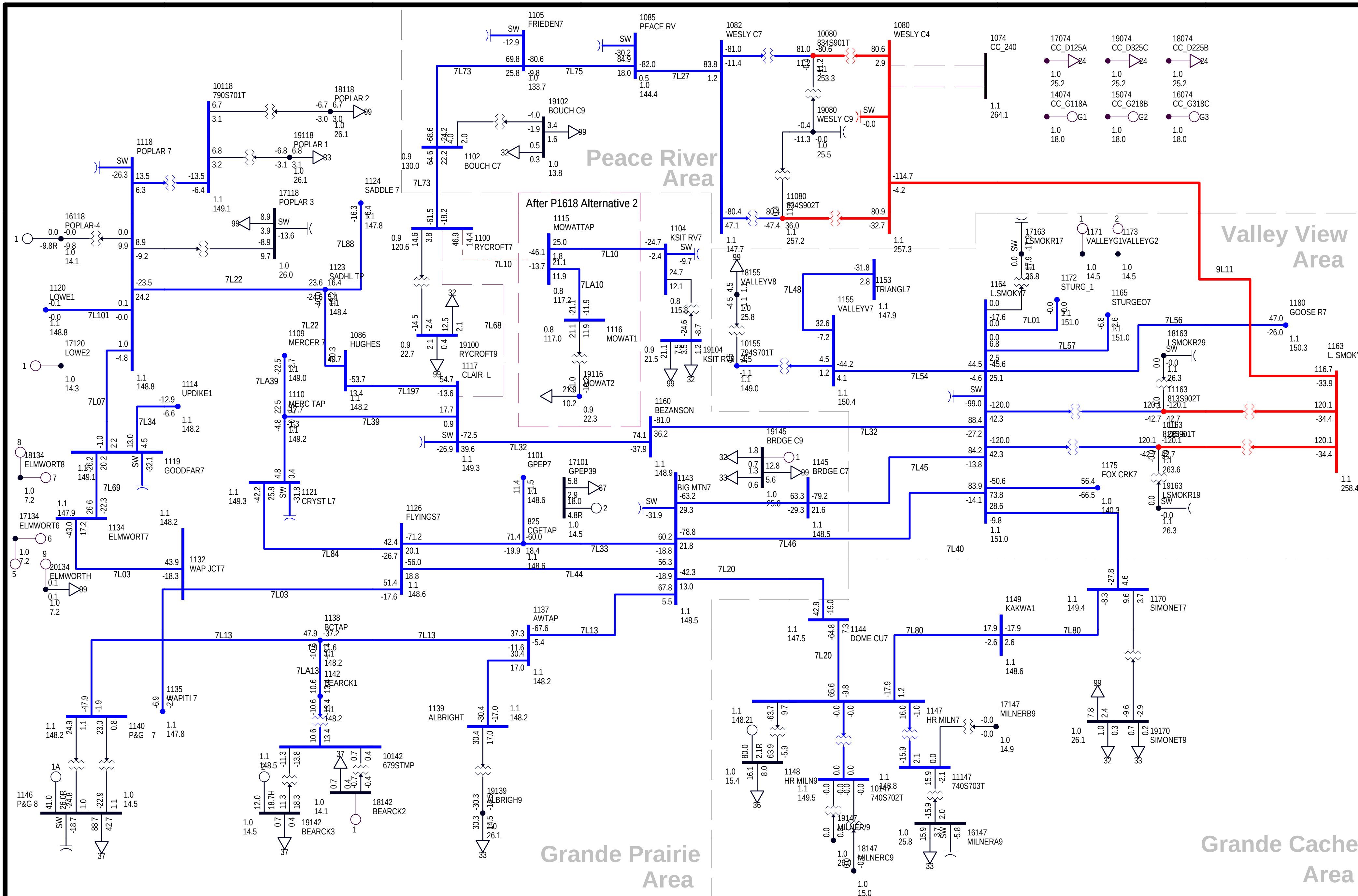


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

Page B- 4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

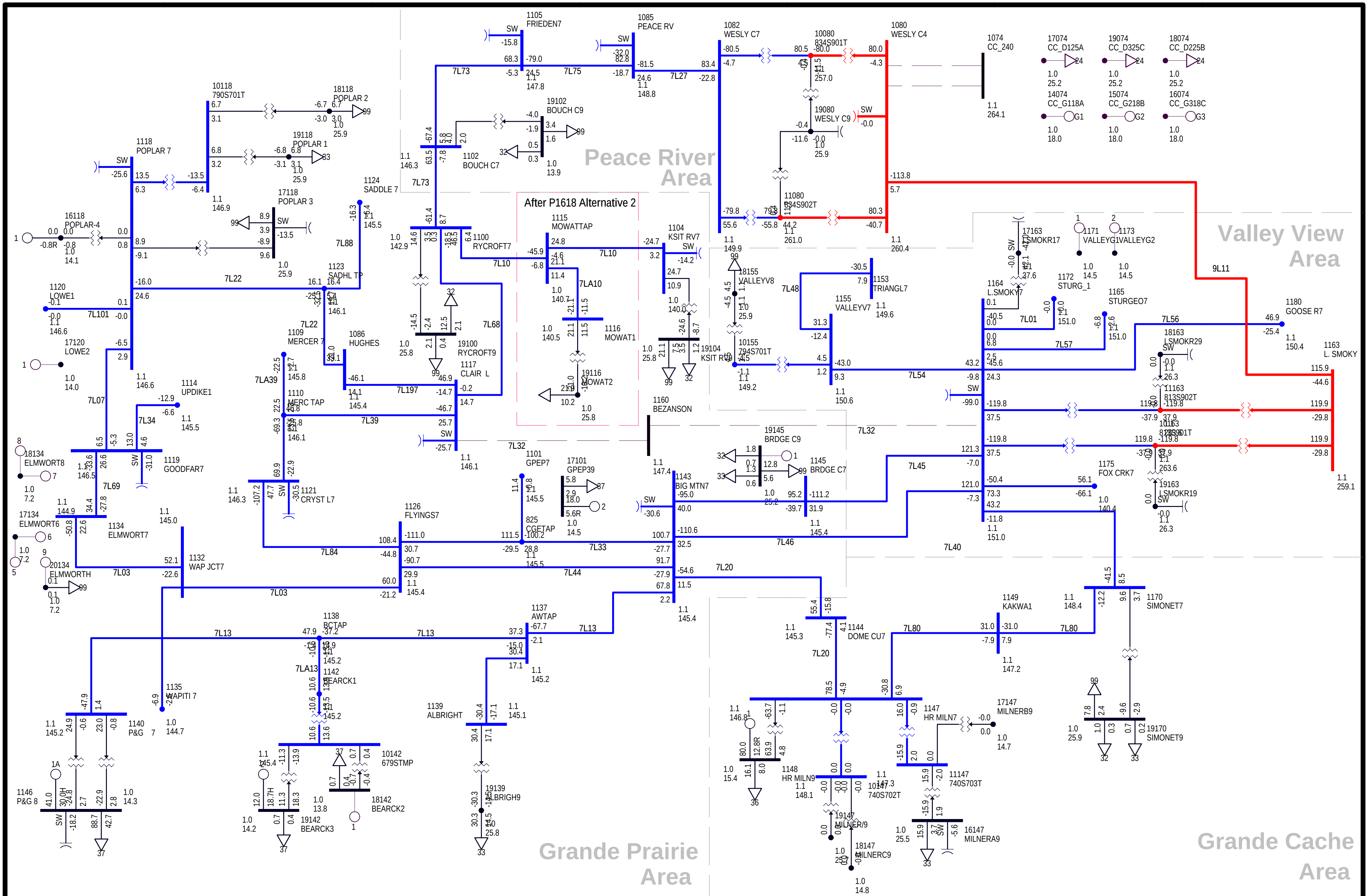


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

Page B- 5

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

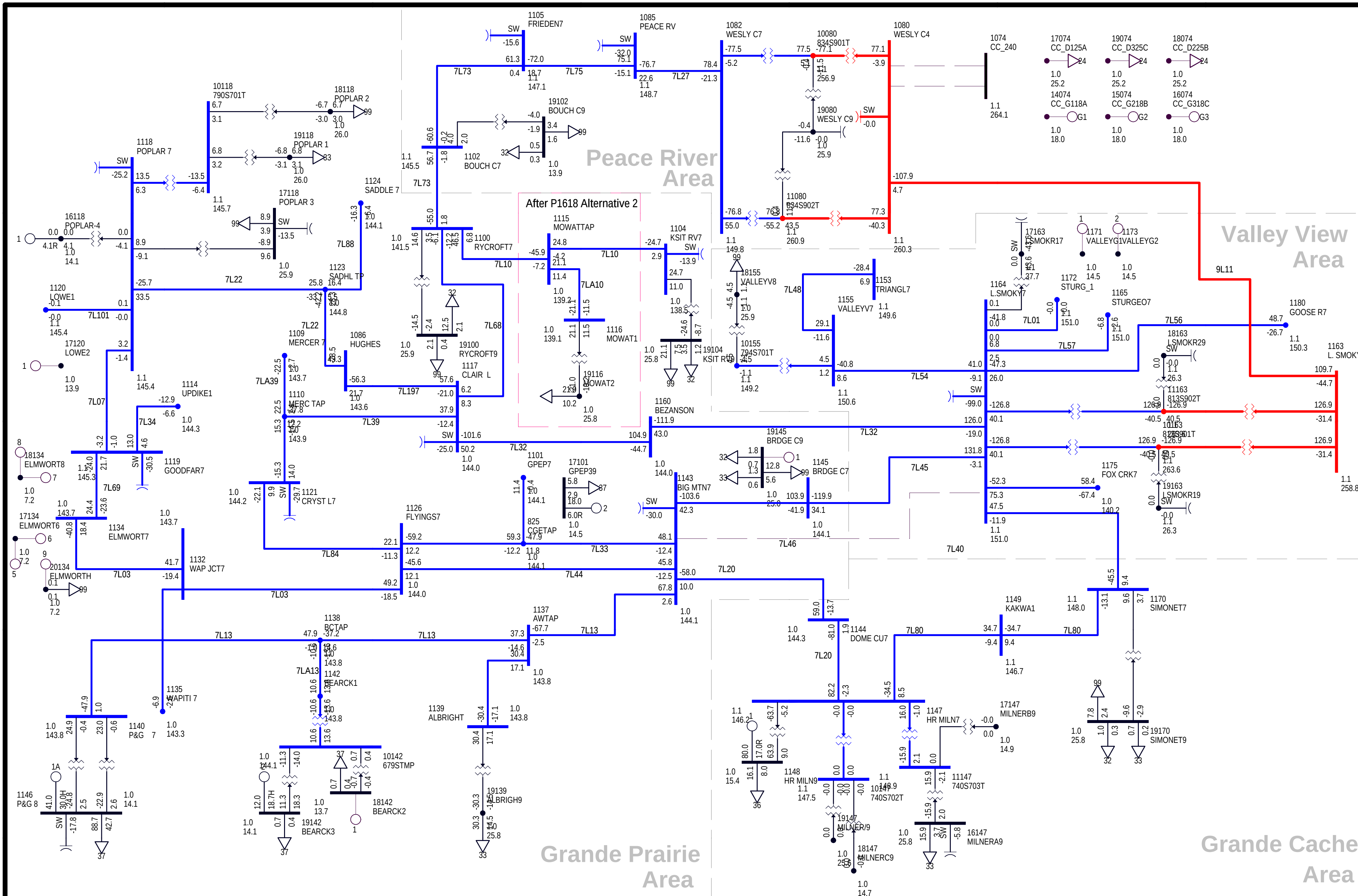


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

Page B- 6

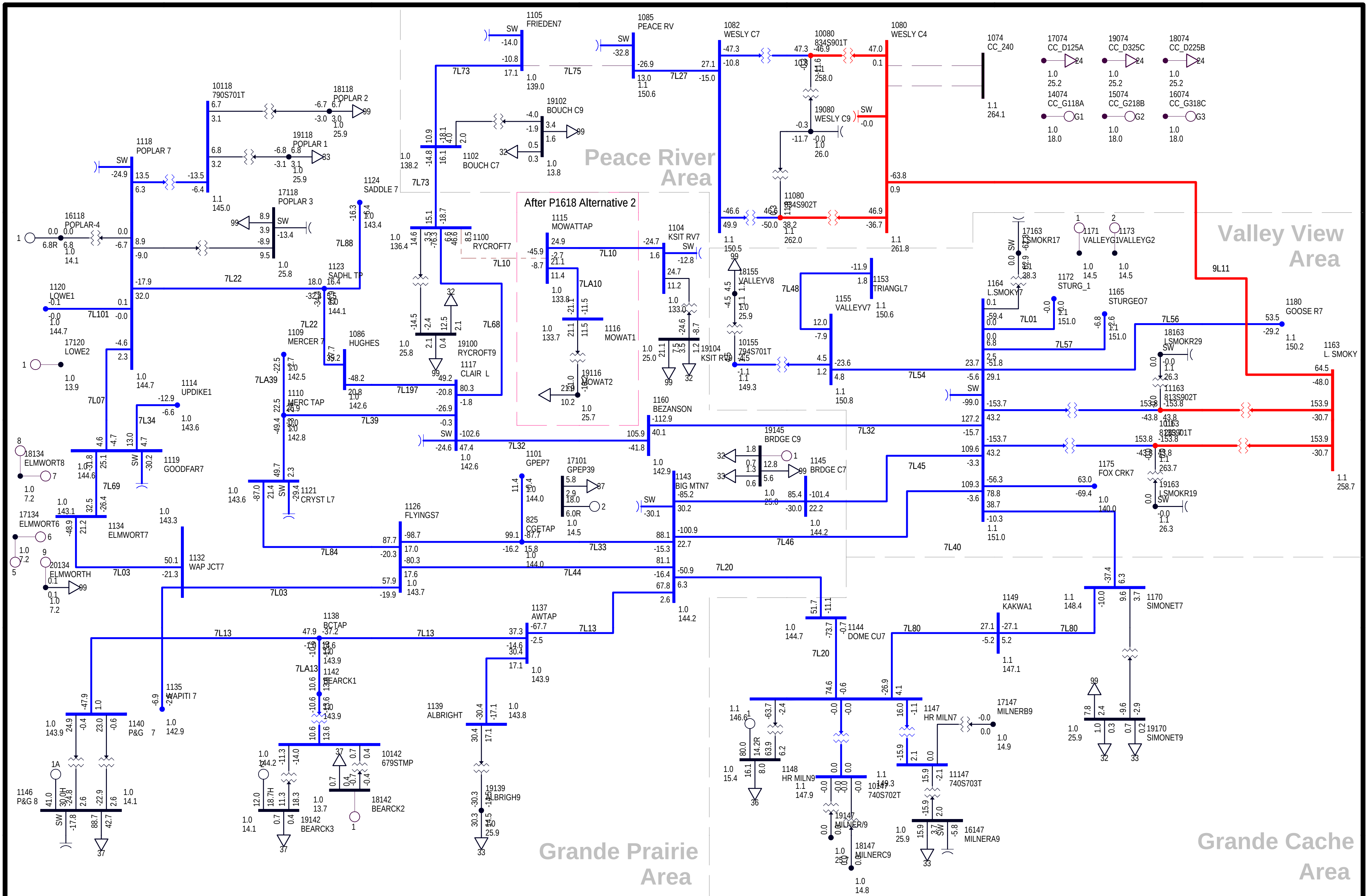
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

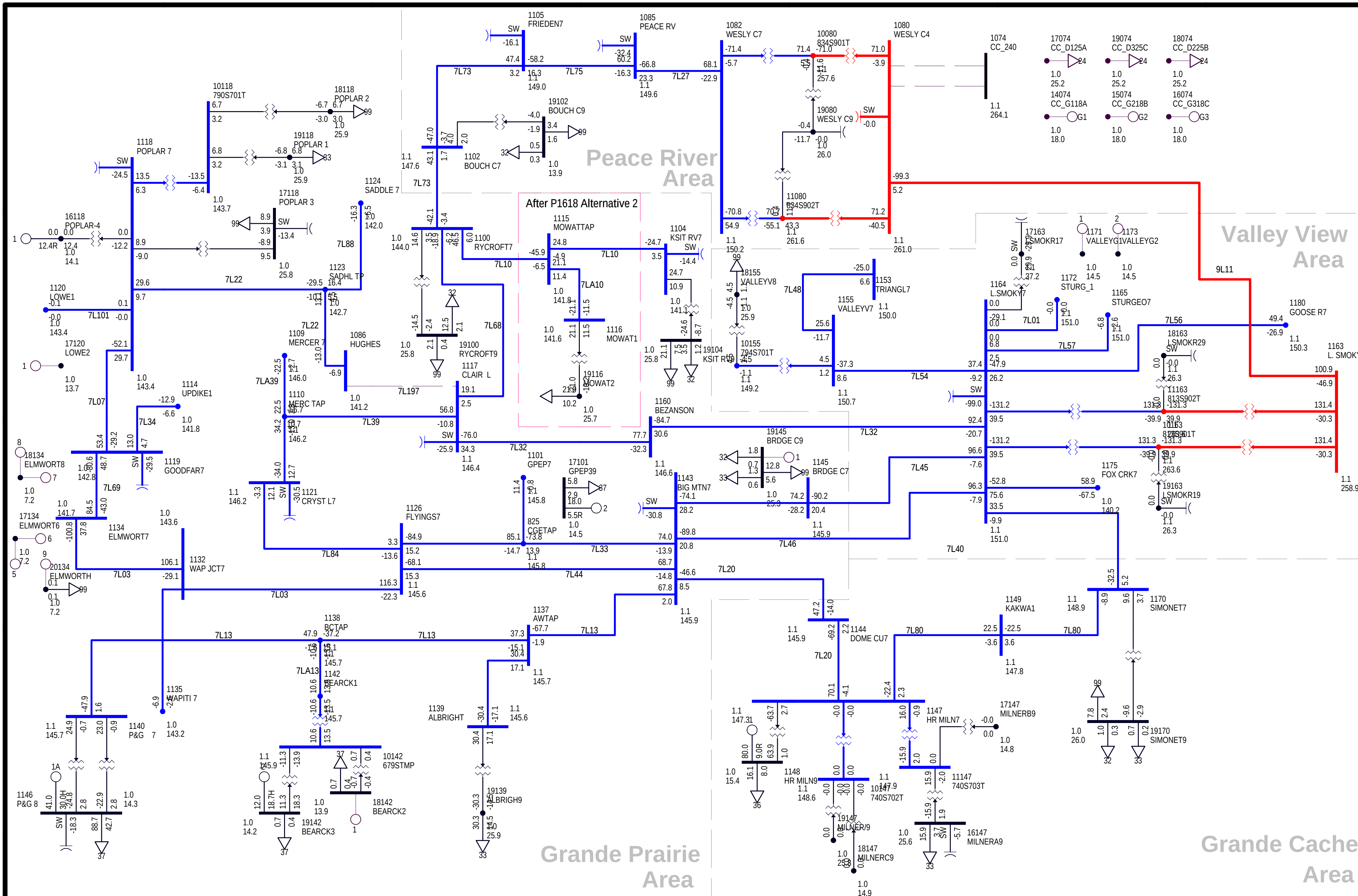
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

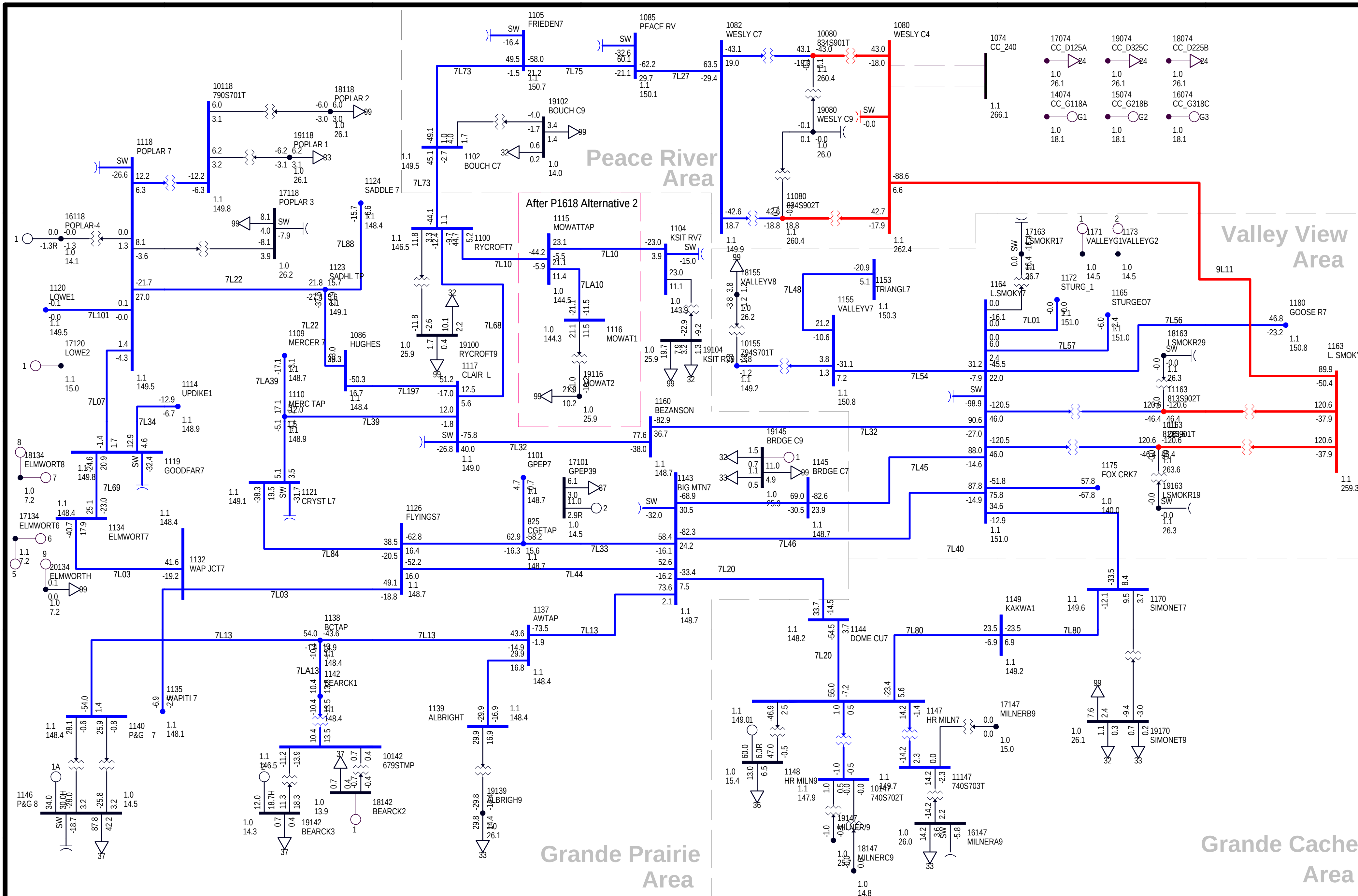


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2016 WP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:15

Page B- 9

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

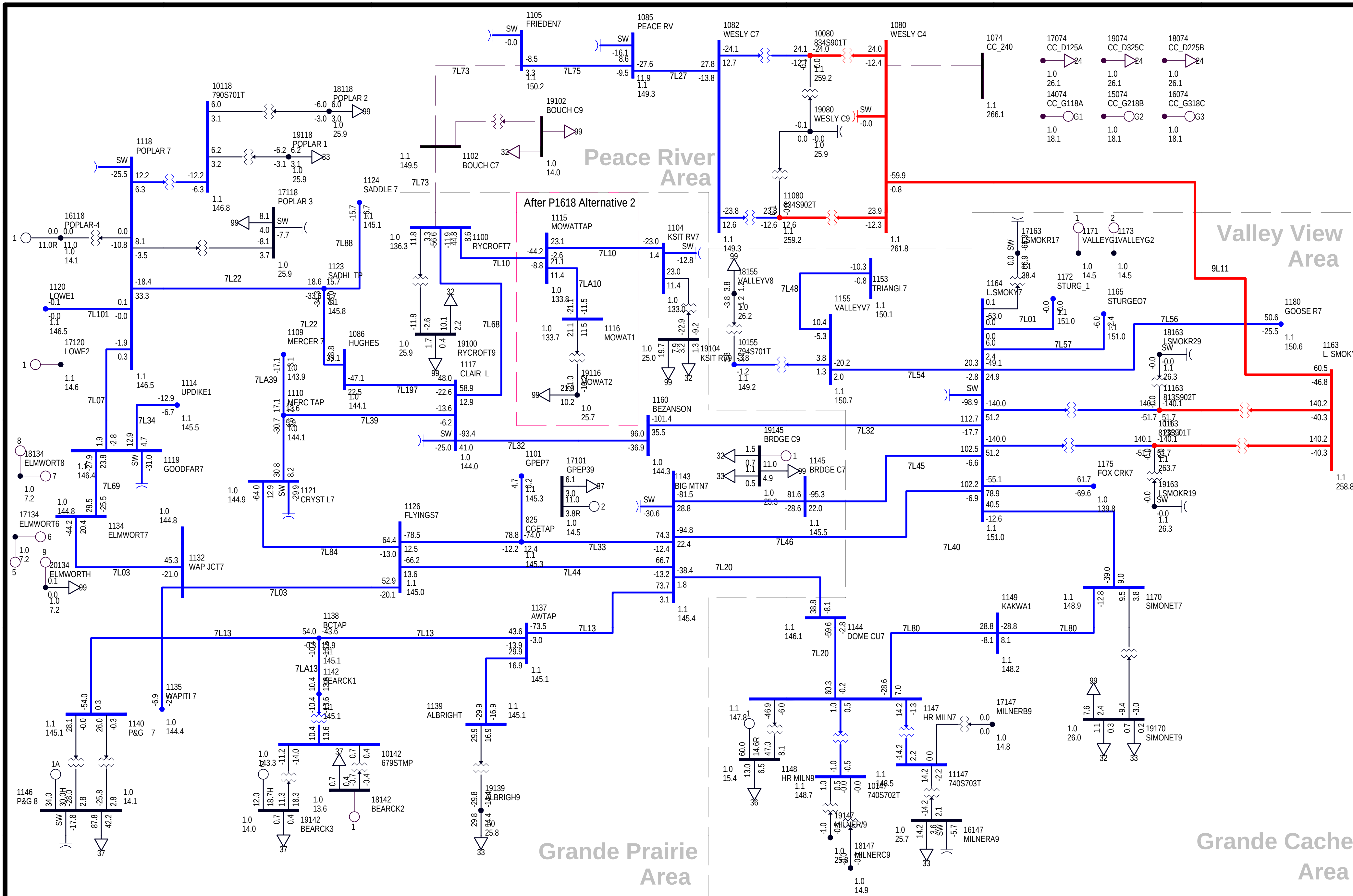


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY A, N-G-0
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Page B- 10

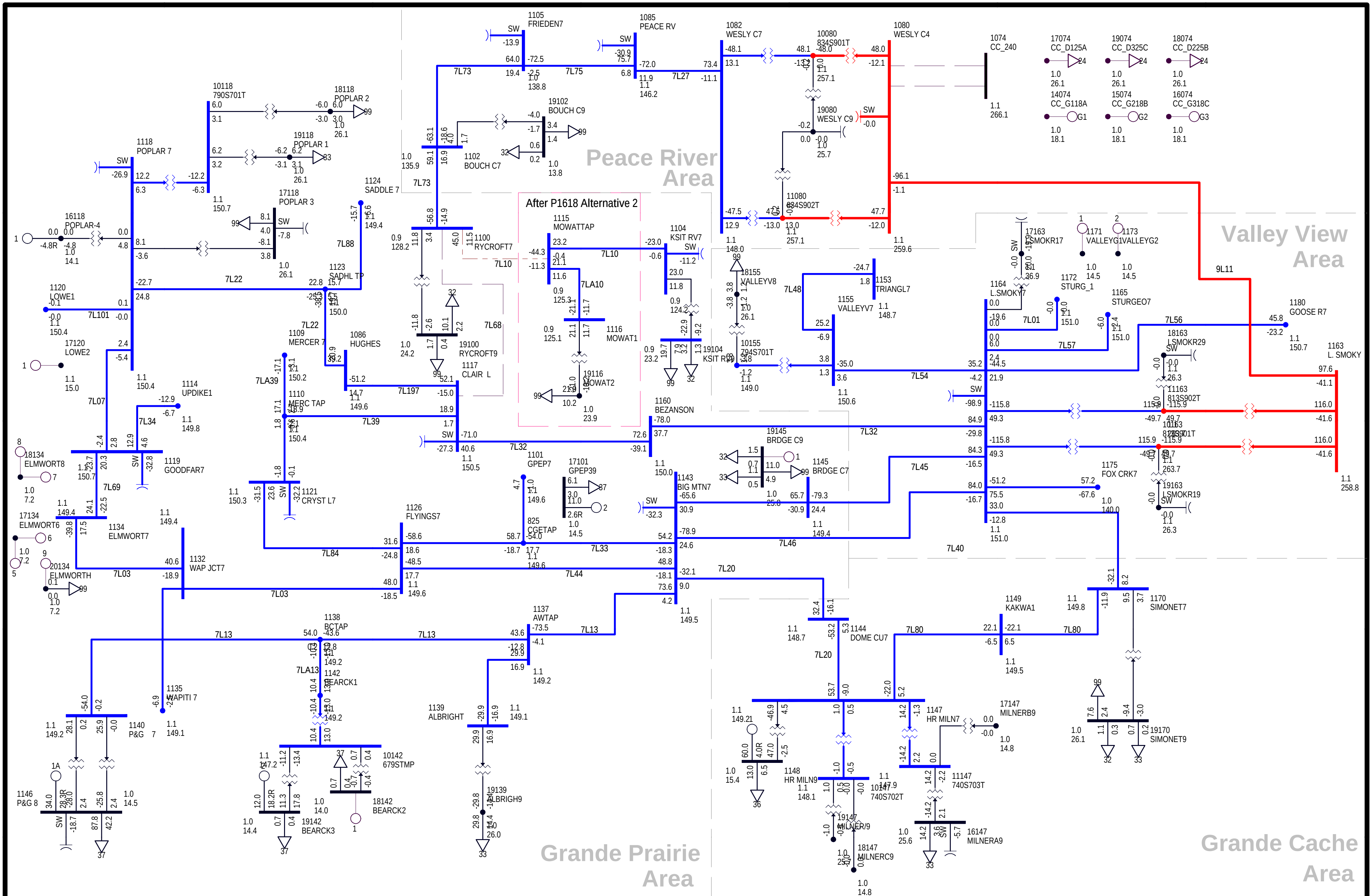
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

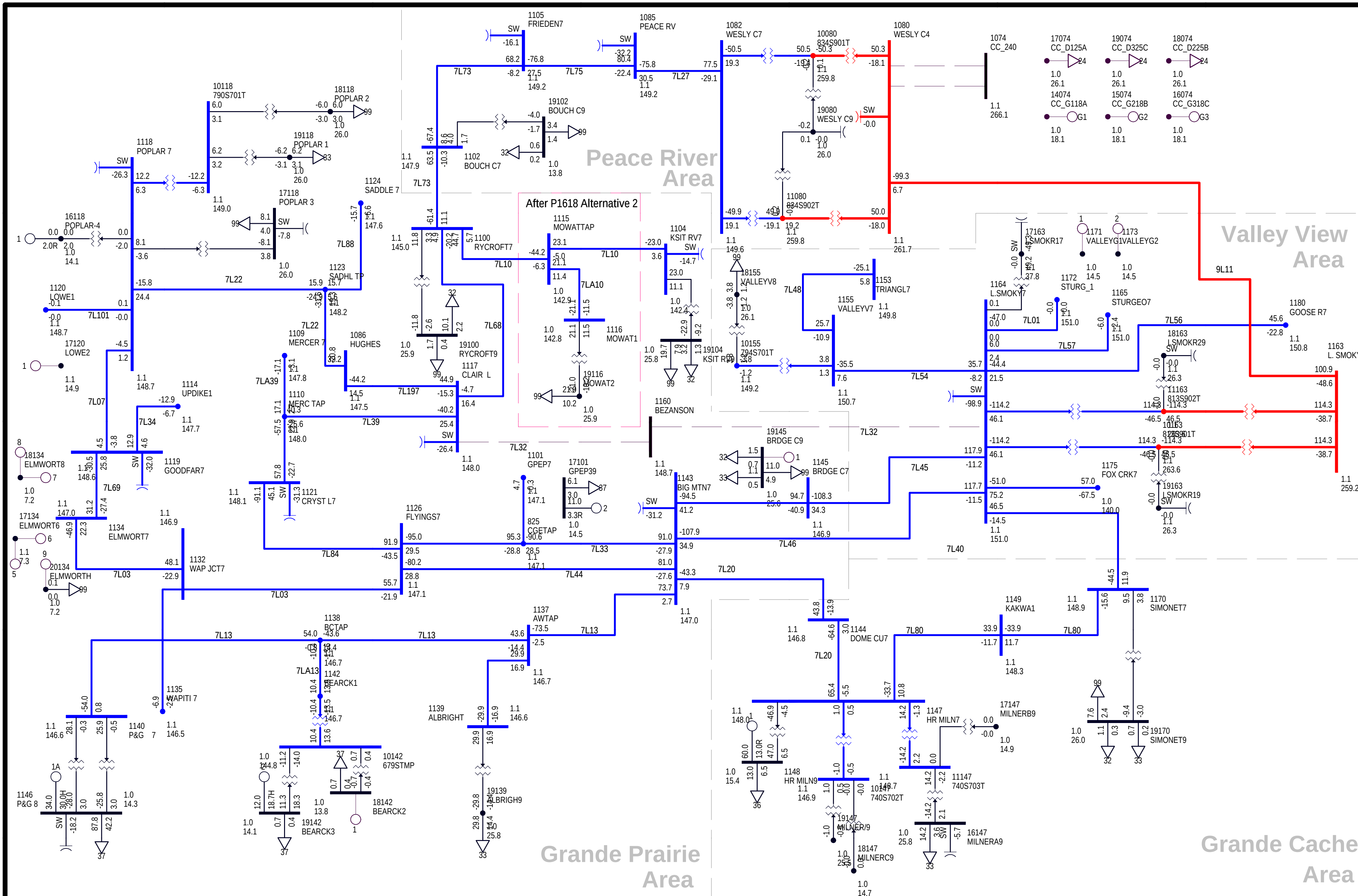


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Page B- 12

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

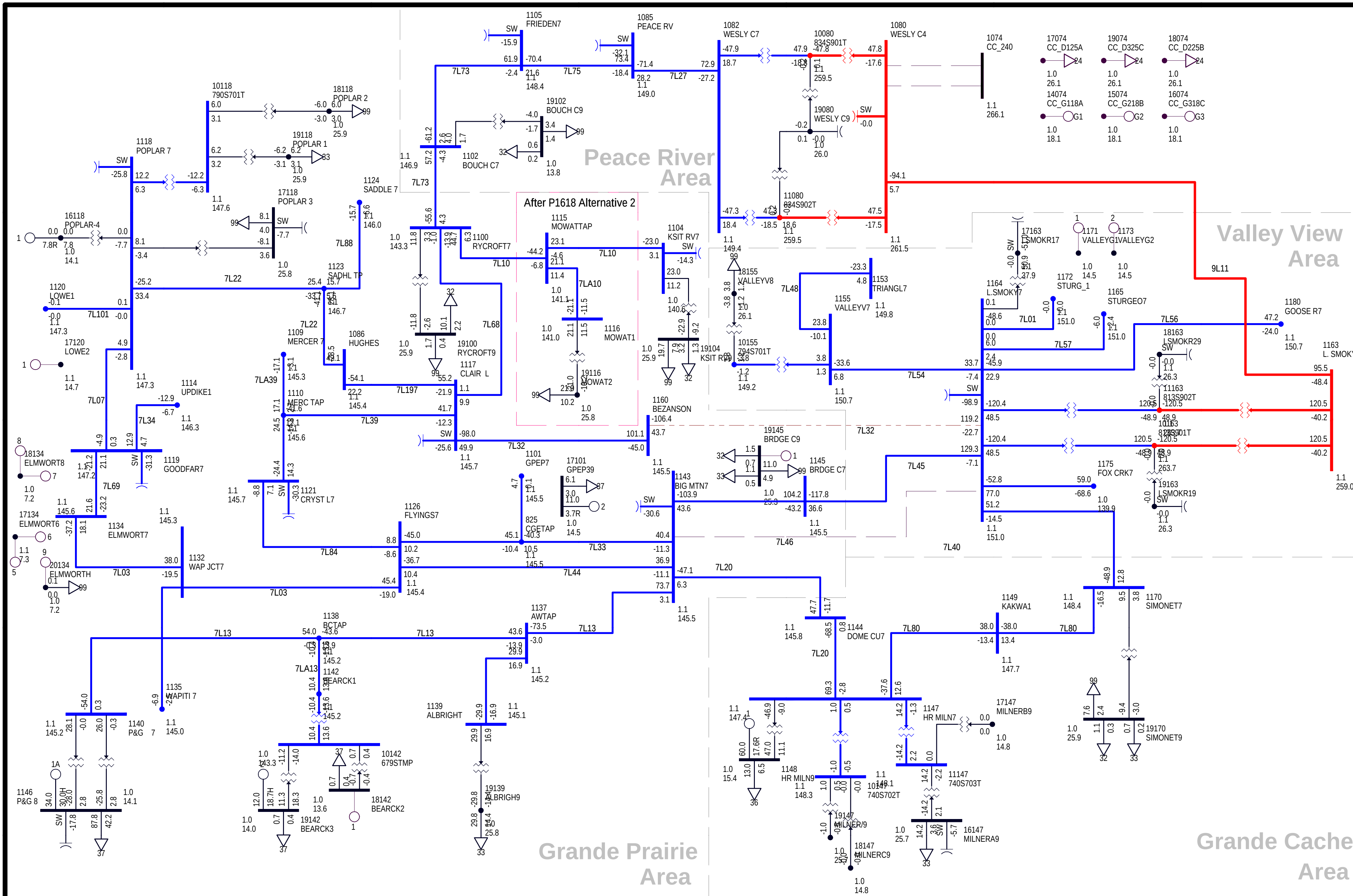


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Page B- 13

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

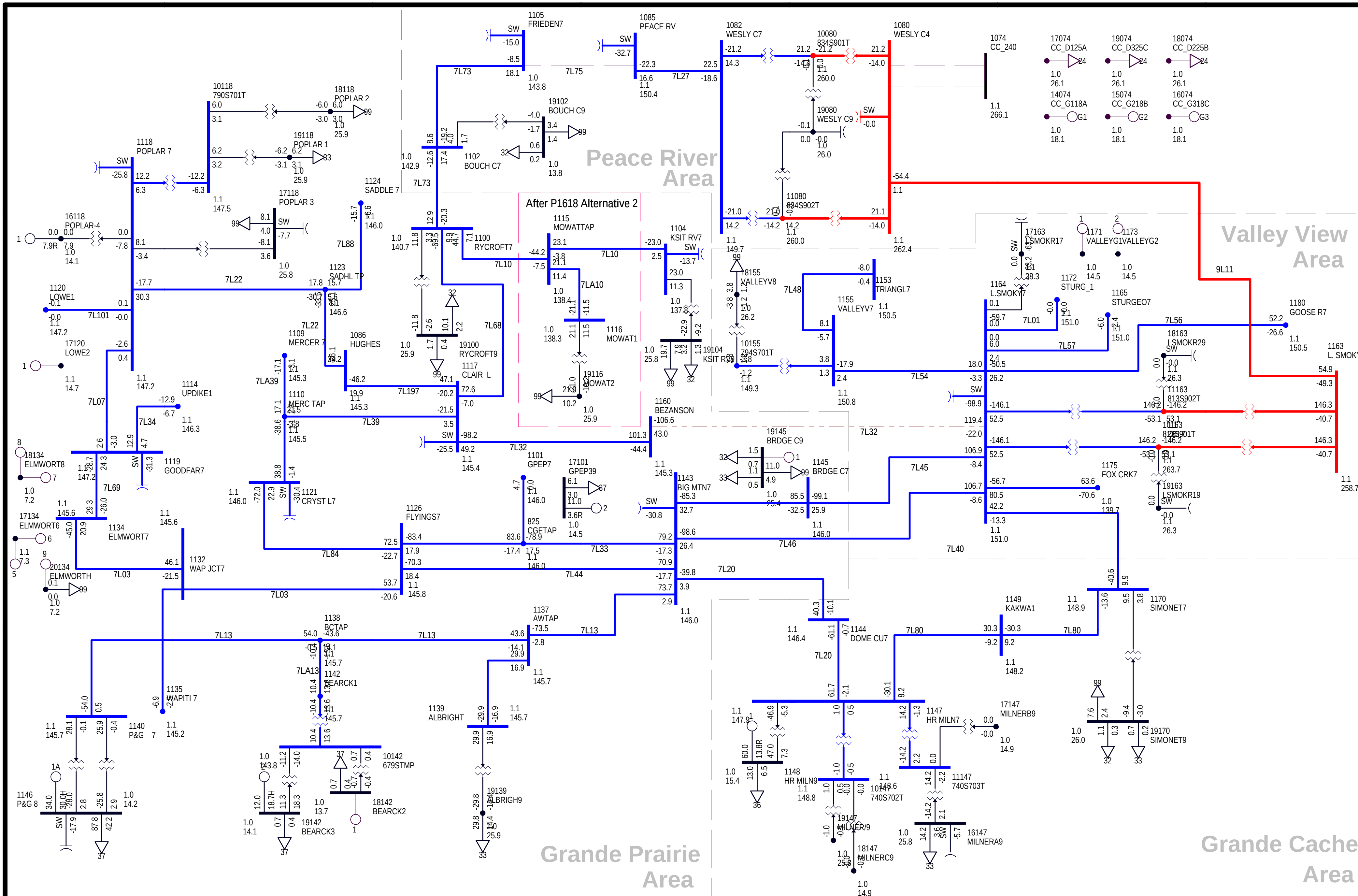


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Page B- 14

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

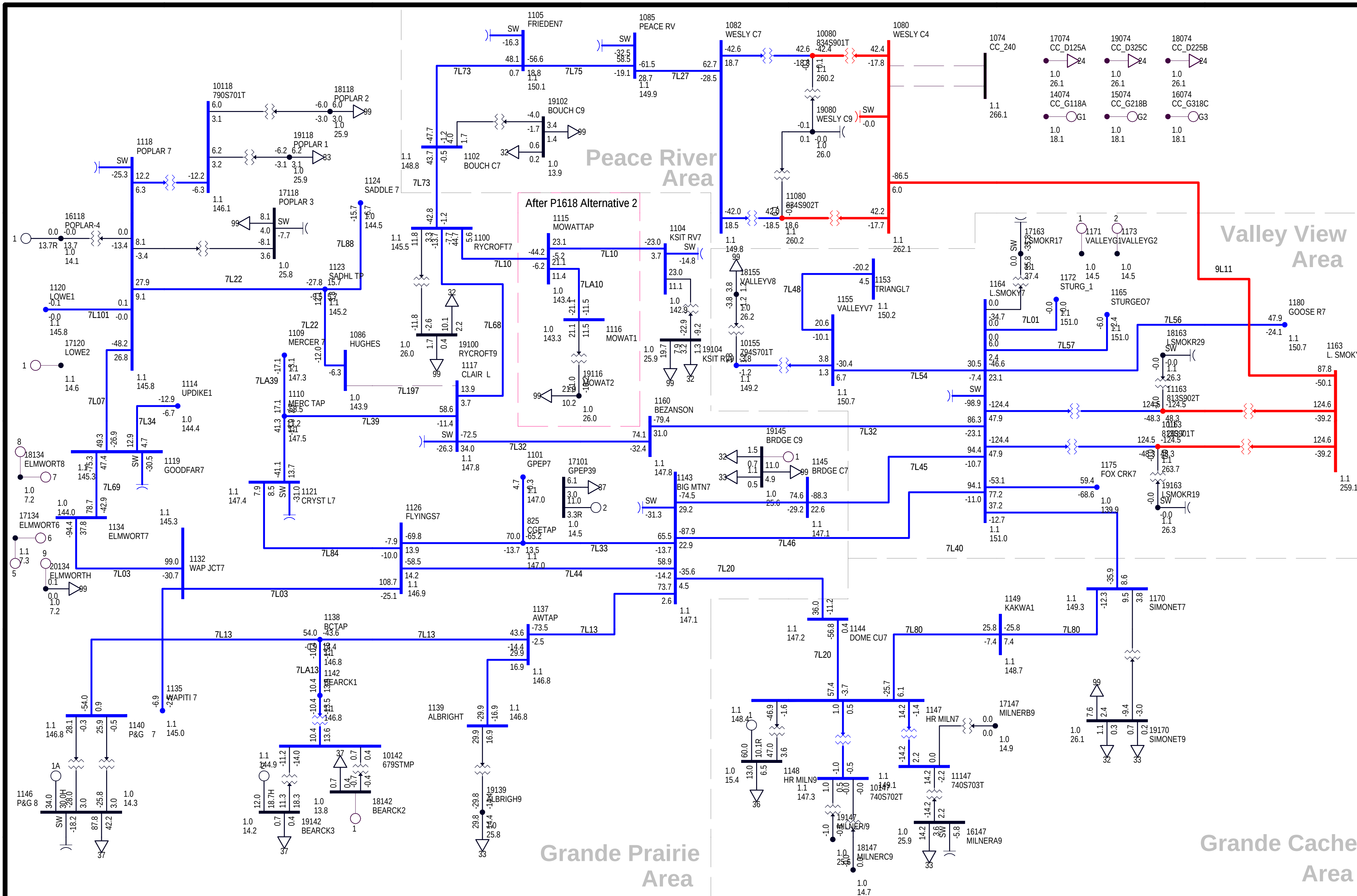


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Page B- 15

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2017 SP WITH PROJECT - ALTERNATIVE 2
WED, FEB 10 2016 14:14

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

ATTACHMENT C

Post-Project Alternative 2 With Two 144 kV Capacitor Banks at Mowat 2033S (10 and 15 MVAr): System Power Flow Plots

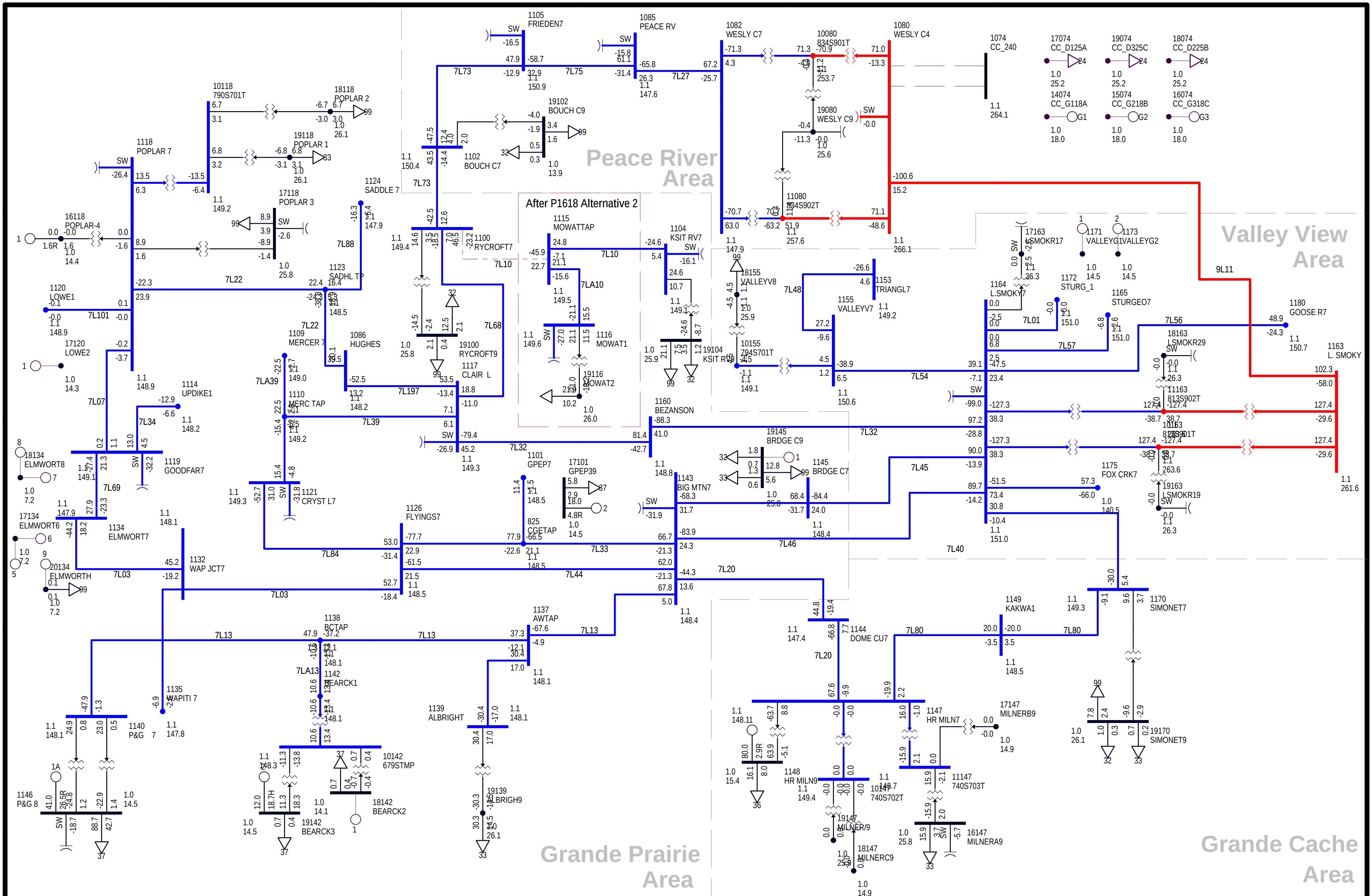
System Power Flow Results

Power Flow Diagrams

Power flow diagrams for Category A and selected B contingencies are provided in this section for the post-Project alternative 2 with two 144 kV capacitor banks at Mowat 2033S (10 and 15 MVAr). The following table presents the list of the power flow diagrams. Please note that Lowe Lake generator is turned off for the analyzed case.

Table C-1: List of post-Project power flow diagrams

Scenario	Power flow diagram	Page number
2016 WP	N-G-0, System Normal Condition	C-3
	N-G-1, Loss of 7L73	C-4
	N-G-1, Loss of 7L68	C-5
	N-G-1, Loss of 7L32	C-6
	N-G-1, Loss of 7L46	C-7
	N-G-1, Loss of 7L75	C-8
	N-G-1, Loss of 7L197	C-9
2017 SP	N-G-0, System Normal Condition	C-10
	N-G-1, Loss of 7L73	C-11
	N-G-1, Loss of 7L68	C-12
	N-G-1, Loss of 7L32	C-13
	N-G-1, Loss of 7L46	C-14
	N-G-1, Loss of 7L75	C-15
	N-G-1, Loss of 7L197	C-16

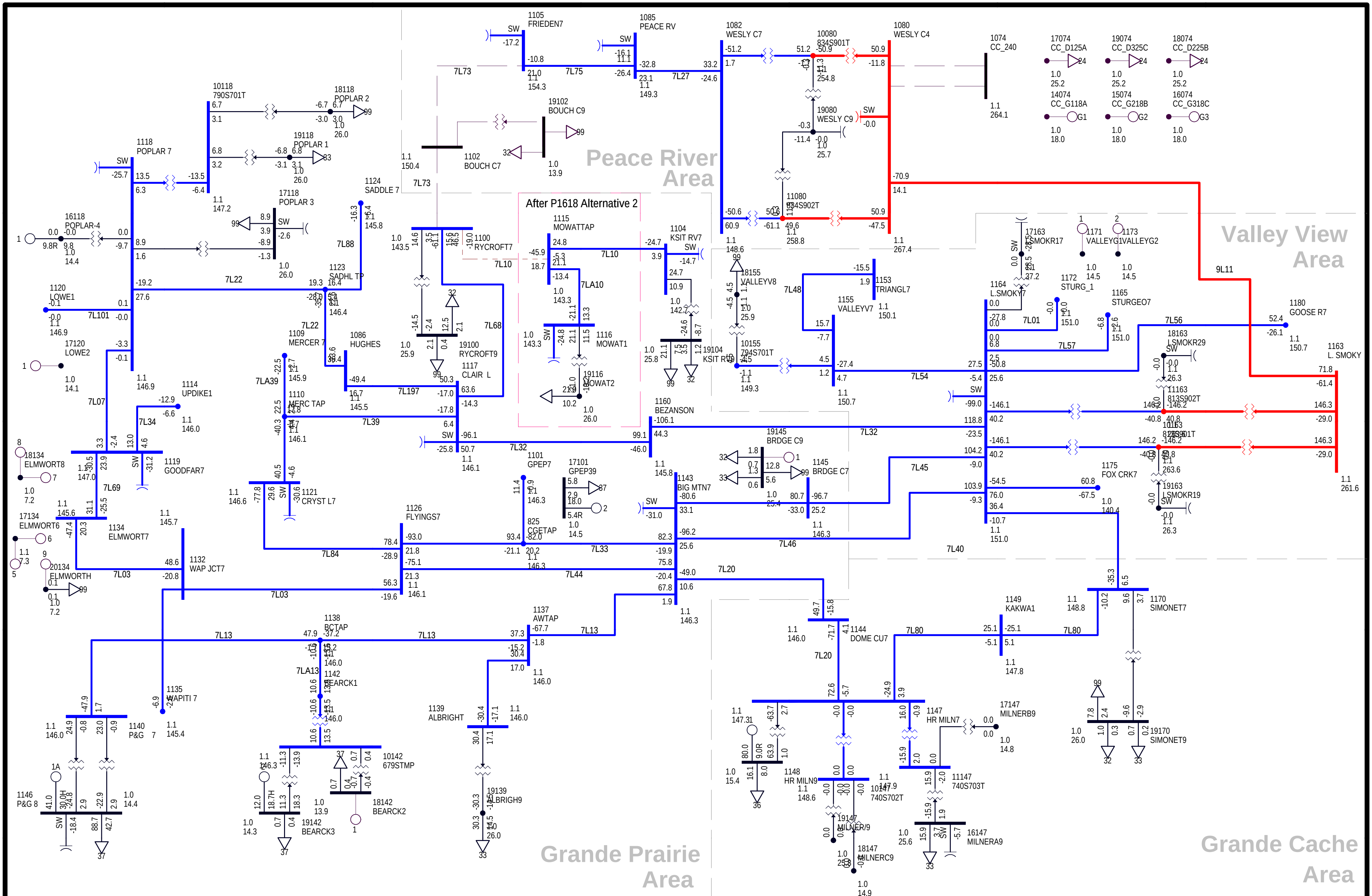


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY A, N-G-0
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

Page C- 3

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

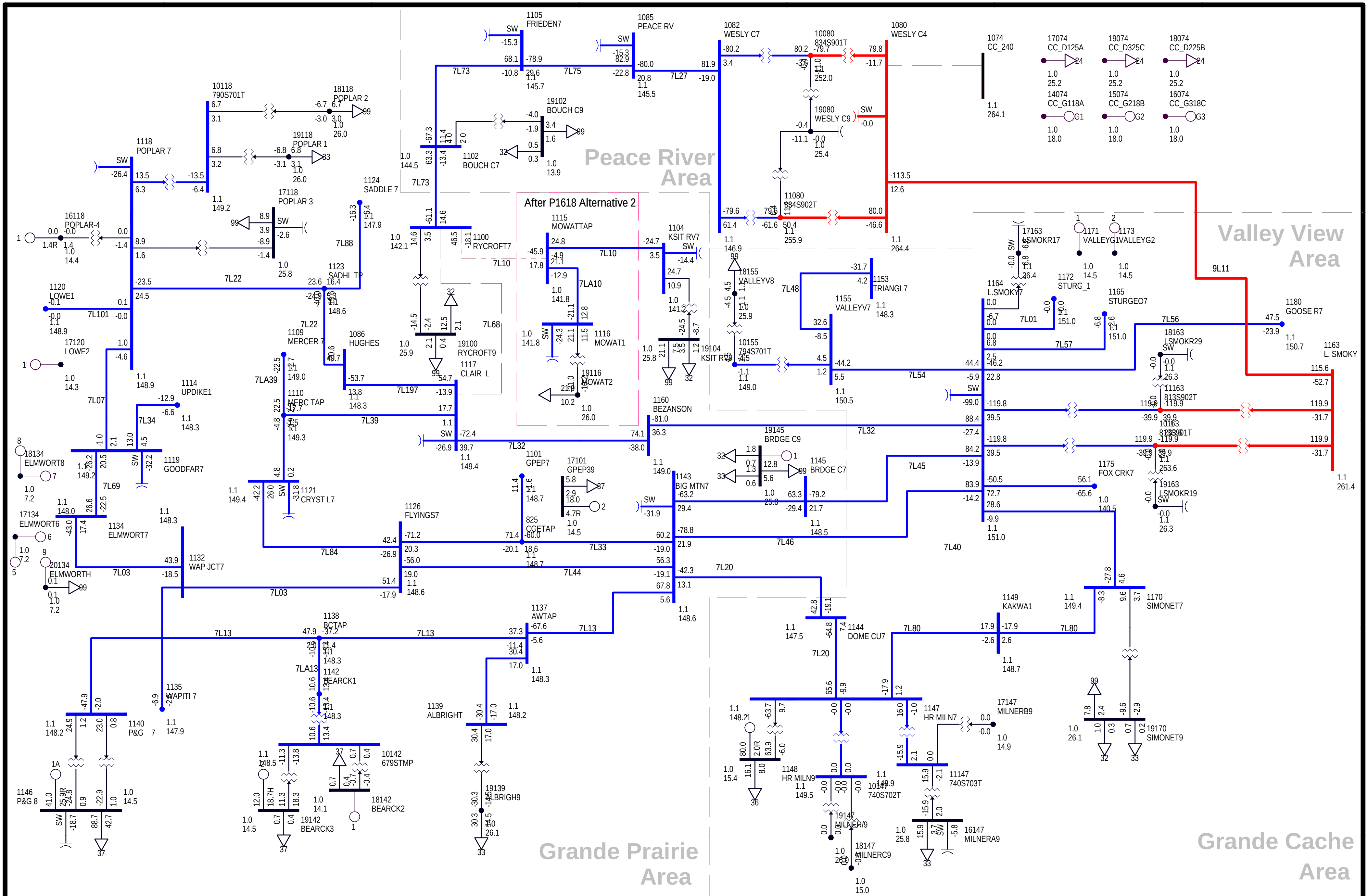


P1618 - Spirit River new POD (Mowatt 2033S)

CATEGORY B, LOSS OF 7L73
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

Page C- 4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

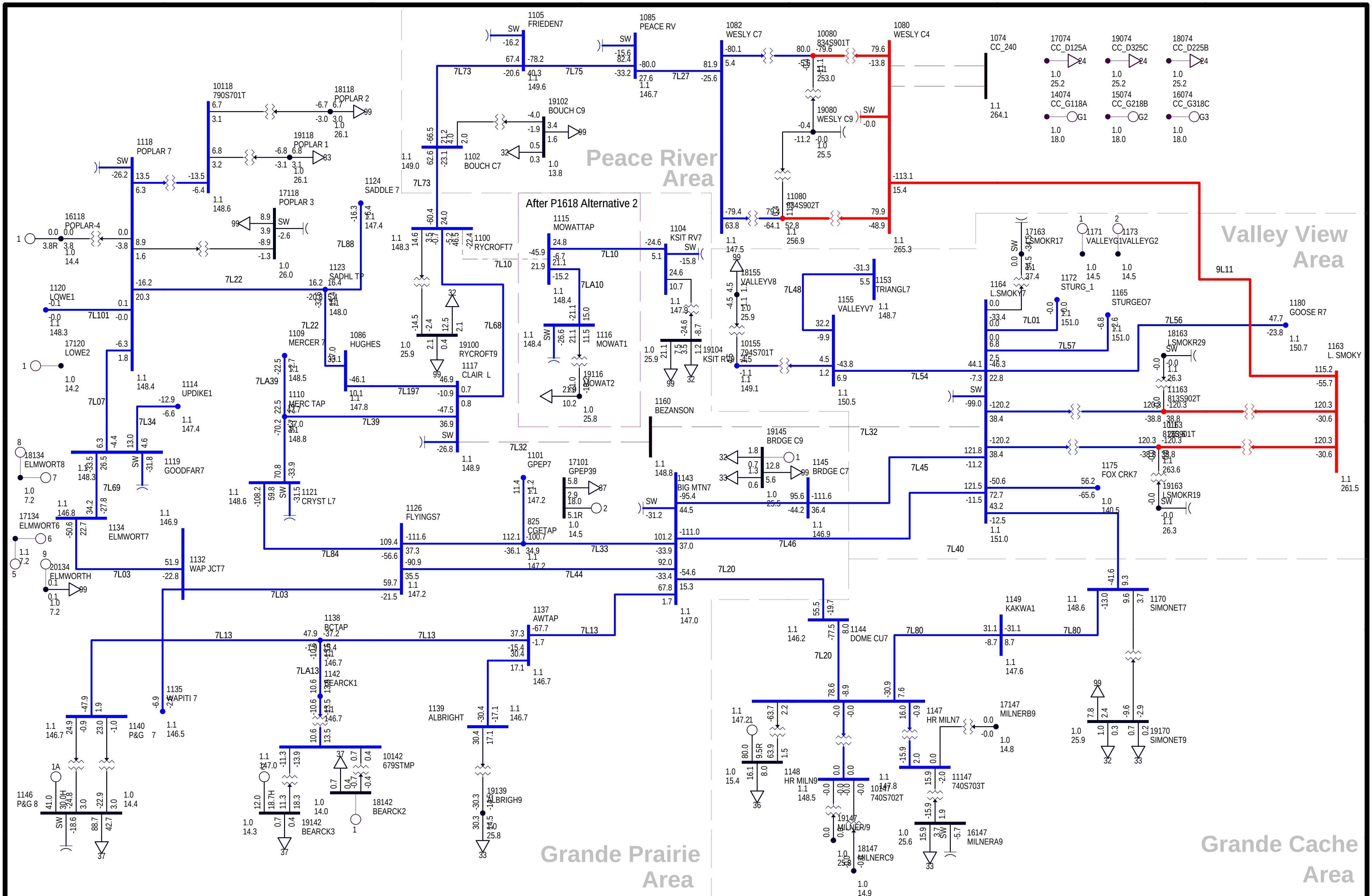


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

Page C- 5

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

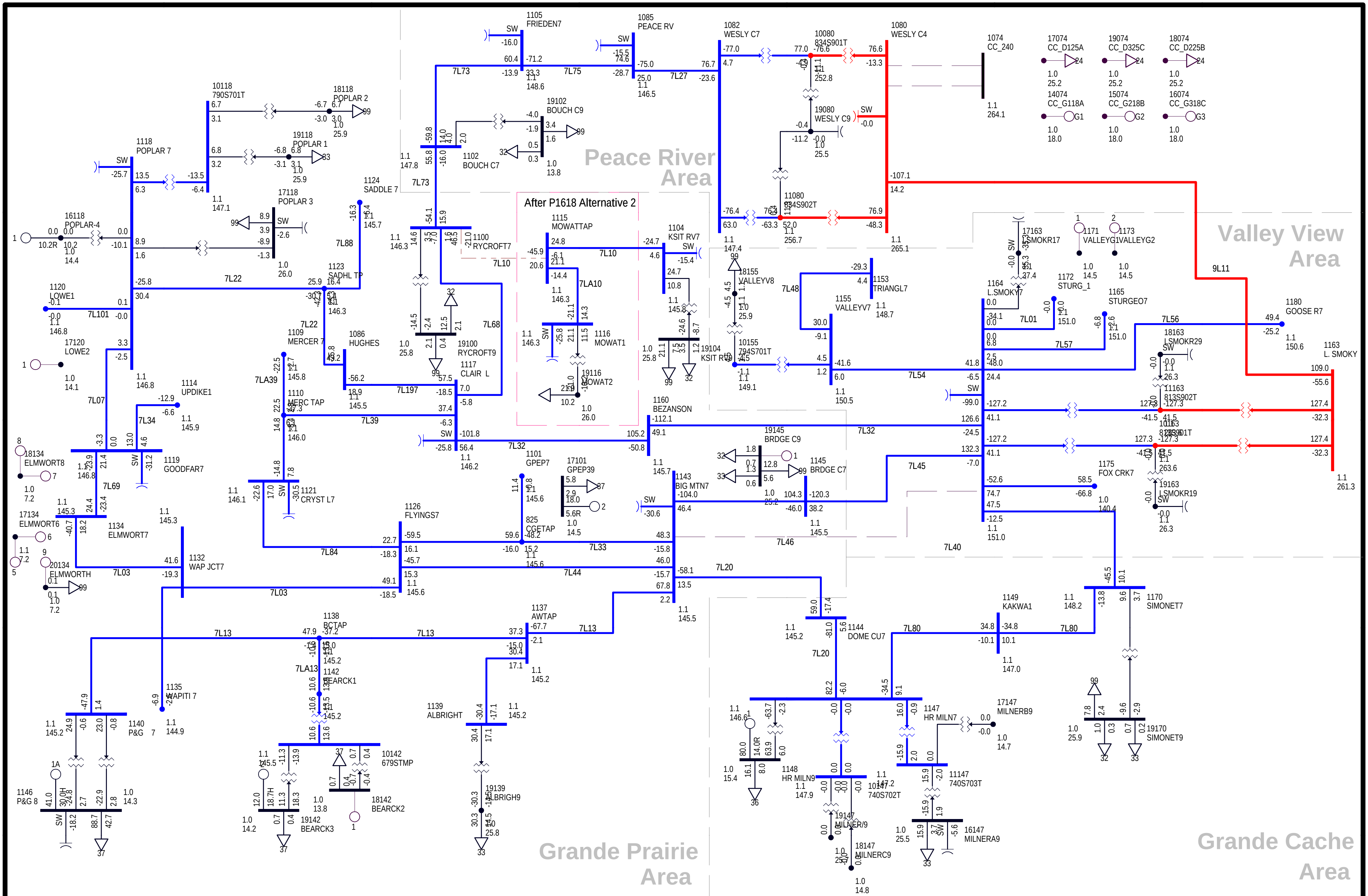


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

Page C- 6

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

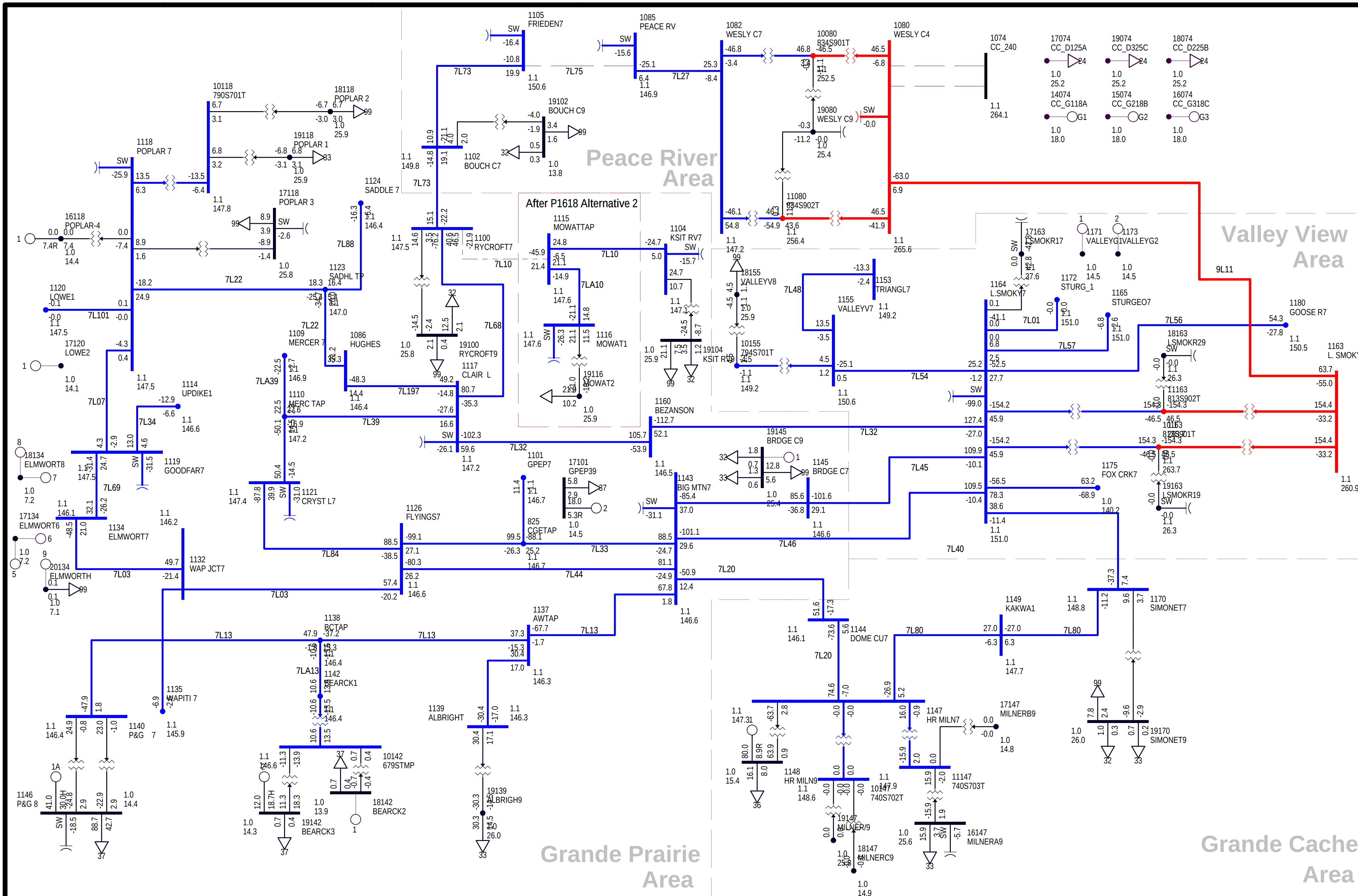


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

Page C- 7

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

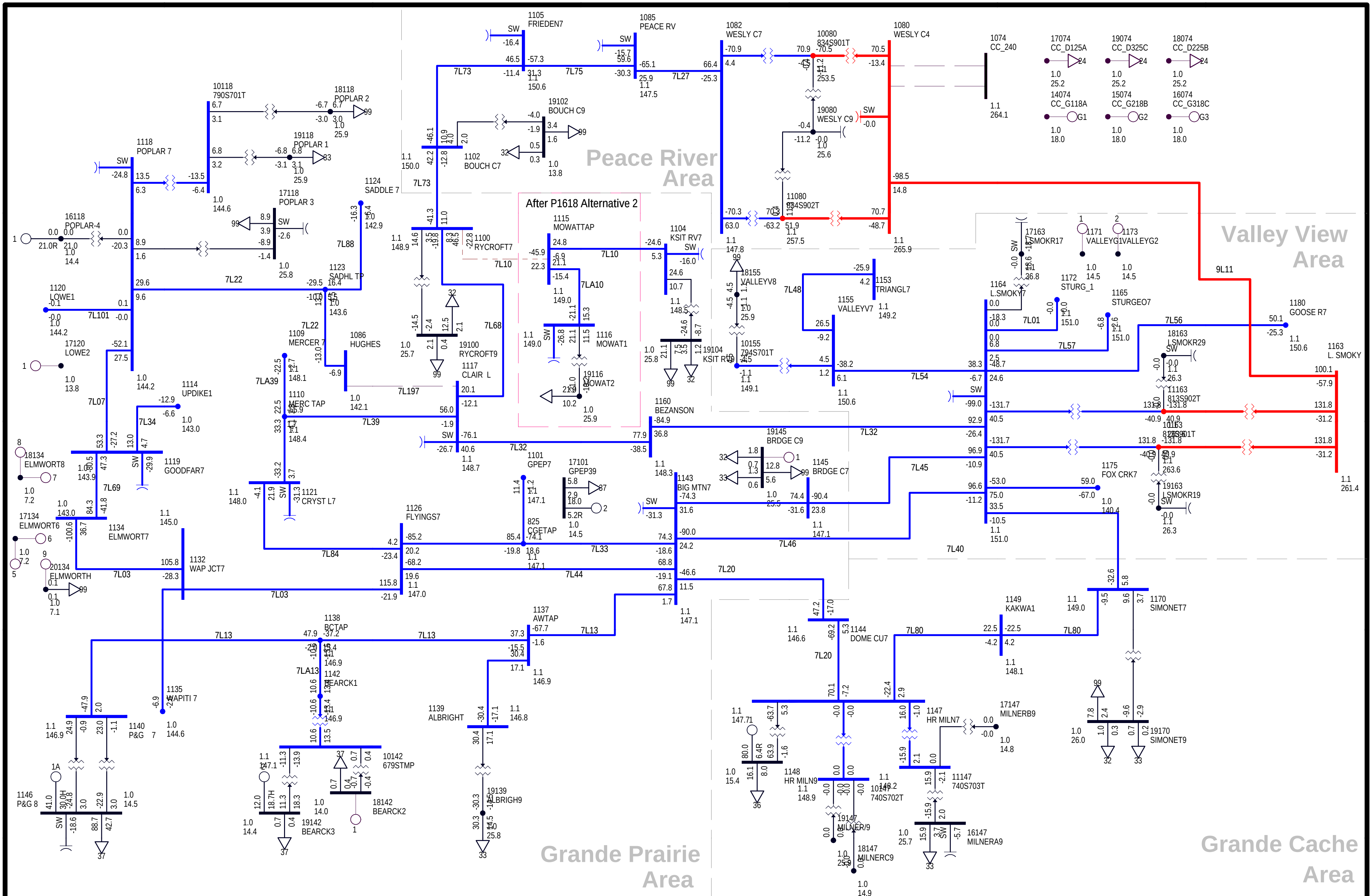


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

Page C- 8

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2016 WP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:09

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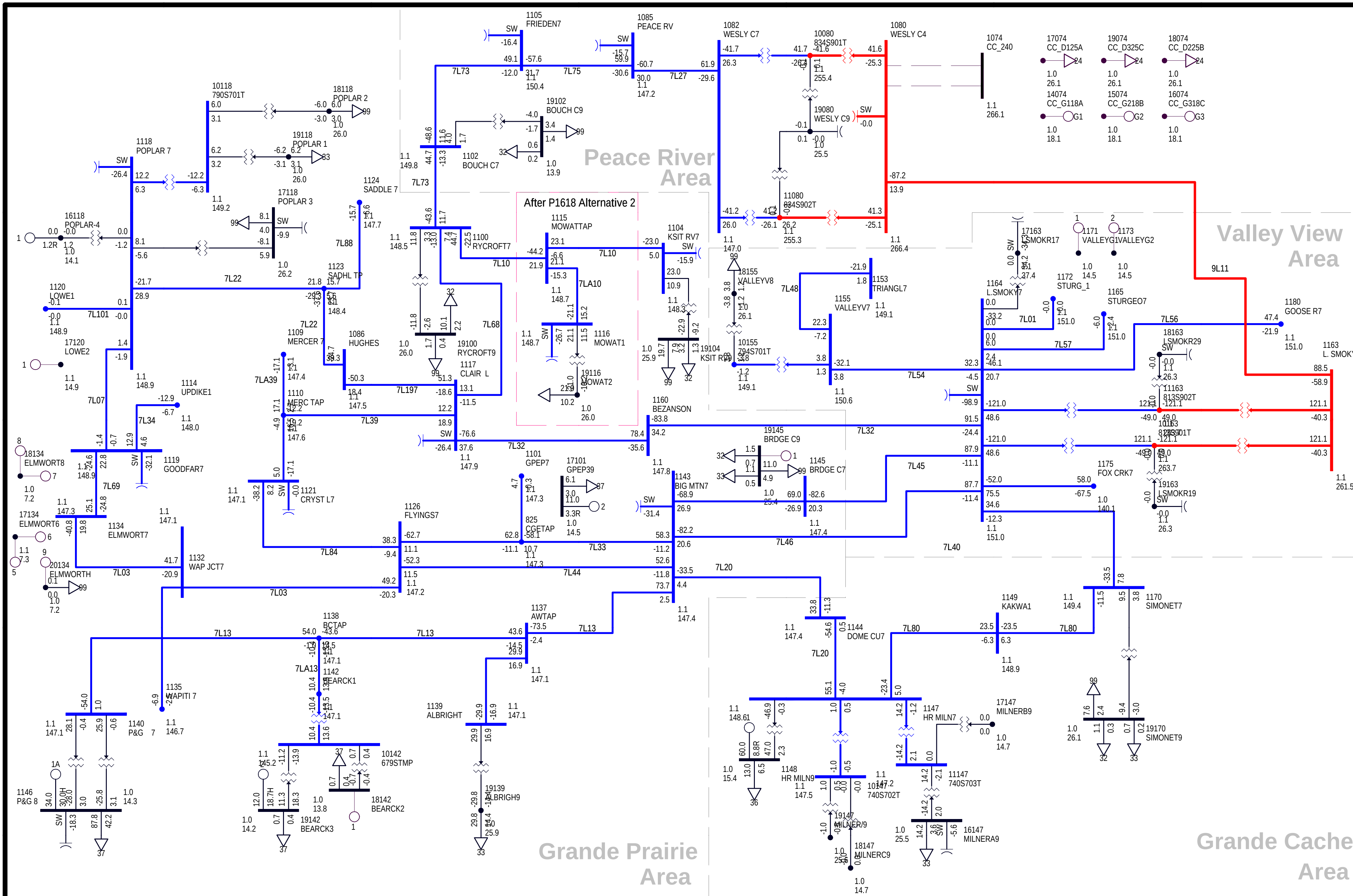
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY A, N-G-0
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

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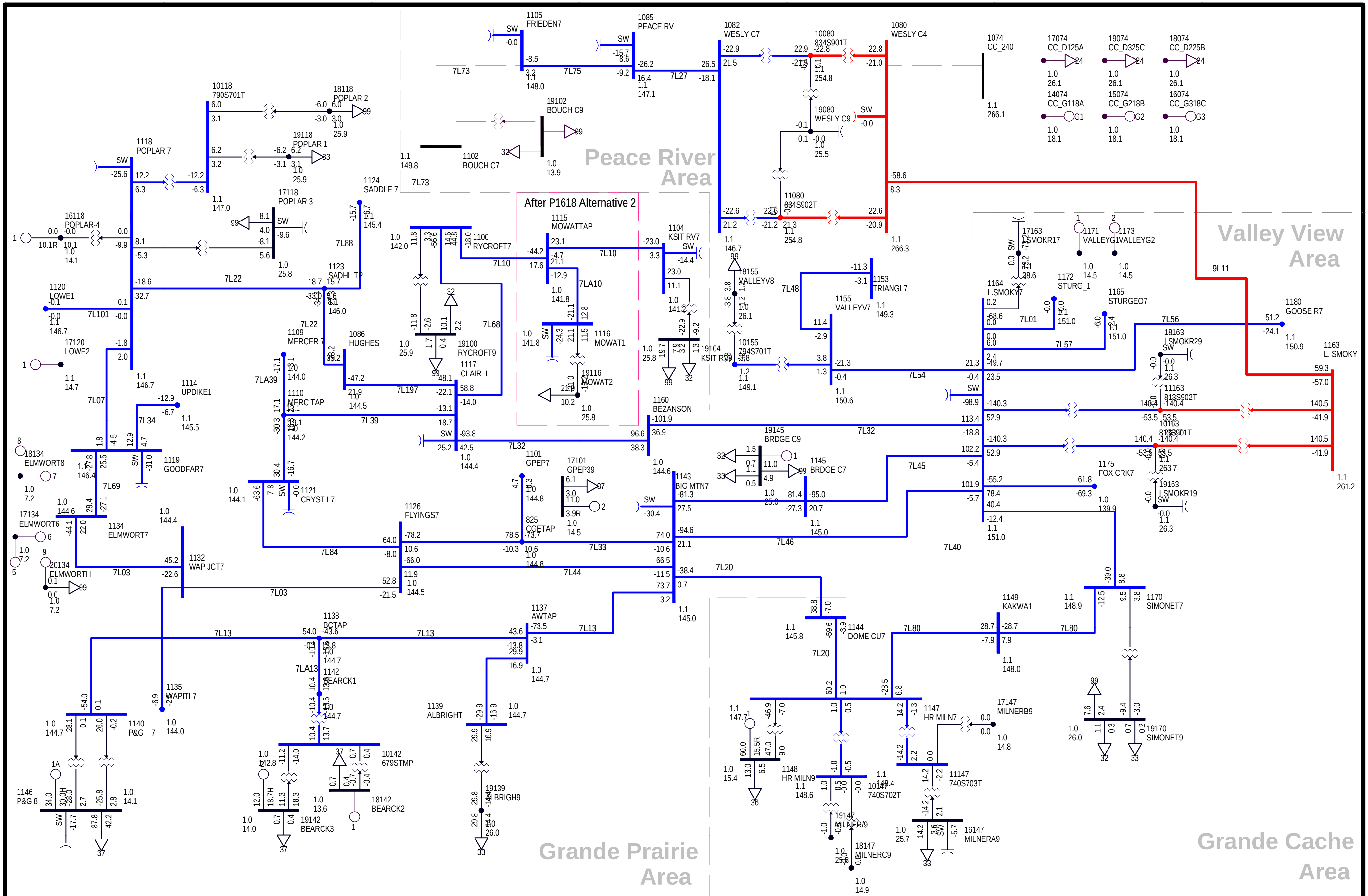
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

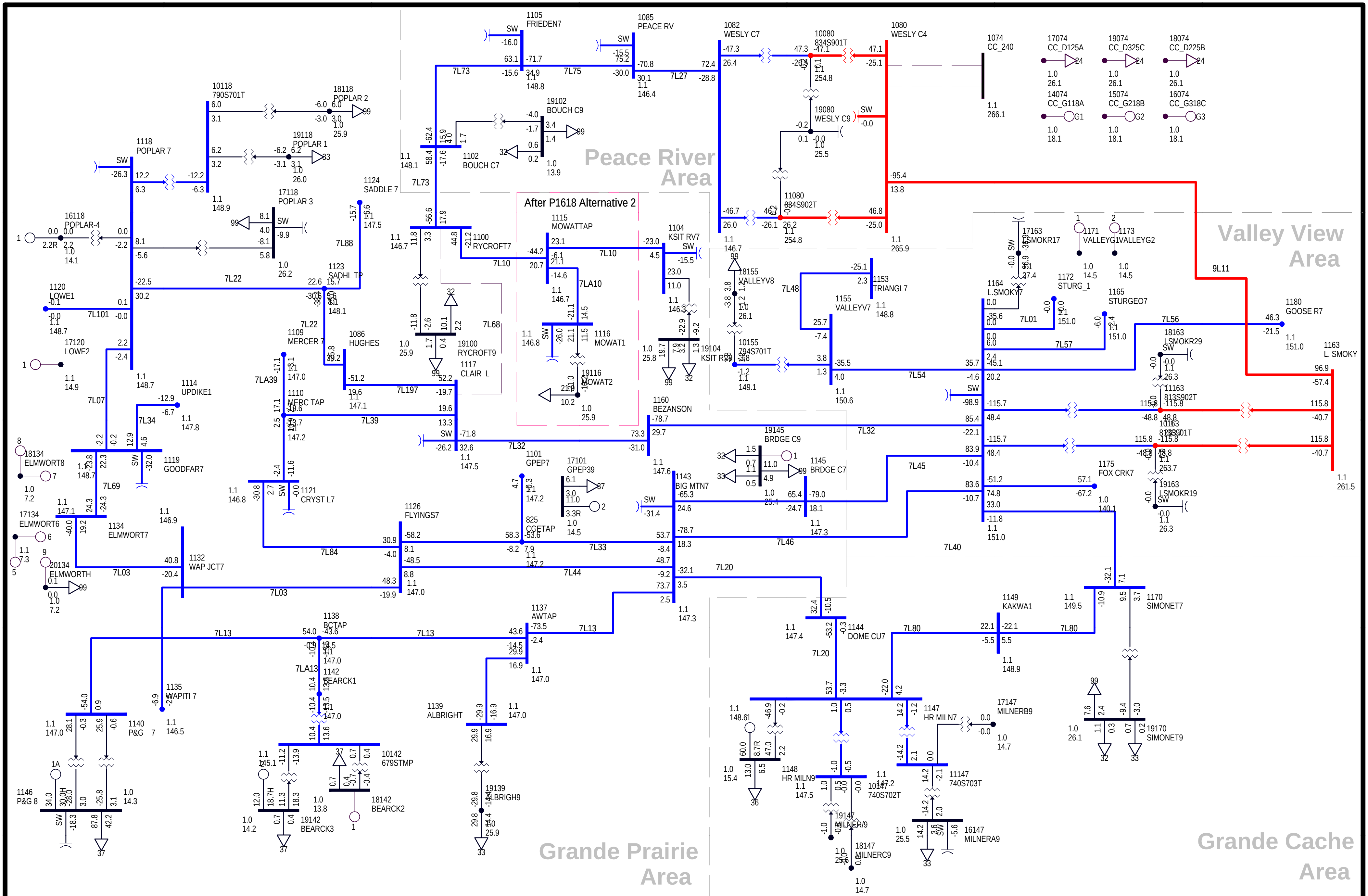


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

Page C- 11

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

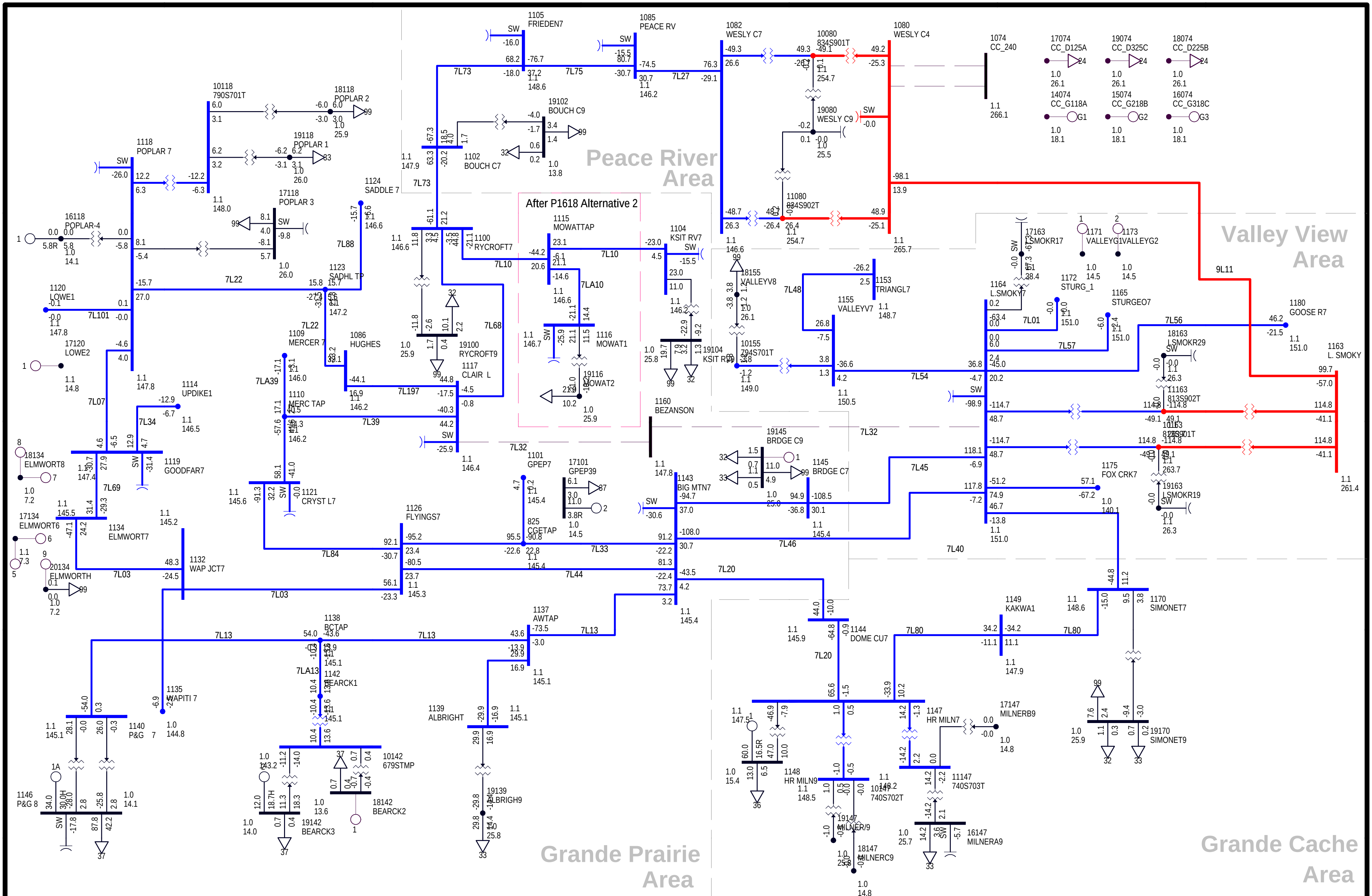


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

Page C- 12

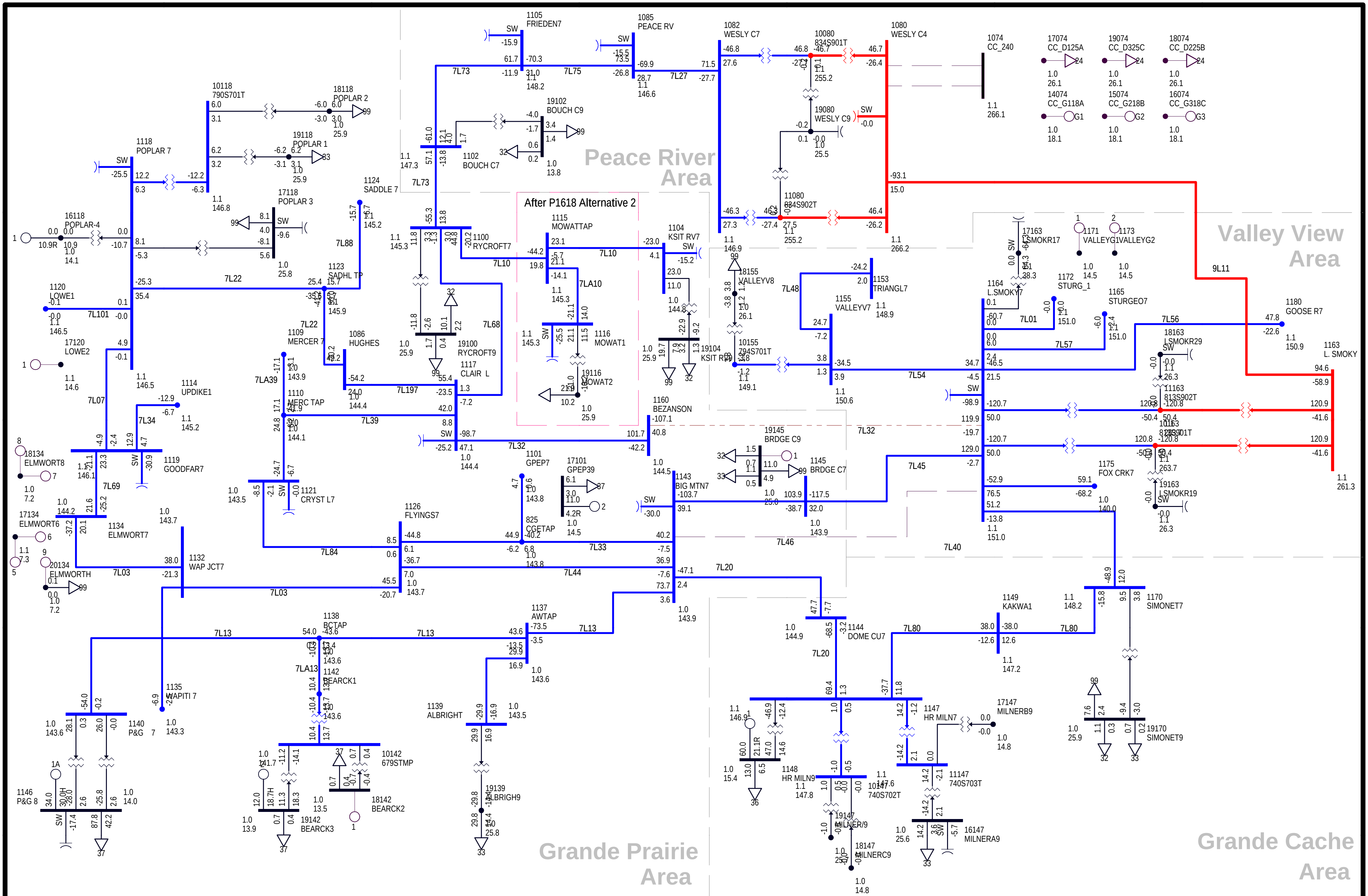
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

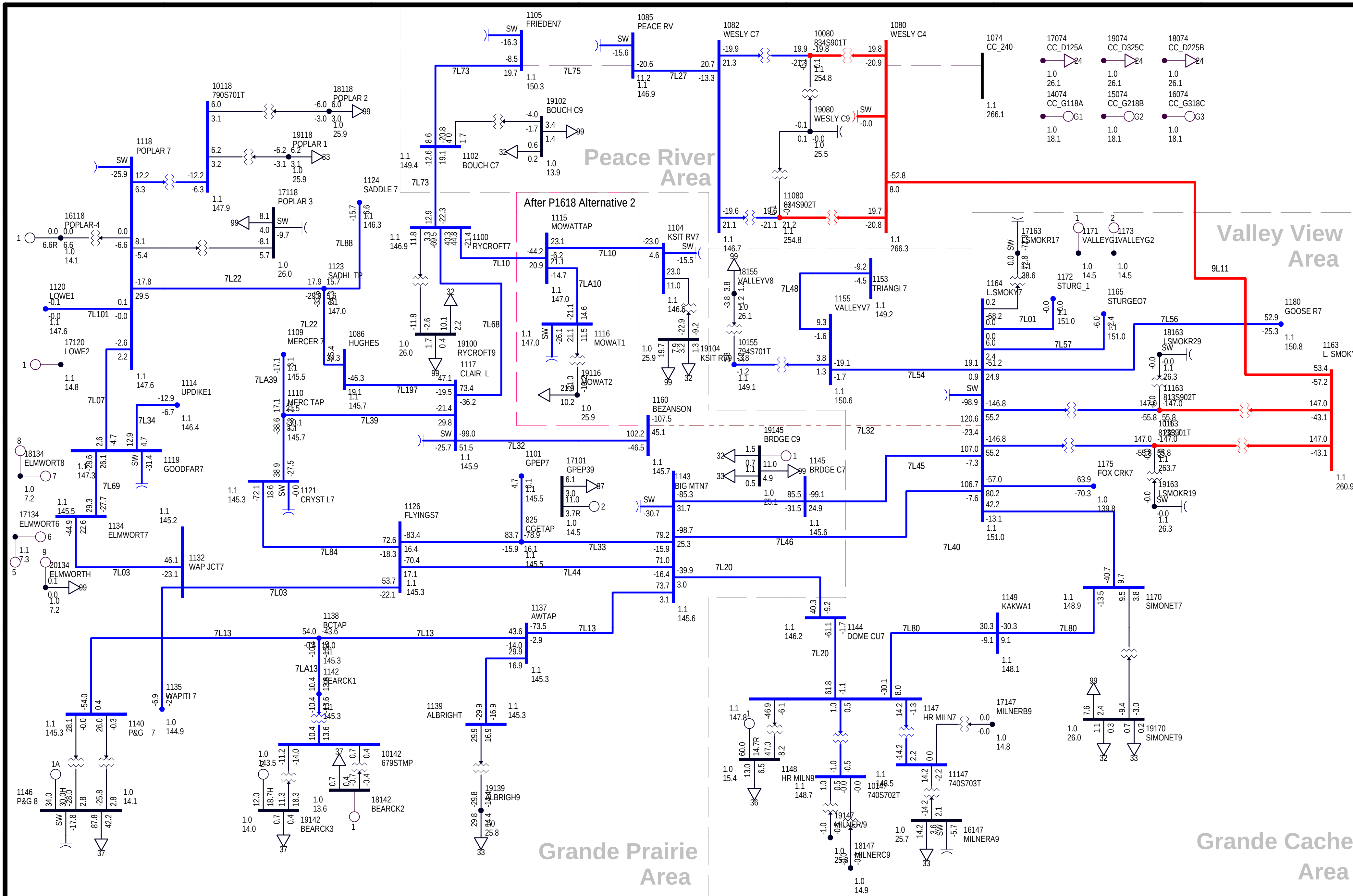
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

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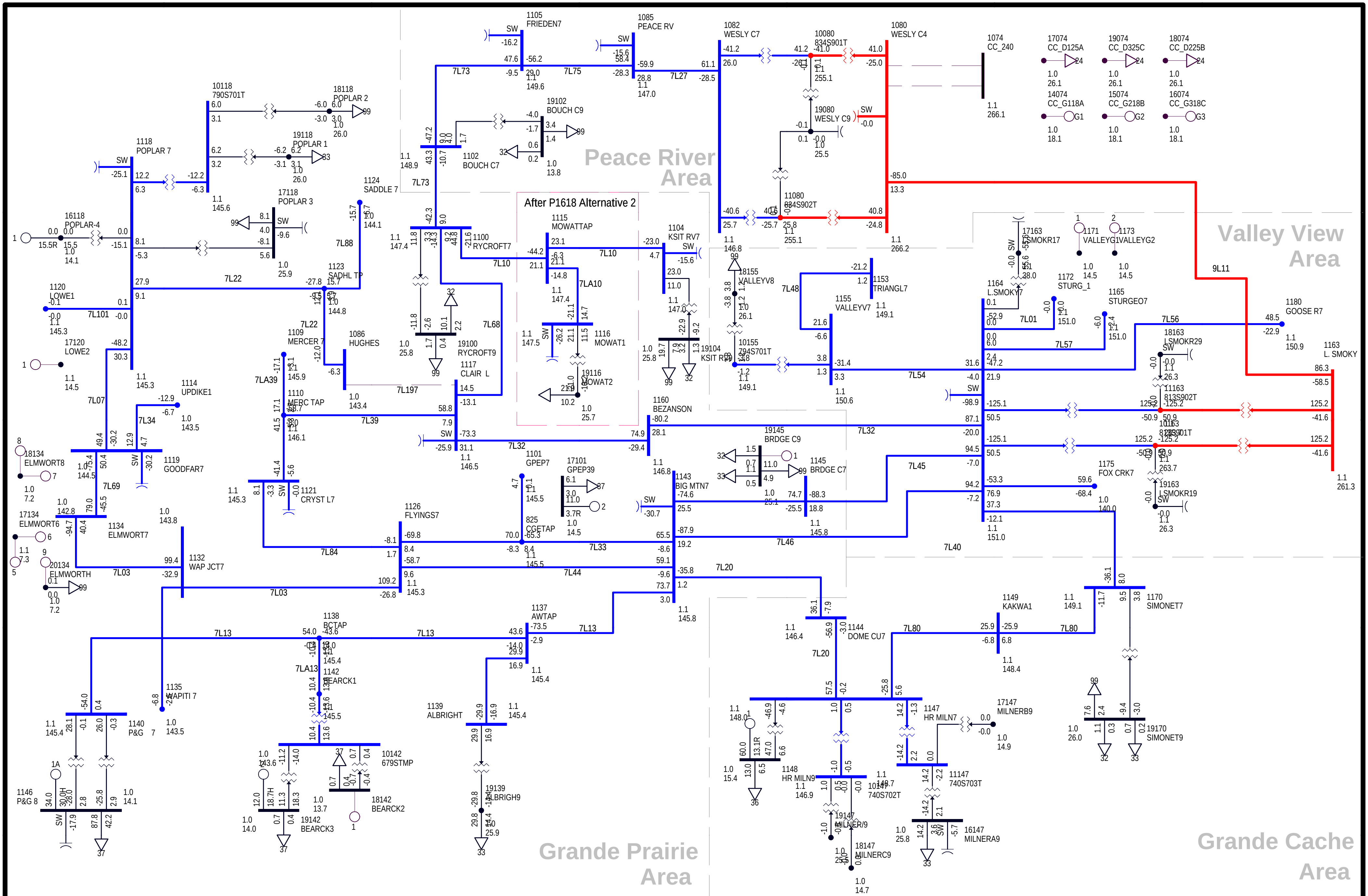
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2017 SP ALT. 2 - 10MVAR AND 15MVAR CAP BANKS AT 2033S
WED, MAR 09 2016 13:10

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Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

ATTACHMENT D

Post-Project Alternative 2 – Sensitivity Studies: System Power Flow Plots

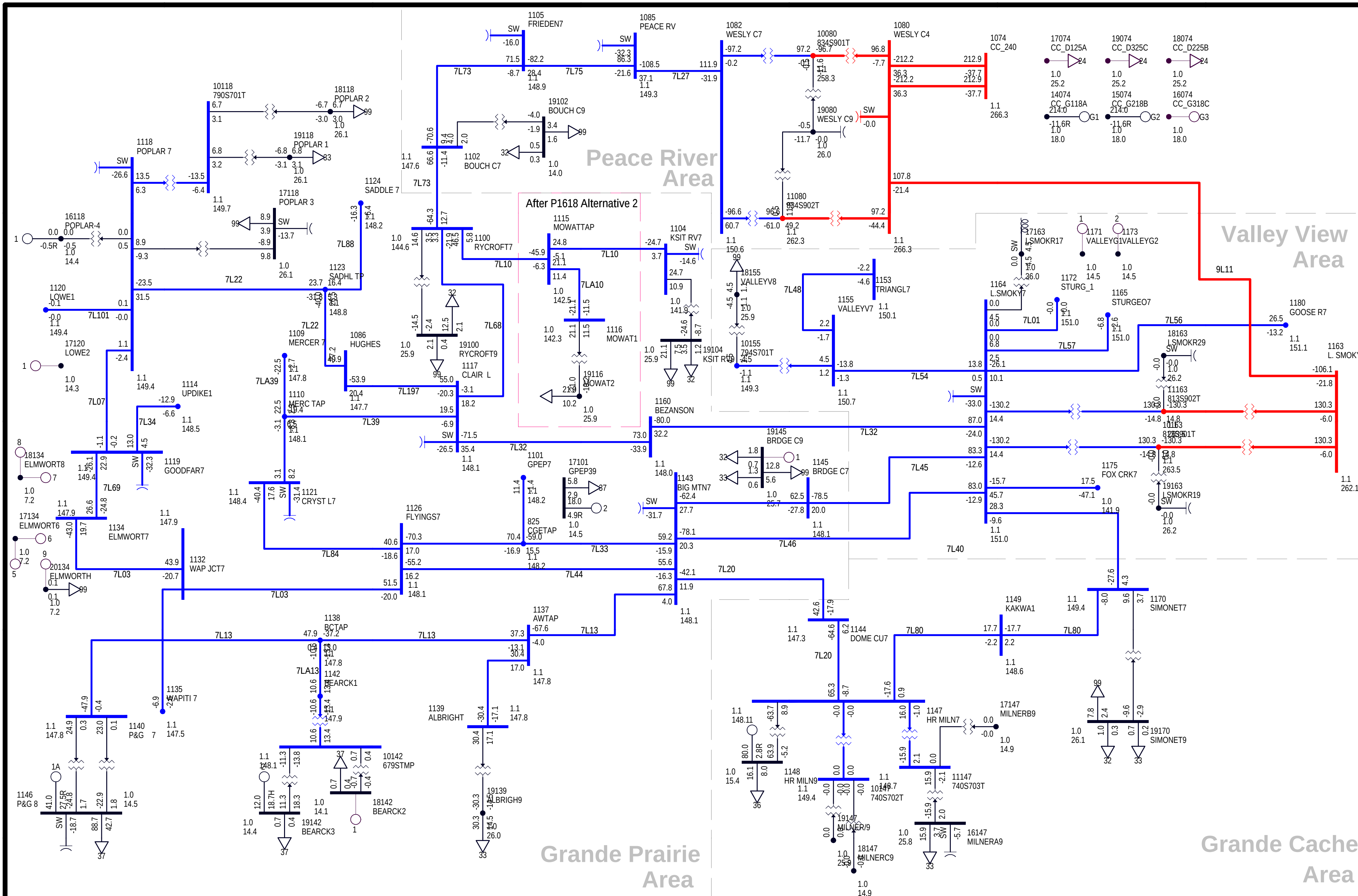
System Power Flow Results

Power Flow Diagrams

The sensitivity studies were conducted for 2016 WP and 2017 SP post-connection scenarios with Alternative 2 assuming two P1321 Shell Carmon Creek generators in-service. The following table presents the list of the power flow diagrams. Please note that Lowe Lake generator is turned off for the analyzed case.

Table D-1: List of post-Project power flow diagrams

Scenario	Power flow diagram	Page number
2016 WP	N-G-0, System Normal Condition	D-3
	N-G-1, Loss of 7L73	D-4
	N-G-1, Loss of 7L68	D-5
	N-G-1, Loss of 7L32	D-6
	N-G-1, Loss of 7L46	D-7
	N-G-1, Loss of 7L75	D-8
	N-G-1, Loss of 7L197	D-9
2017 SP	N-G-0, System Normal Condition	D-10
	N-G-1, Loss of 7L73	D-11
	N-G-1, Loss of 7L68	D-12
	N-G-1, Loss of 7L32	D-13
	N-G-1, Loss of 7L46	D-14
	N-G-1, Loss of 7L75	D-15
	N-G-1, Loss of 7L197	D-16

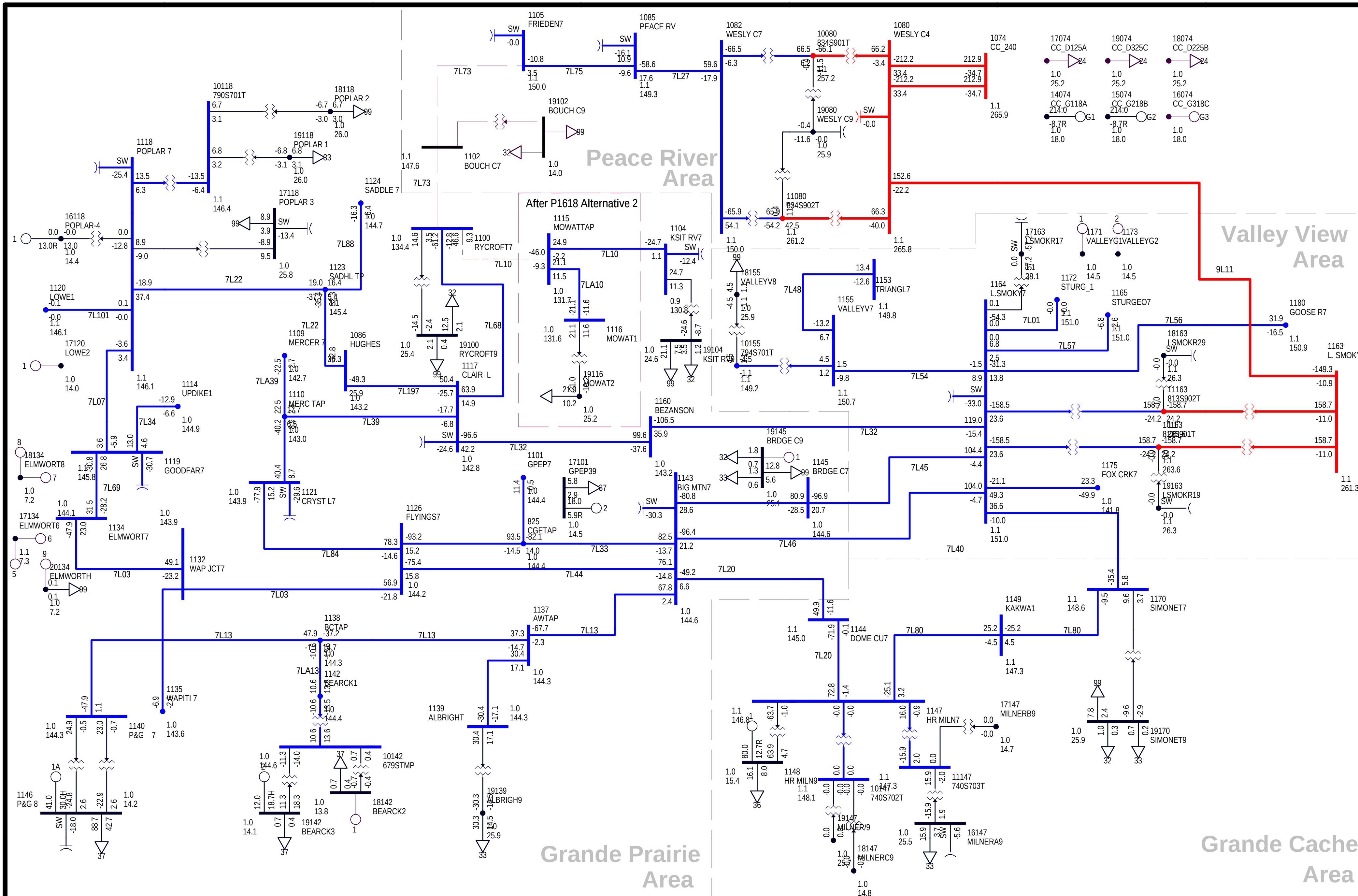


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY A, N-G-0
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02

Page D- 3

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

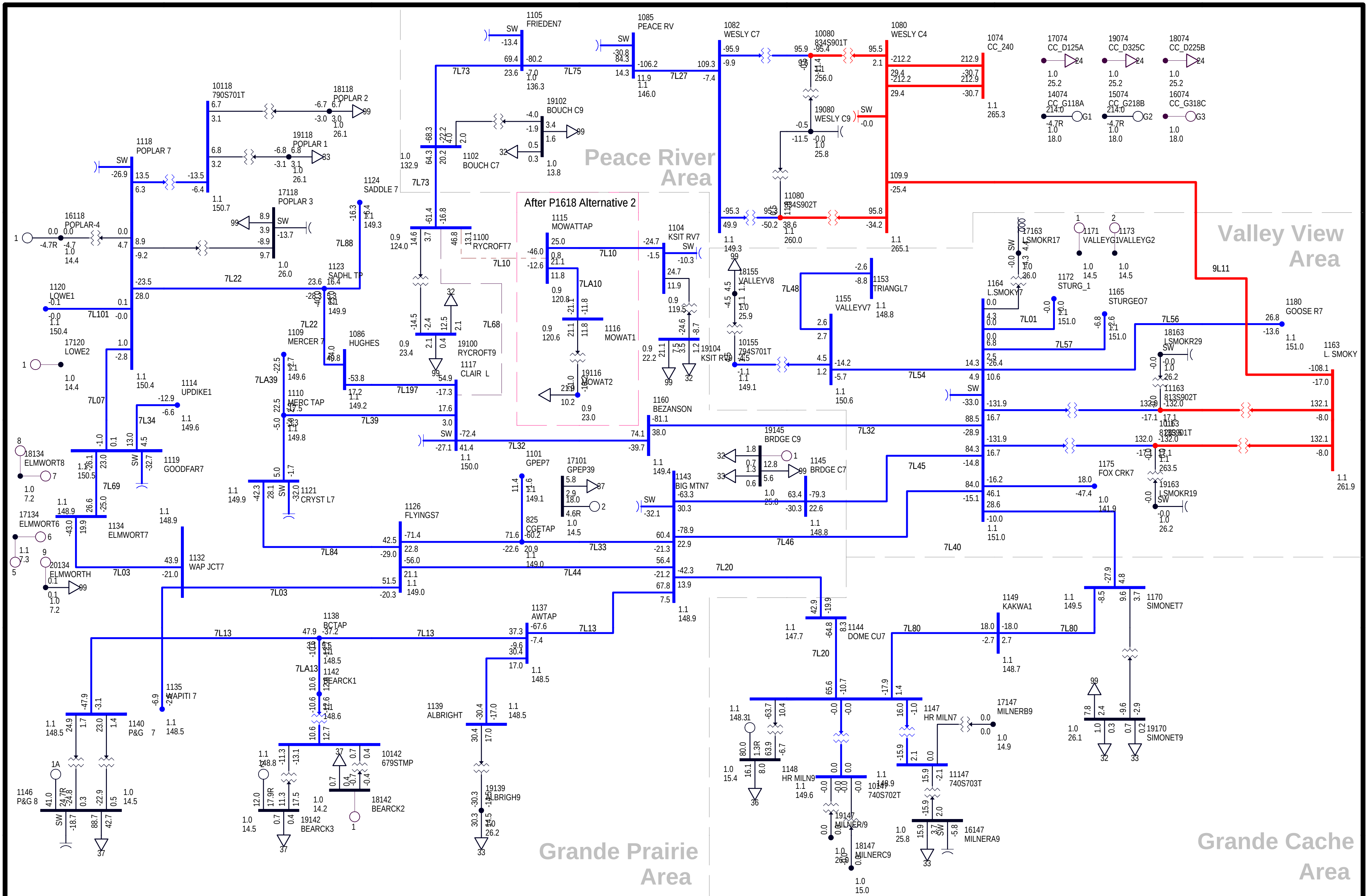


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02

Page D- 4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

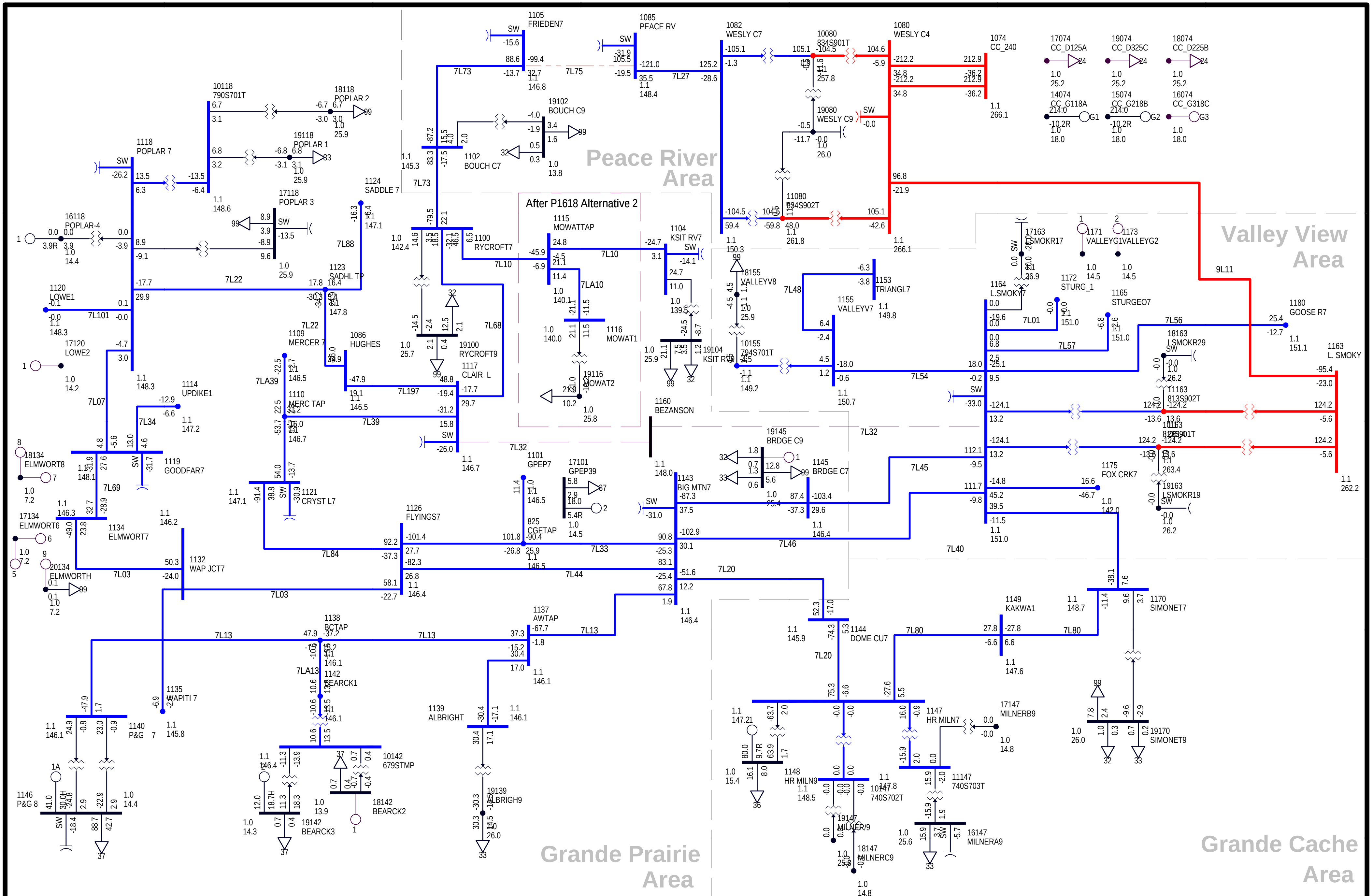


P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02

Page D- 5

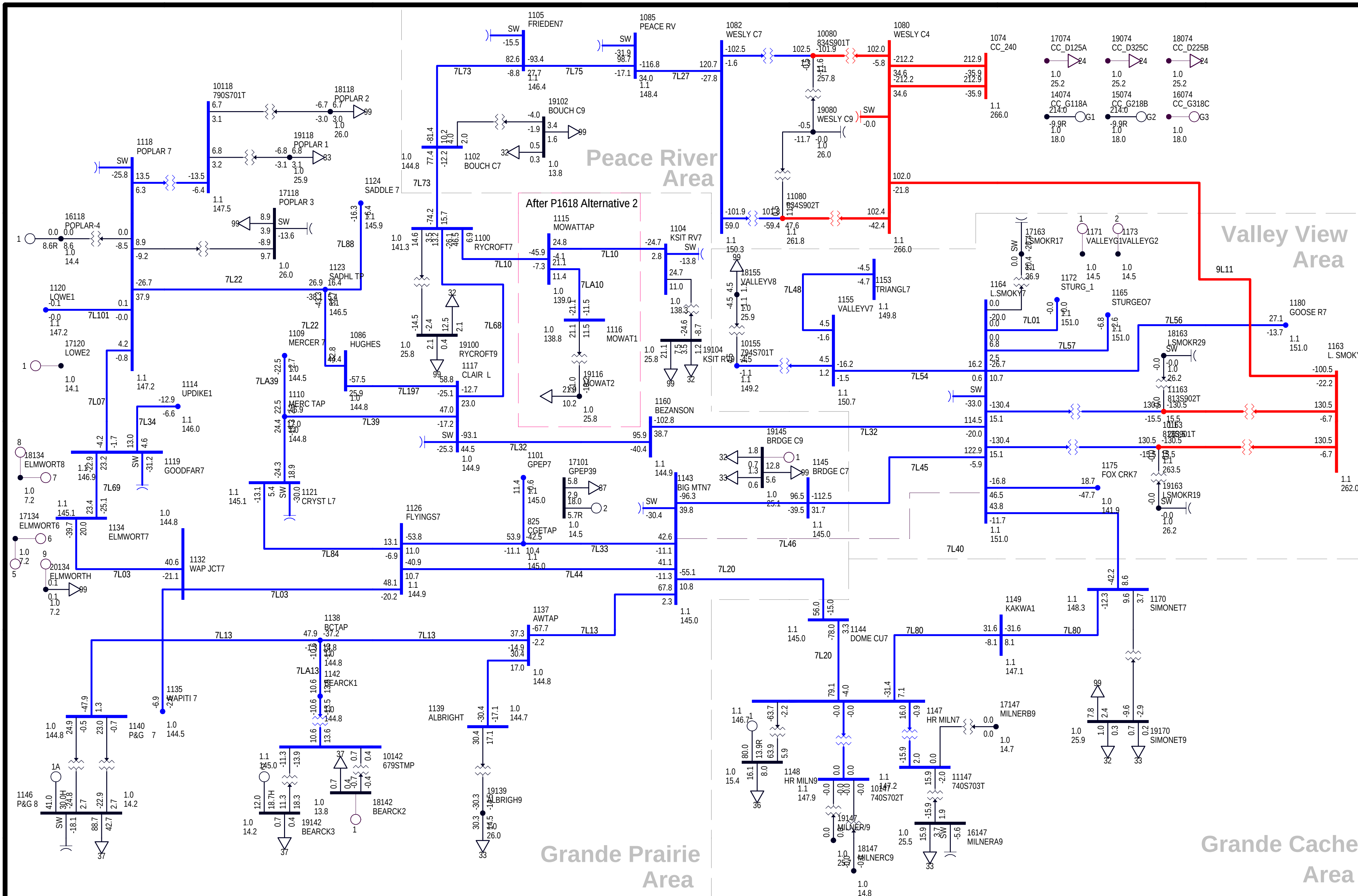
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02 **Page D- 6**

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02

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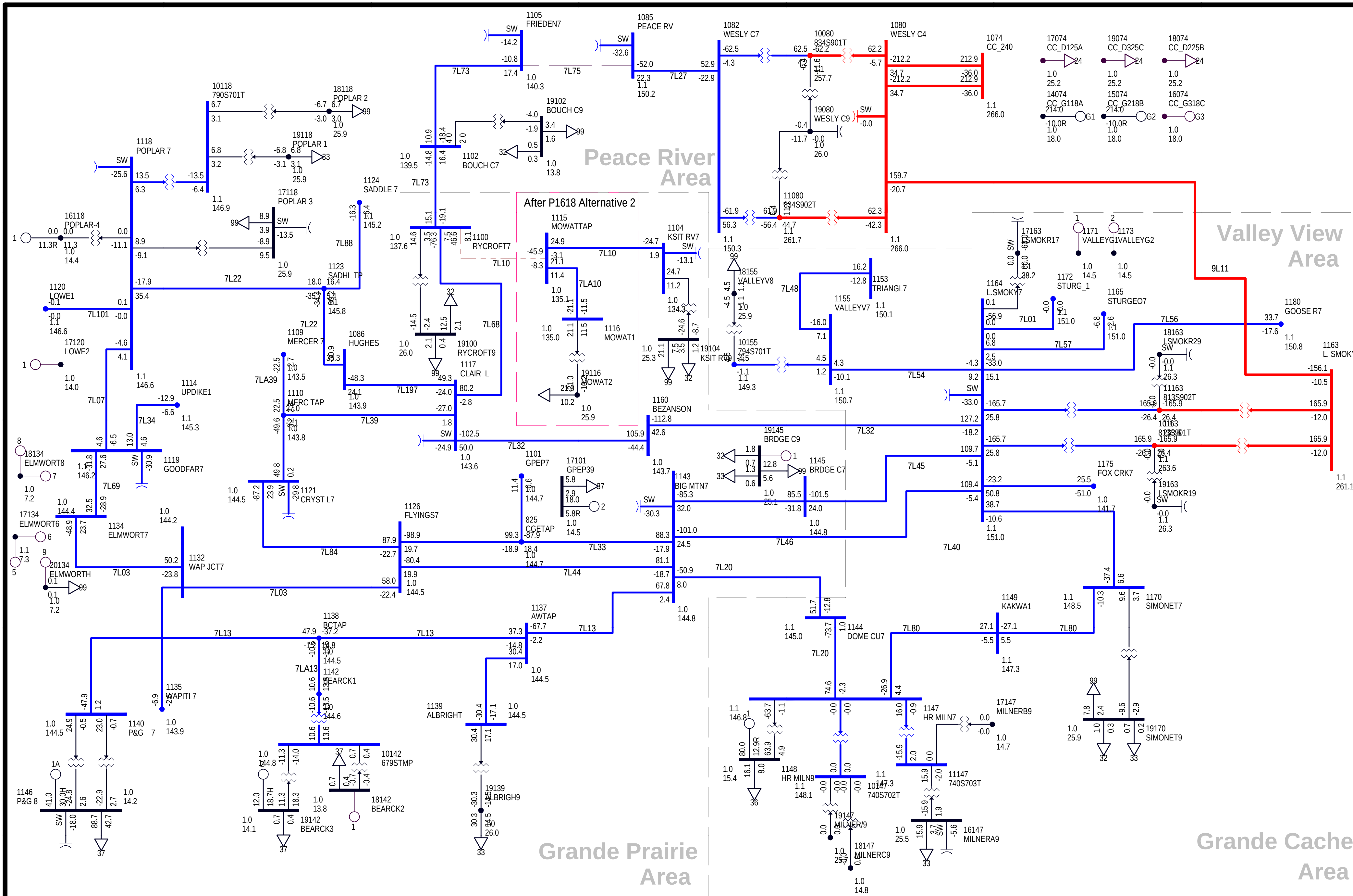
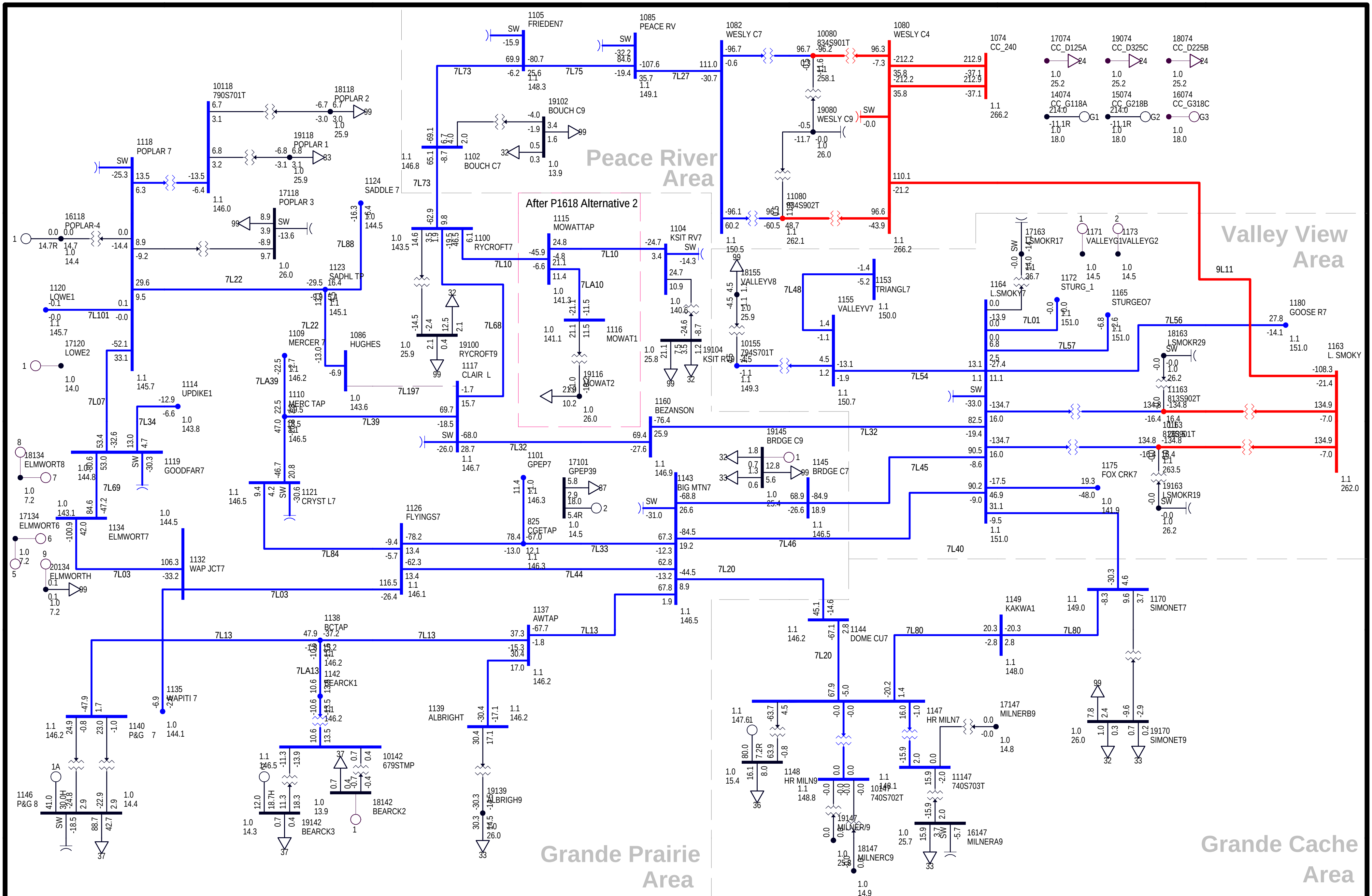
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowatt 2033S)

CATEGORY B, LOSS OF 7L75
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02
Page D- 8

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

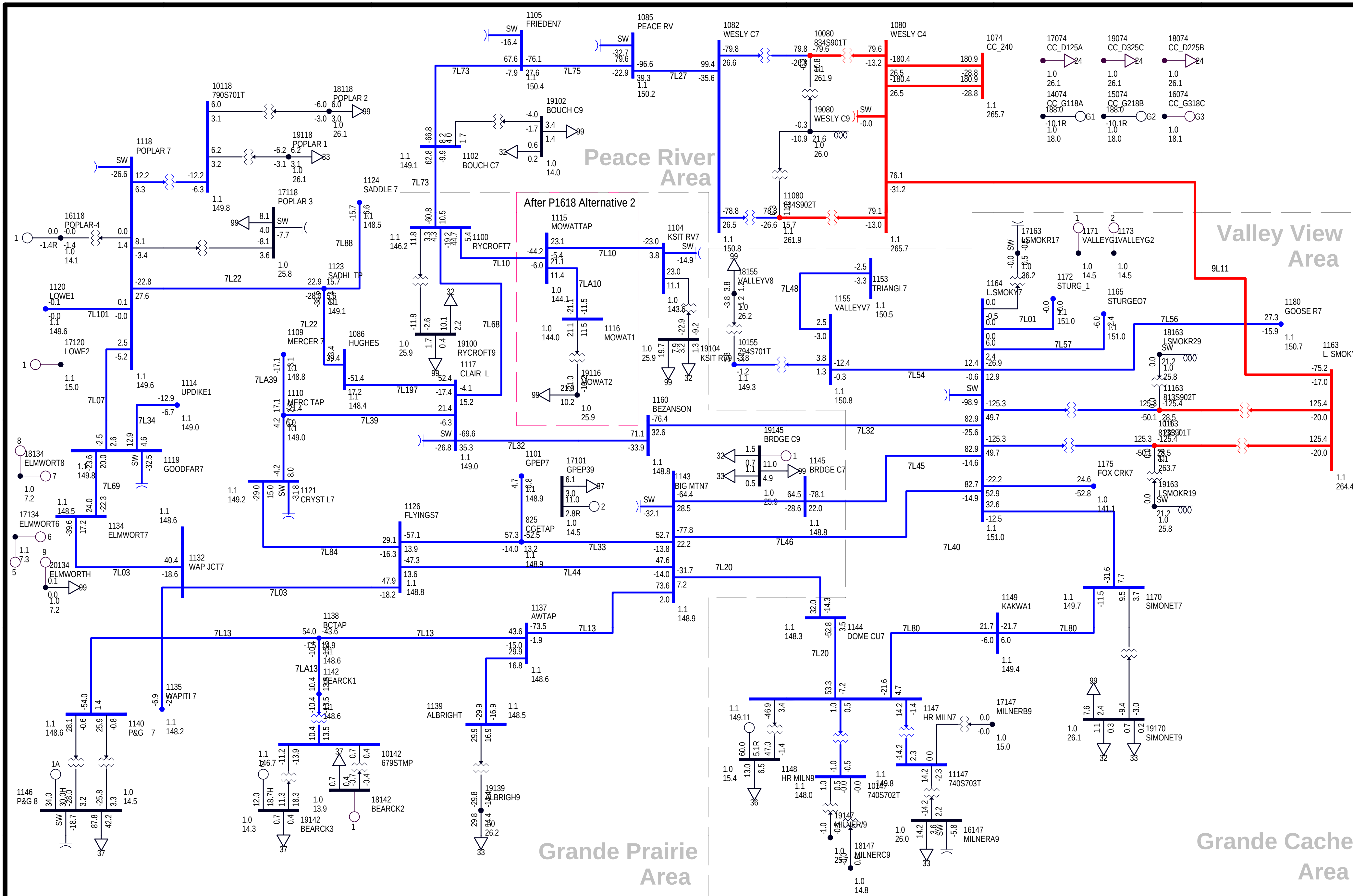


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2016 WP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
THU, MAR 10 2016 12:02

Page D- 9

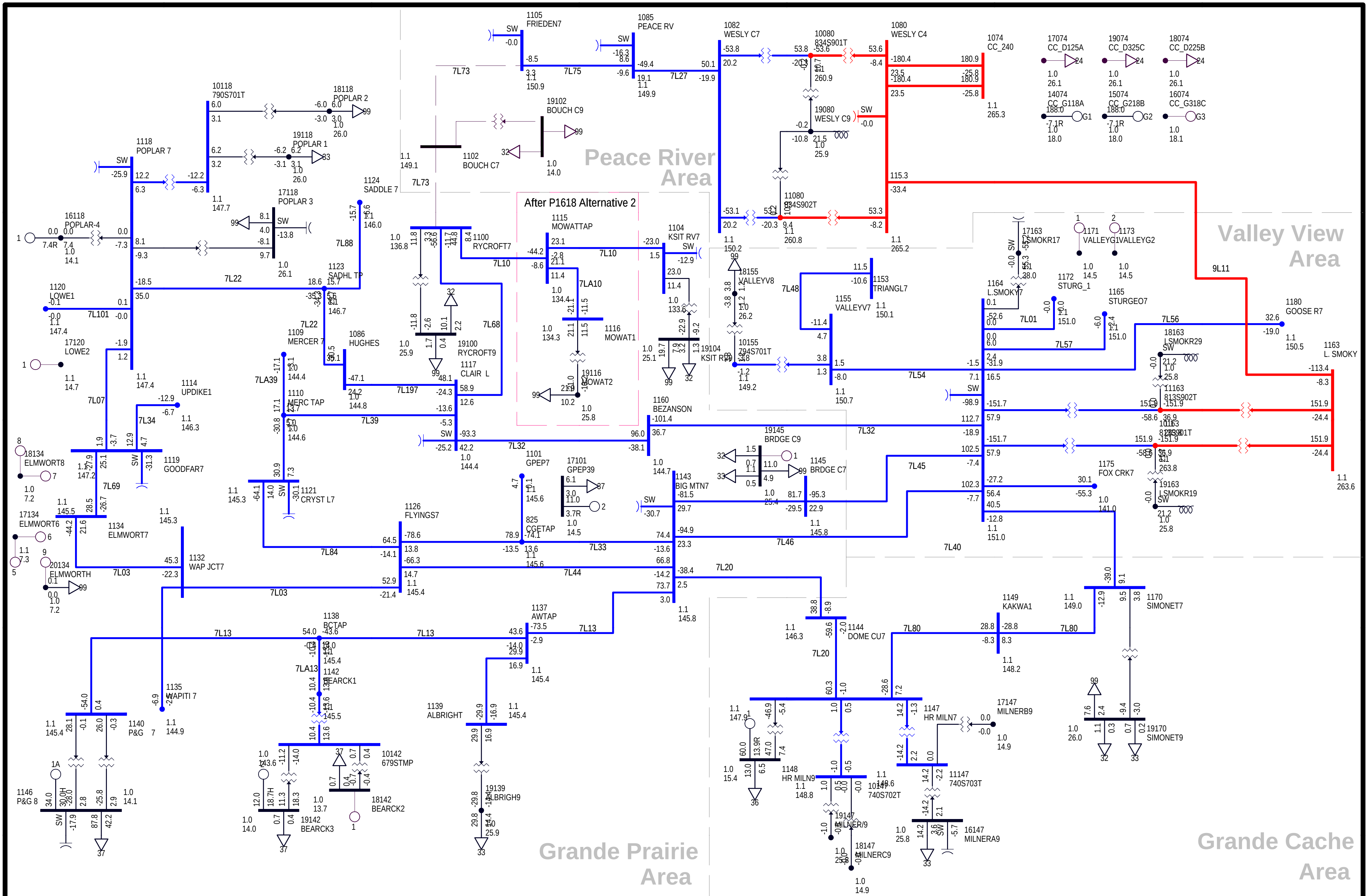
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY A, N-G-0
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18
Page D- 10

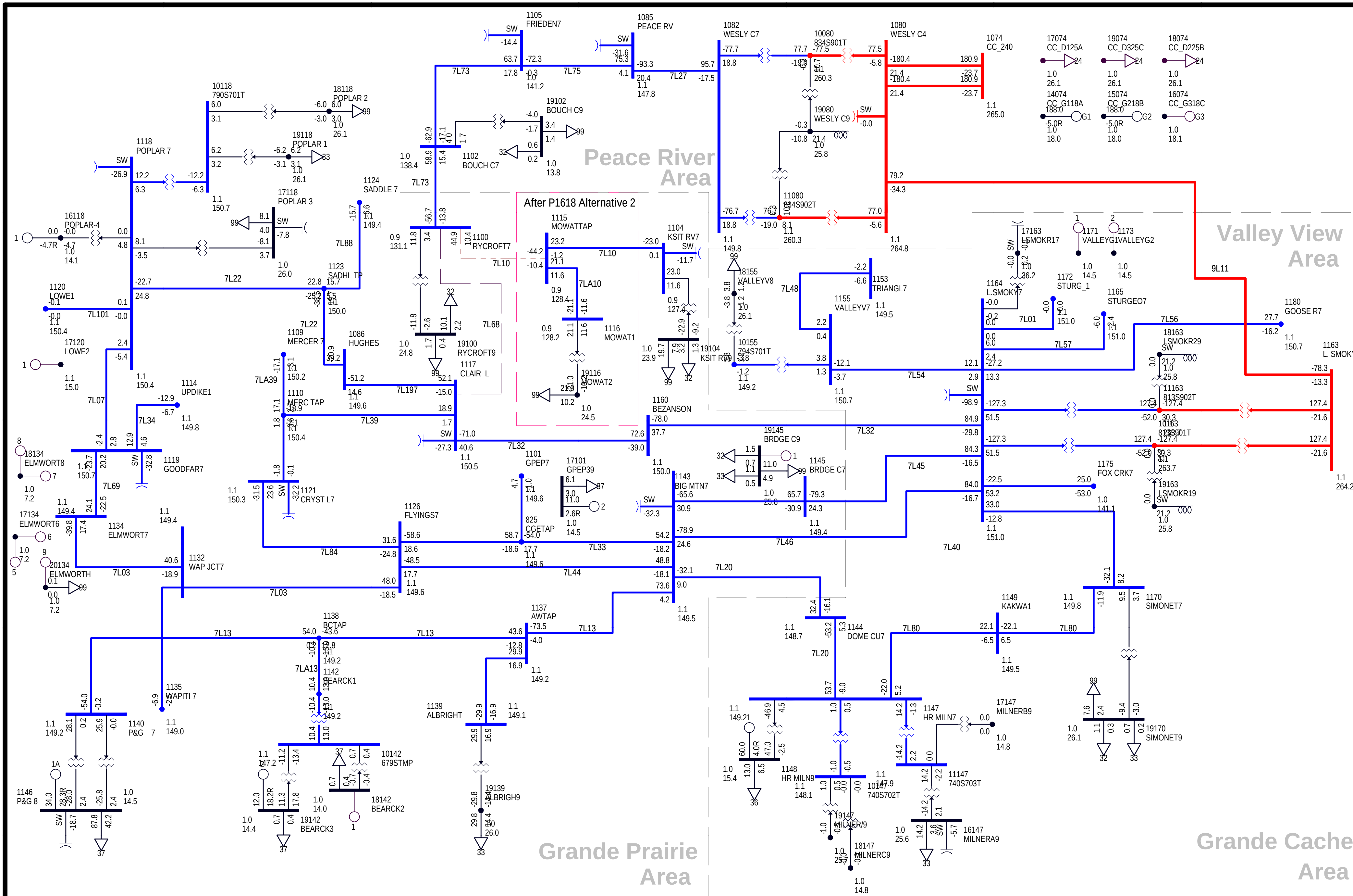
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L73
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

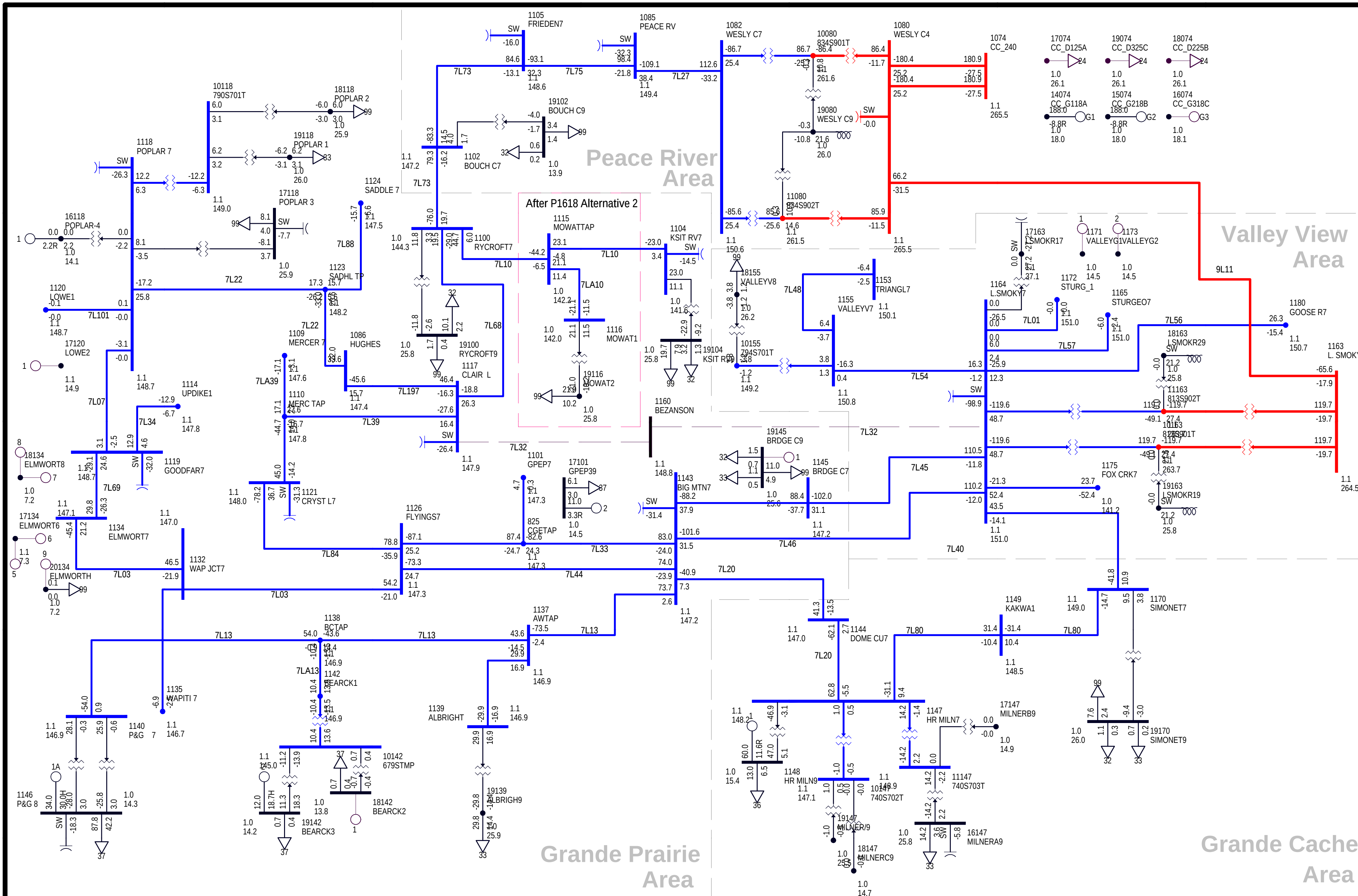


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L68
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18

Page D- 12

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

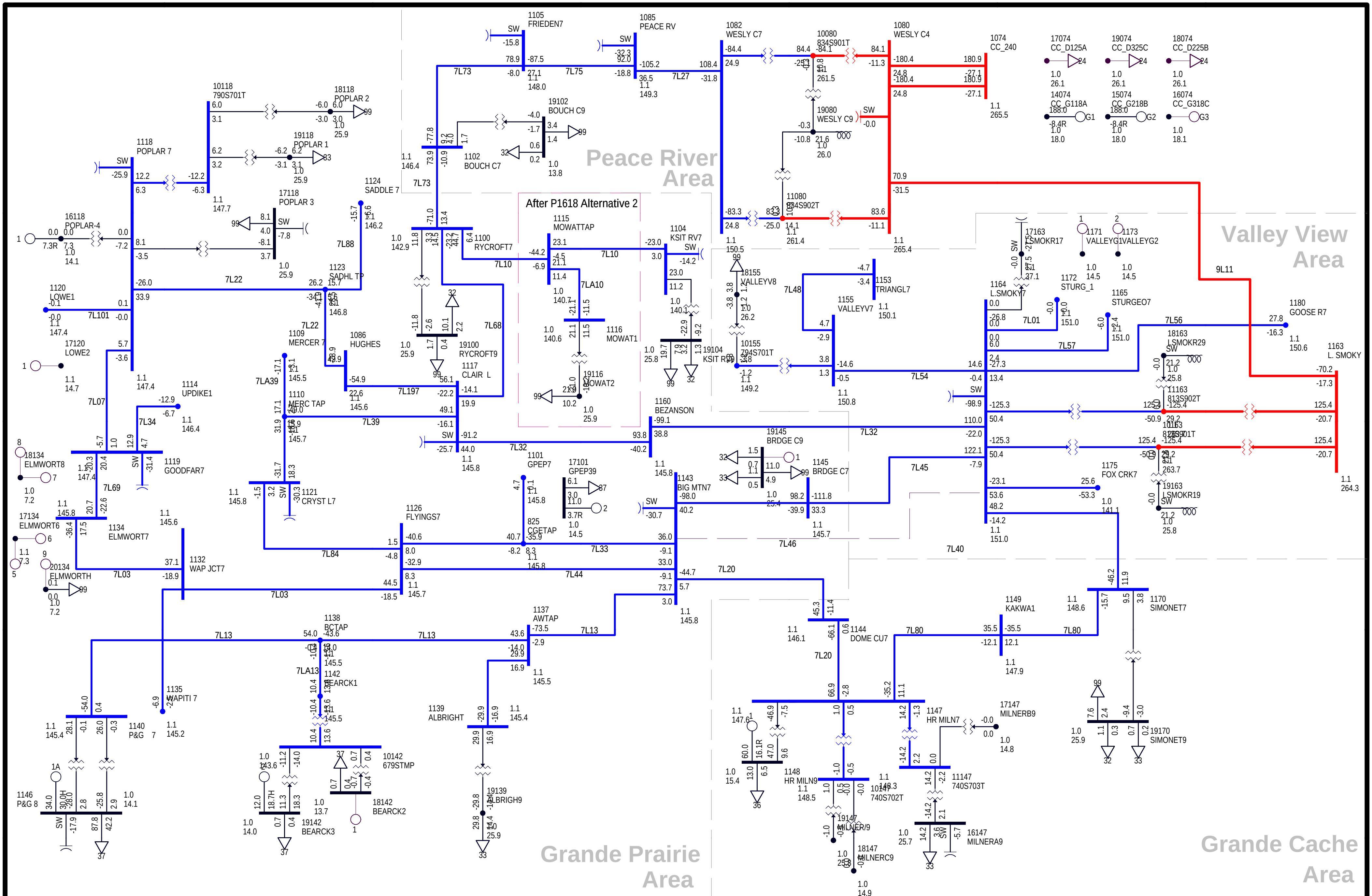


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L32
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18

Page D- 13

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD
(Mowat 2033S)

CATEGORY B, LOSS OF 7L46
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18

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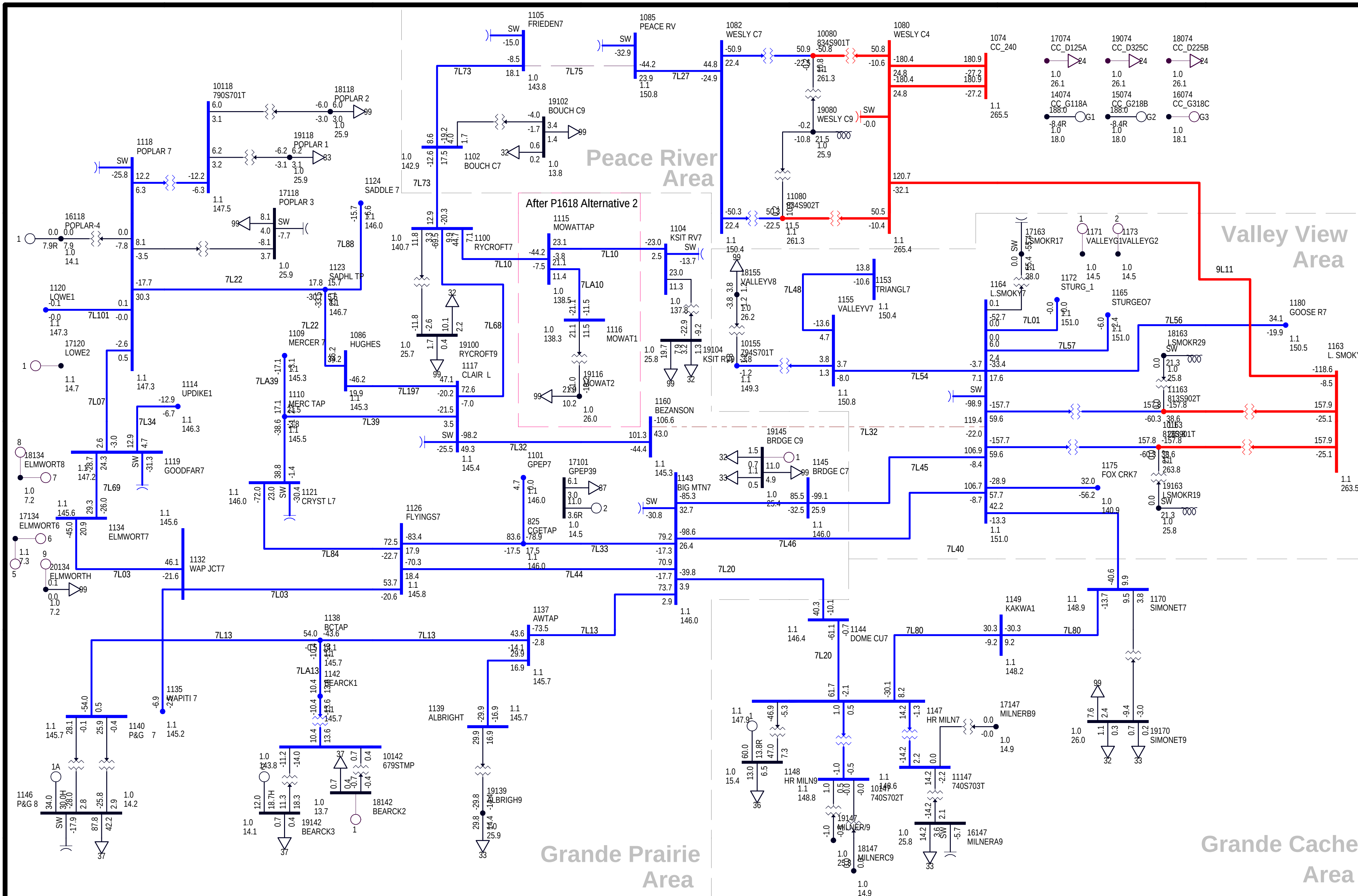
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

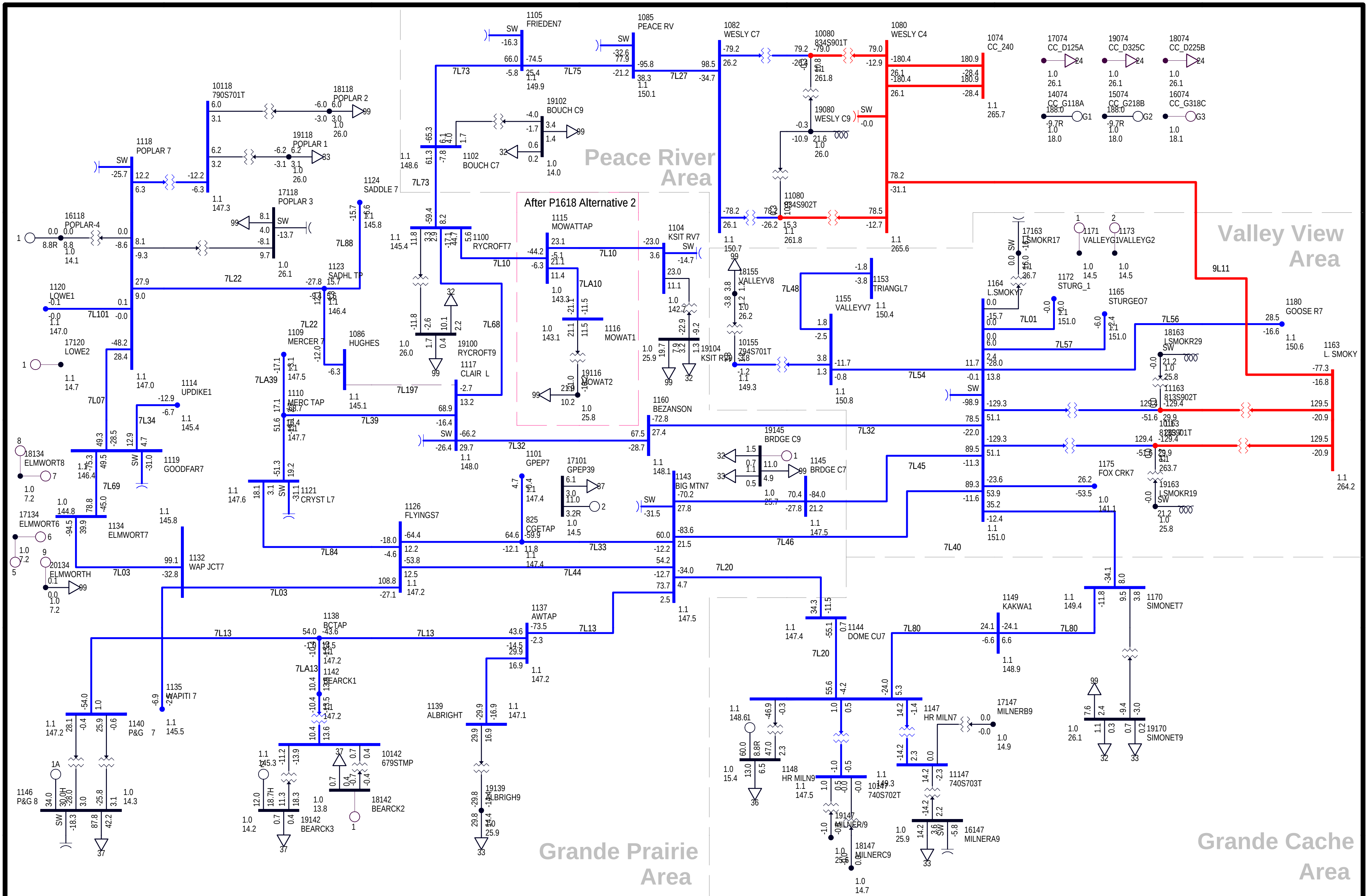


P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L75
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18

Page D- 15

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000



P1618 - Spirit River new POD (Mowat 2033S)

CATEGORY B, LOSS OF 7L197
2017 SP WITH PROJECT ALT.2 - SENSITIVITY STUDIES
WED, FEB 10 2016 15:18

Page D- 16

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.123OV 0.942UV
kV: >0.000 <=34.500 <=72.000 <=144.000 <=240.000

ATTACHMENT E

Post-Project Alternative 2 With Two 144 kV Capacitor Banks at Mowat 2033S (10 and 15 MVAr): Voltage Stability Results

This attachment presents the voltage stability analysis for the 2016 WP post-Project Alternative 2 with two 144 kV switched capacitor banks (10 and 15 MVAr) at Mowat 2033S substation. The PV margin criterion was met for this scenario.

The reference load level for the study area (Area 20) is 404.0 MW. The minimum incremental load transfer for the Category B contingencies is 5% or 20.2 MW (0.05 x 404.0 MW = 20.2 MW) to meet the voltage stability criteria. Table E-1 summarizes the worst Category B contingencies PV margin in the project study area. Also, Figure E-1 and Figure E-2 depict the PV curves at Mowat 2033S and Ksituan River 754S for those contingencies.

Table E-1: 2016 WP Post-Project Alternative 2 With Two 144 kV Capacitor Banks at Mowat 2033S (10 and 15 MVAr) – PV Analysis Results

Contingency	From	To	Maximum incremental transfer (MW)	Meets 105% PV margin?
Category A	System Normal		75.6	Yes
7L75	West Peace River 793S	Friedenstal 800S	35.0	Yes
7L197	Clairmont Lake 811S	Hughes 2030S	37.5	Yes
7L73	Friedenstal 800S	Rycroft 730S	40.6	Yes
7L68	Clairmont Lake	Rycroft 730S	41.9	Yes
7L46	Big Mountain 845S	Little Smoky 813S	43.1	Yes

Figure E-1: PV Curves at Mowat 2033S substation for the five worst Category B contingencies.

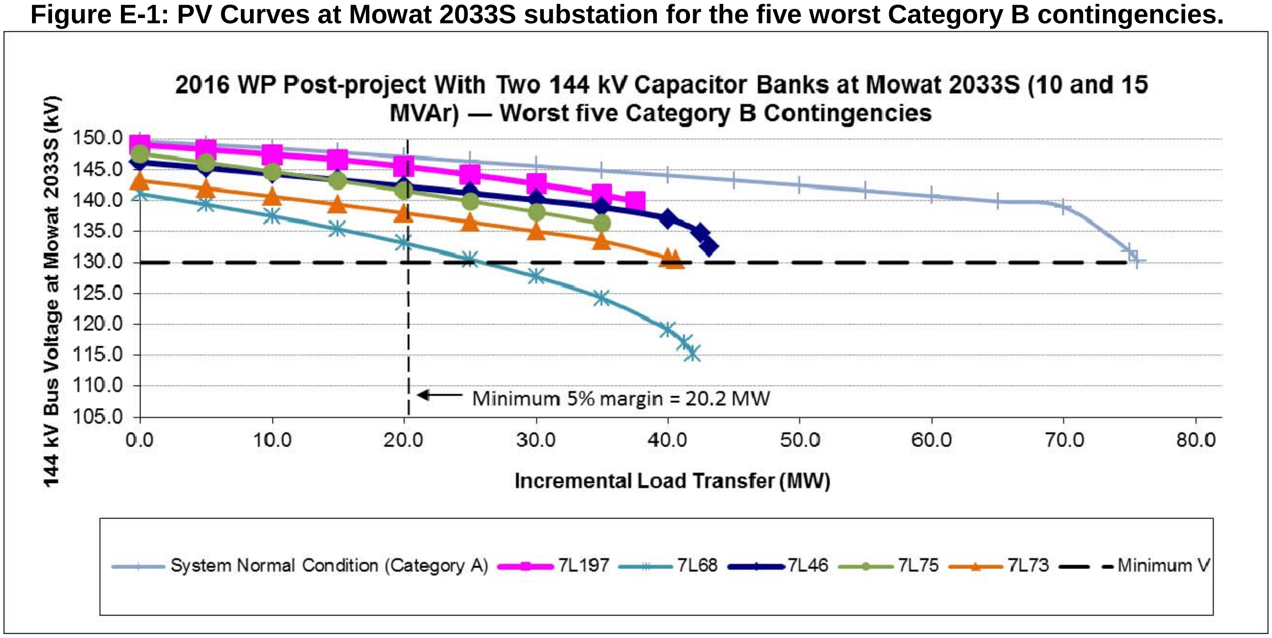
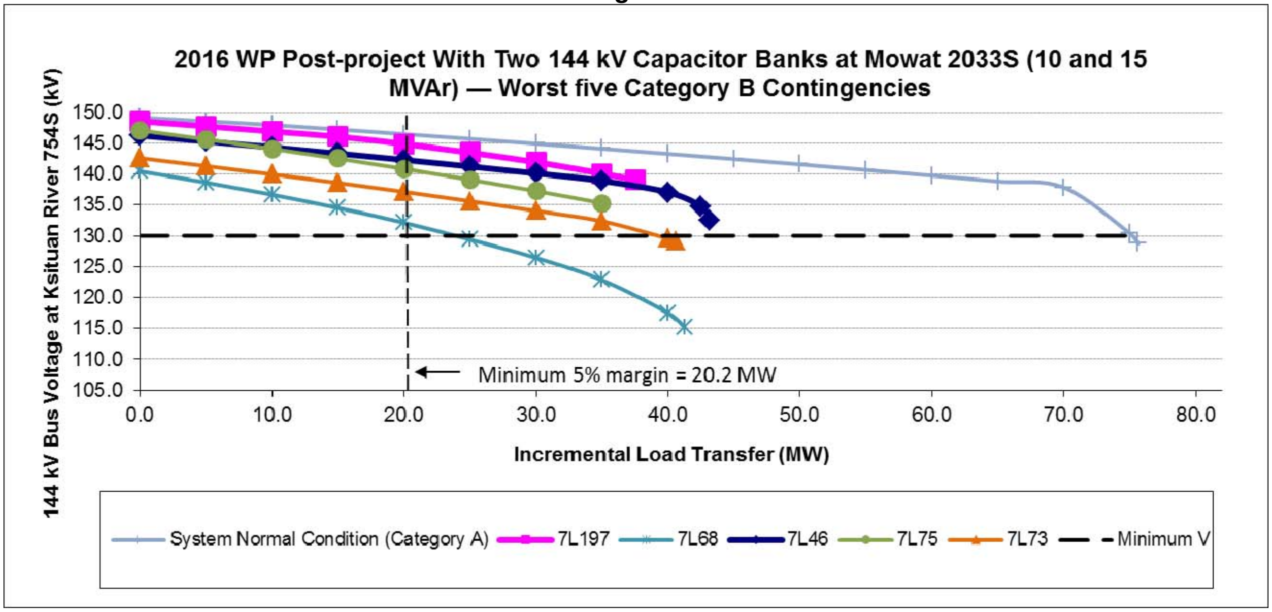


Figure E-2: PV Curves at Ksituan River 754S substation for the five worst Category B contingencies.



ATTACHMENT F
Mitigated Post-Connection Alternative 2
With 144 kV Two Capacitor Banks at Mowat 2033S (10 and 15 MVAr):

Voltage Recovery Transient Stability Analysis
CLOD File and Results

Post-Connection: 2016 WP Scenario 3 Transient Stability Analysis

From the PV analysis provided in section 6.1.2.1, the worst contingencies identified were:

- 7L68 (Rycroft 730S to Clairmont Lake 811S)
- 7L75 (West Peace River 793S to Friedenstal 800S)
- 7L73 (Rycroft 730S to Friedenstal 800S)

These contingencies will be analyzed using the CLOD motor model to ensure voltage recovery after three phase line faults. Unless otherwise specified in Table F-1, the percentage large and small motor loads used in the Northwest and Northeast regions were 40% and 30% respectively. For all other regions of the AIES, 10% large and 10% small motor load was used.

Table F-1: Specific Substation Percentage Large and Small Motor Mix used for CLOD model

Substation	Name	AREA	% Load Type				Large Motor % used	Small Motor % used
			Residential	Commercial	Industrial	Others		
754S	Ksituan River	20	0.8	2.8	81.4	15	32.6	25.3
730S	Rycroft	20	9.2	21.4	45.9	23.5	18.4	20.2
731S	Elmworth	20	0.6	1	89.3	9.1	35.7	27.1
790S	Poplar Hill	20	2.6	1	78.7	17.7	31.5	23.9
865S	Saddle Hills	20	1.1	1.3	95.5	2.2	38.2	29.0
886S	Updike	20	0.5	0.6	95.8	3.1	38.3	28.9
815S	Goodfare	20	17.3	16.9	53	12.8	21.2	21.0
798S	Bridge Creek	20	1	34	31	34	12.4	19.5
823S	Wapiti	20	24	6	42	28	16.8	14.4
862S	South Bezanson	20	7.83	5.86	61.5	24.81	24.6	20.2
728S	Mercer Hill	20	27.5	56.36	4.7	11.4	1.9	18.3
722S	Crystal Lake	20	61.4	36.5	1	1	0.4	11.3
749S	Flyingshot Lake	20	37.1	57.1	1.6	4.1	0.6	17.6
752S	Albright Wilson	20	0	0	100	0	40.0	30.0
679S	Bear Creek	20	0	0	100	0	40.0	30.0
808S	P&G	20	0	0	100	0	40.0	30.0
927S	Buchanan Creek	19	60	18	20	2	8.0	11.4
724S	Hines Creek	19	10	14.8	41.5	33.7	16.6	16.9
784S	Donnelly	19	16.4	29.3	29.4	25	11.8	17.6
793S	West Peace River	19	22.4	30.2	37.9	9.5	15.2	20.4
829S	Boucher Creek	19	0	0.2	99.7	0.2	39.9	30.0
861S	Eureka River	19	2.8	10.2	47.7	39.3	19.1	17.4
800S	Friedenstal	19	19.13	27.59	31.81	21.47	12.7	17.8
788S	Hotchkiss	19	15.4	23.8	35.1	25.7	14.0	17.7
830S	Carmon	19	0.1	1.3	97.9	0.6	39.2	29.8
855S	Hamburg	19	0	5.2	94.7	0.1	37.9	30.0
869S	Seal Lake	19	2.95	3.2	88.24	5.6	35.3	27.4
878S	Kidney Lake	19	16.3	13.43	69.69	0.58	27.9	24.9
812S	Norcen	19	8.35	4.05	87.53	0.07	35.0	27.5
827S	Cranberry Lake	19	10.79	19.91	69.19	0.1	27.7	26.7
796S	Nipisi	19	3.59	1.74	94.6	0.07	37.8	28.9
789S	High Level	18	21.21	31.35	41.08	6.36	16.4	21.7
832S	Blumenort	18	29.65	23.53	25.23	21.58	10.1	14.6
740S	HRMilner	22	16	17.8	65.7	0.4	26.3	25.1
810S	Dome Cutbank	22	0	26	50	24	20.0	22.8

Table F-2: Existing Fault Clearing Times

Contingency	Fault Location (First Substation is Near End, Second Substation is Far End)	Clearing Time (Cycles)	
		Near end	Far end
7L68 (Rycroft 730S to Clairmont Lake 811S)	Rycroft 730S	6	--
	Clairmont Lake 811S	--	24
7L68 (Rycroft 730S to Clairmont Lake 811S)	Clairmont Lake 811S	6	--
	Rycroft 730S	--	42
7L75 (West Peace River 793S to Friedenstal 800S)	Friedenstal 800S	6	--
	West Peace River 793S	--	24
7L75 (West Peace River 793S to Friedenstal 800S)	West Peace River 793S	6	--
	Friedenstal 800S	--	24
7L73 (Rycroft 730S to Friedenstal 800S)	Rycroft 730S	6	--
	Friedenstal 800S	--	42
7L73 (Rycroft 730S to Friedenstal 800S)	Friedenstal 800S	6	--
	Rycroft 730S	--	24

Post-Connection: Faults on 7L68

As shown by Figure F-1, for faults near the Rycroft 730S end on 7L68 with the existing clearing times have no voltage recovery problems.

For faults on 7L68 near the Clairmont Lake 811S end, voltage recovery problems were identified. Testing was completed with the existing Rycroft clearing times as identified in Table F-2, as well as with a reduced total clearing times of 24, 18 and even a test with only 14 cycles as shown by Figures F-2a through F-2d. At 14 cycles total clearing time, the installation of teleprotection to ensure correct operation of the line protection would be necessary as confirmed by the area TFO.

Voltage recovery testing showed the critical clearing time was 9 cycles. Hence, the inclusion of teleprotection on 7L68 to ensure all faults are cleared as quickly as possible is required. With the proposed Mowat 2033S, telecommunications are required for SCADA data. The area TFO had determined the telecommunications would be teleprotection grade for this project given the planned area developments. Hence, teleprotection grade telecommunications will be available for use on 7L68 with this project.

The addition of teleprotection is the only method by which voltage recovery may be achieved on this line. Please see Figure 3 and Figure 4 for 7L68 performance with teleprotection.

Figure F-1: 7L68 Fault near Rycroft 730S - 144 kV Bus Voltage vs. Time Curve (Rycroft bkr opens in 6 cycles and Clairmont Lake in 24 cycles after fault)

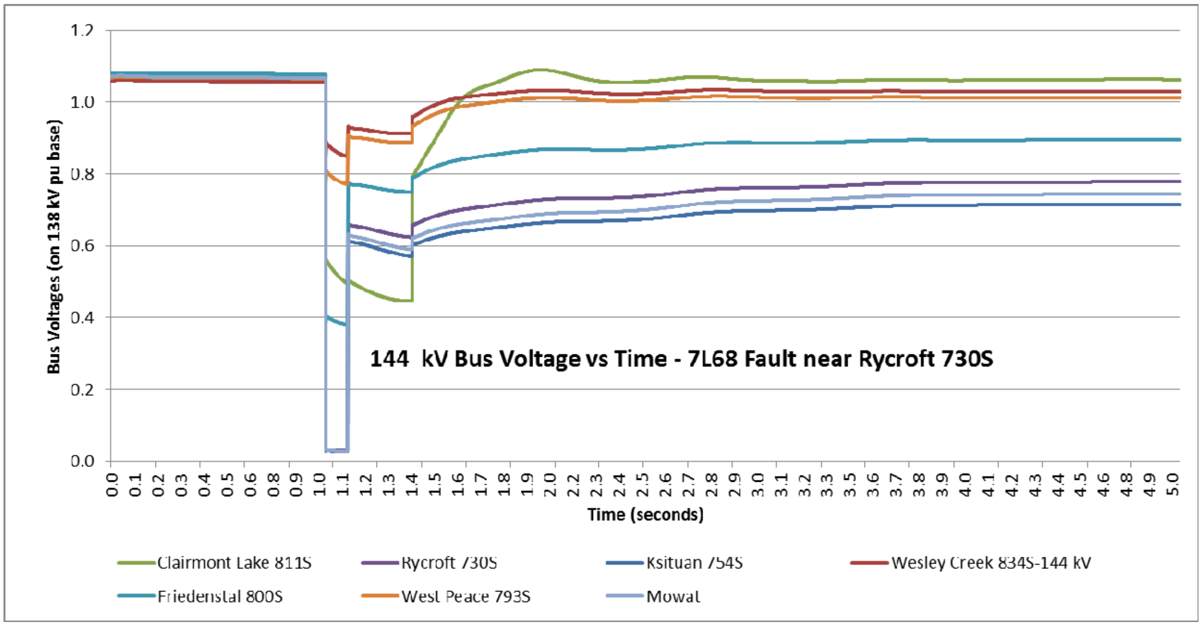


Figure F-2a: 7L68 Fault near Clairmont Lake 811S - 144 kV Bus Voltage vs. Time Curve (Clairmont Lake bkr opens in 6 cycles and Rycroft in 42 cycles after fault)

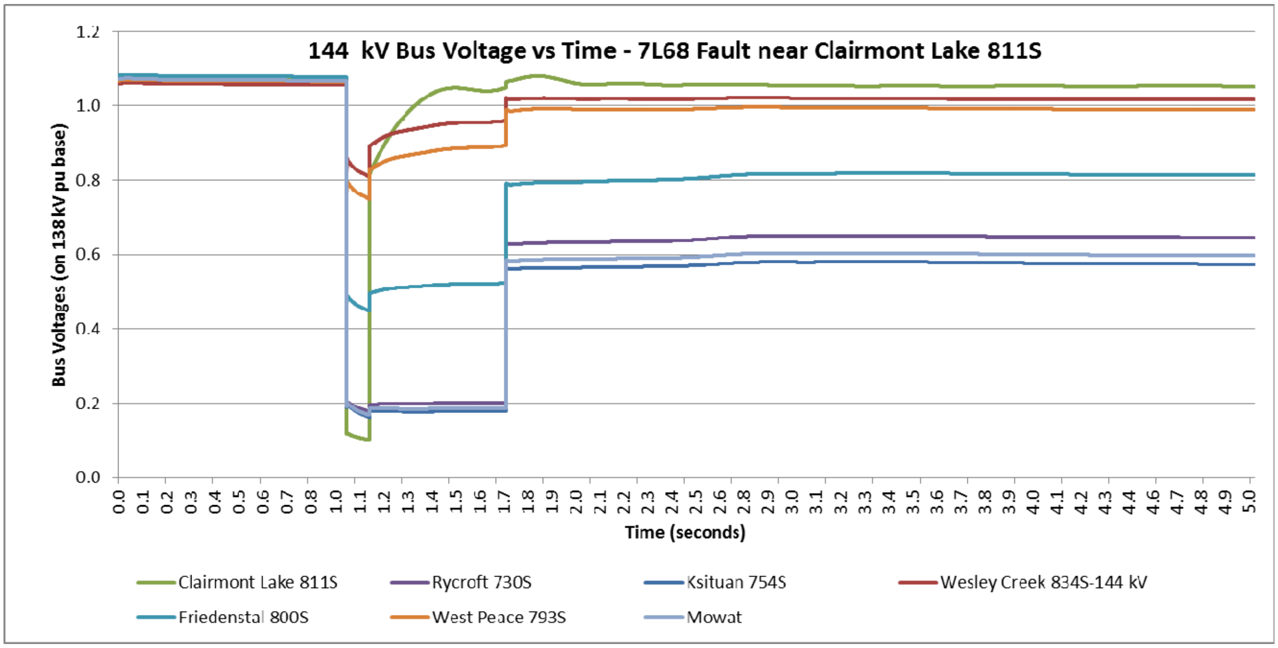


Figure F-2b: 7L68 Fault near Clairmont Lake 811S - 144 kV Bus Voltage vs. Time Curve (Clairmont Lake bkr opens in 6 cycles and Rycroft in 24 cycles after fault)

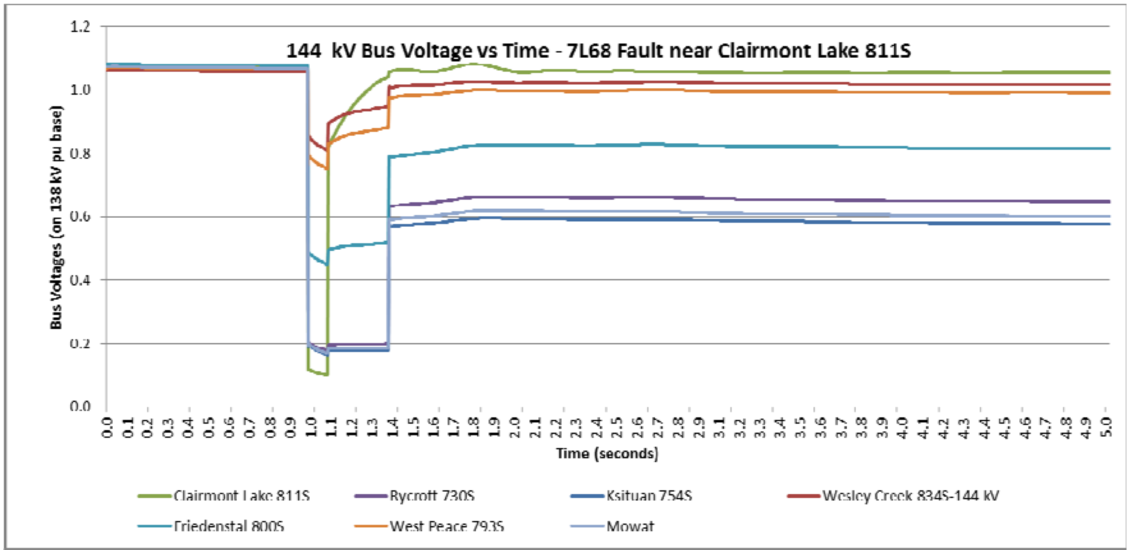


Figure F-2c: 7L68 Fault near Clairmont Lake 811S - 144 kV Bus Voltage vs. Time Curve (Clairmont Lake bkr opens in 6 cycles and Rycroft in 18 cycles after fault)

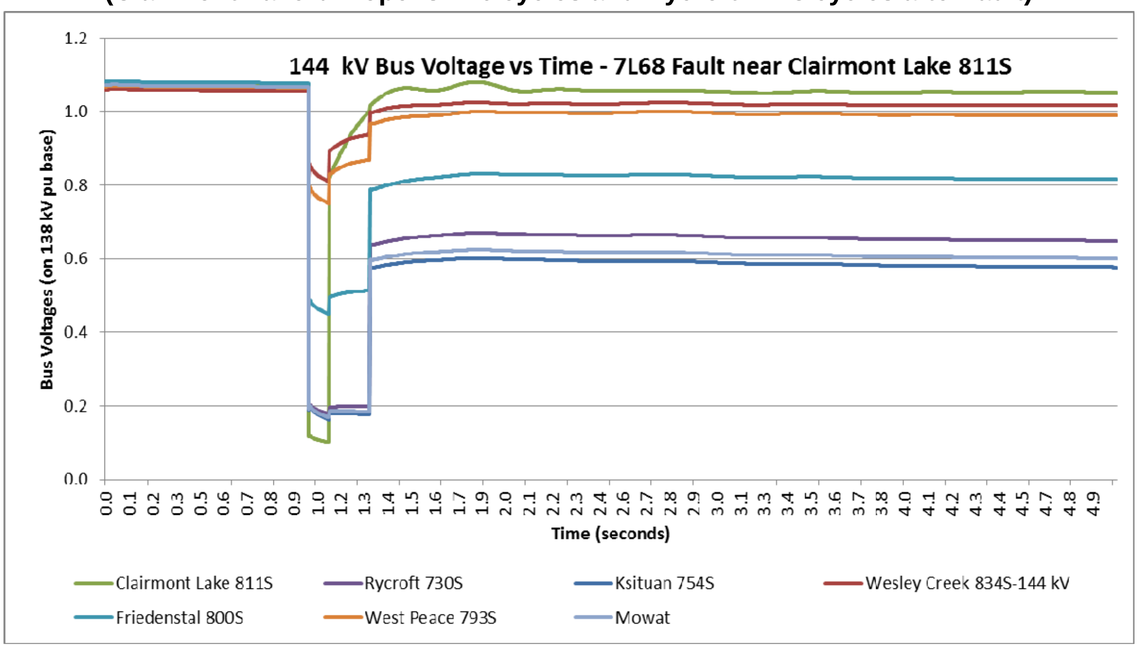


Figure F-2d: 7L68 Fault near Clairmont Lake 811S - 144 kV Bus Voltage vs. Time Curve (Clairmont Lake bkr opens in 6 cycles and Rycroft in 14 cycles after fault)

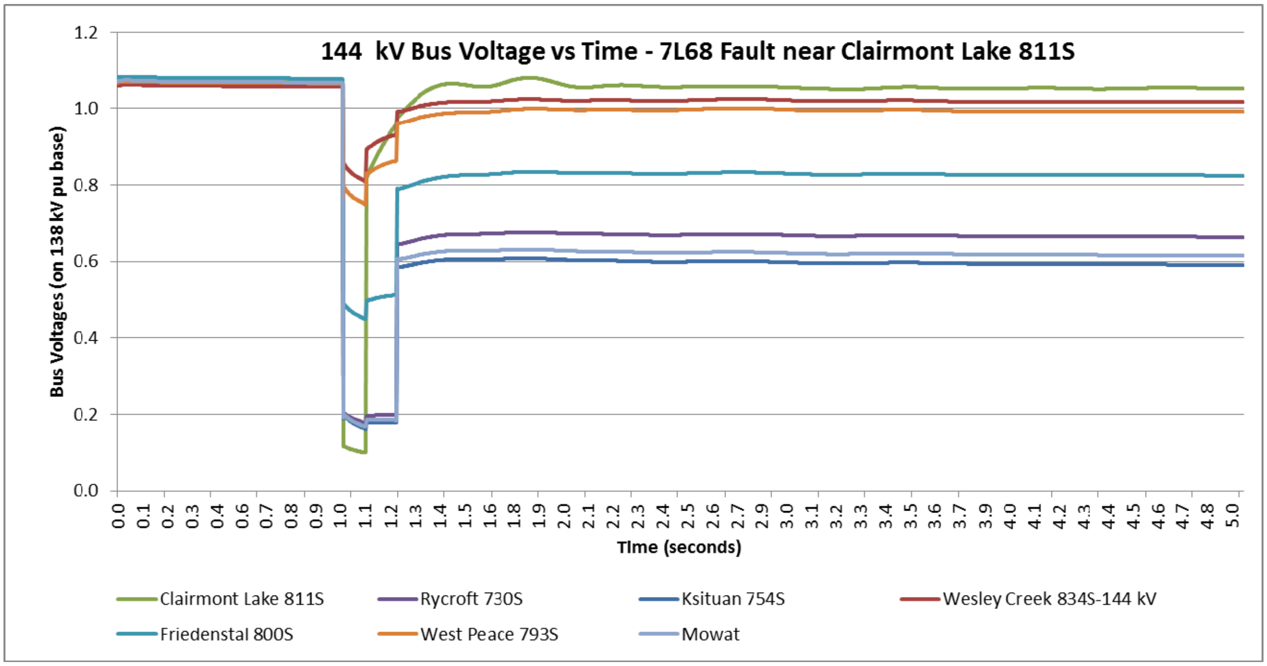


Figure F-3 and Figure F-4 shows 7L68 line faults with teleprotection (T/P) installed to ensure all faults are cleared within 8 cycles to achieve voltage recovery for any 7L68 line fault.

Figure F-3: 7L68 Fault near Rycroft 730S with T/P - 144 kV Bus Voltage vs. Time Curve (Clairmont Lake bkr opens in 6 cycles and Rycroft in 8 cycles after fault)

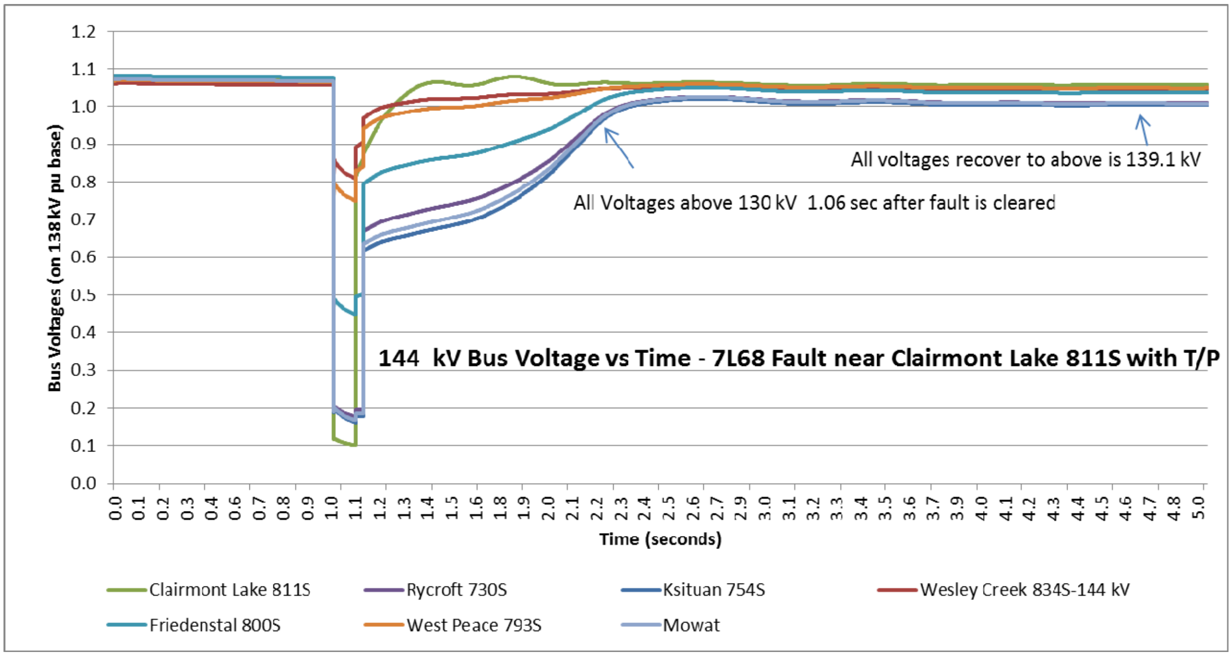
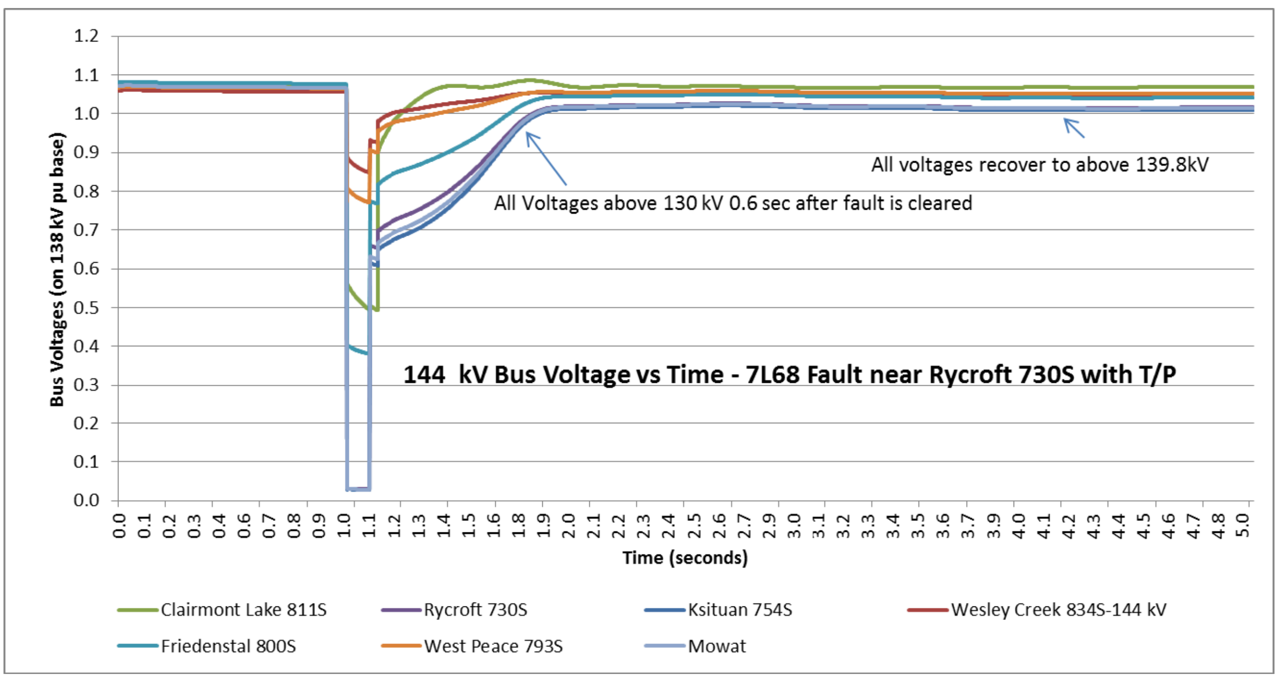


Figure F-4: 7L68 Fault near Clairmont Lake 811S with T/P - 144 kV Bus Voltage vs. Time Curve (Rycroft bkr opens in 6 cycles and Clairmont Lake in 8 cycles after fault)



Post-Connection: Faults on 7L75

As can be seen in Figure F-5a, faults not cleared quickly enough near West Peace River 793S by the Friedenstal 800S substation protection on 7L75 indicate there are voltage recovery problems with the motor loads in the Rycroft area. Hence, acceleration of the zone 2 clearing time is required at the Friedenstal end only for faults near West Peace River 793S as shown in Figure F-5b. Figure F-6 shows no issues for voltage recovery for faults near Friedenstal 800S on 7L75.

Figure F-5a: 7L75 Fault near West Peace River 793S - 144 kV Bus Voltage vs. Time Curve (West Peace River bkr opens in 6 cycles and Friedenstal in 24 cycles after fault)

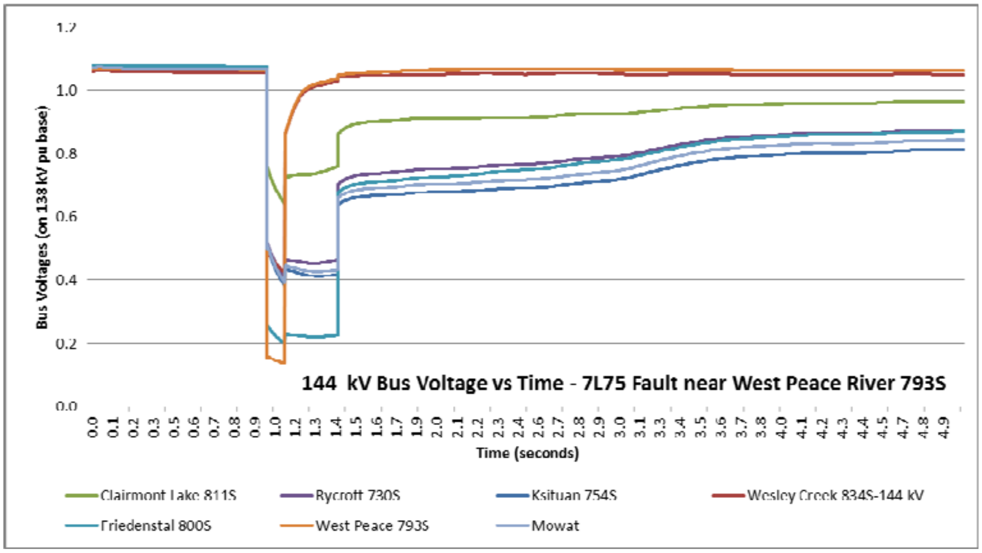


Figure F-5b: 7L75 Fault near West Peace River 793S - 144 kV Bus Voltage vs. Time Curve (West Peace River bkr opens in 6 cycles and Friedenstal in 18 cycles after fault)

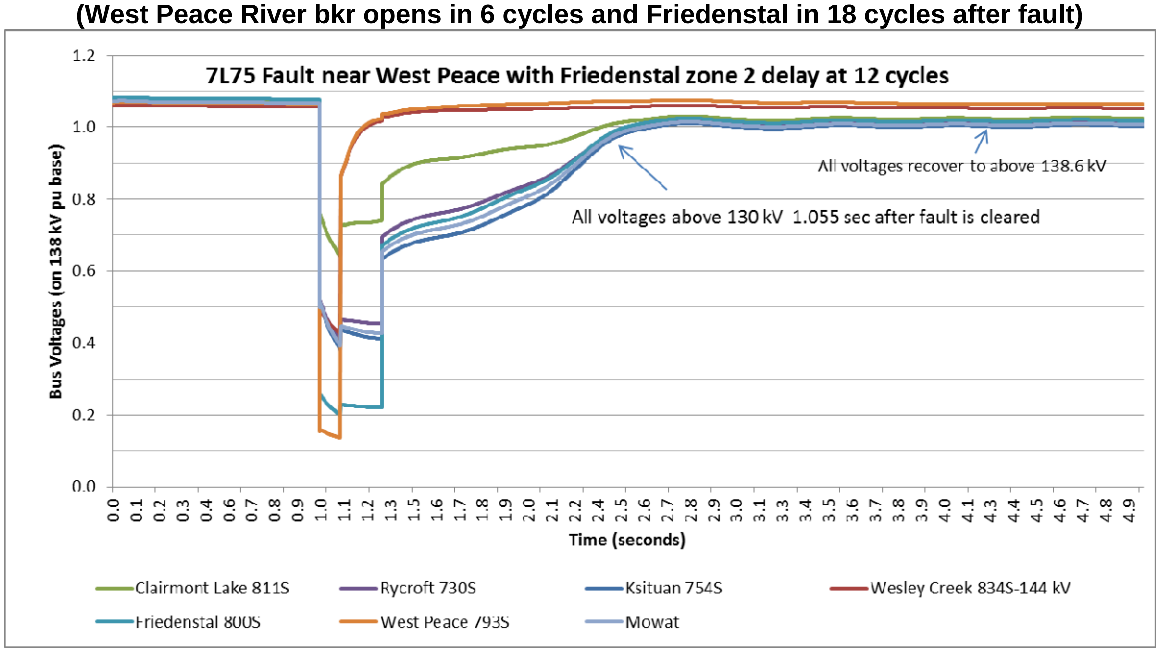
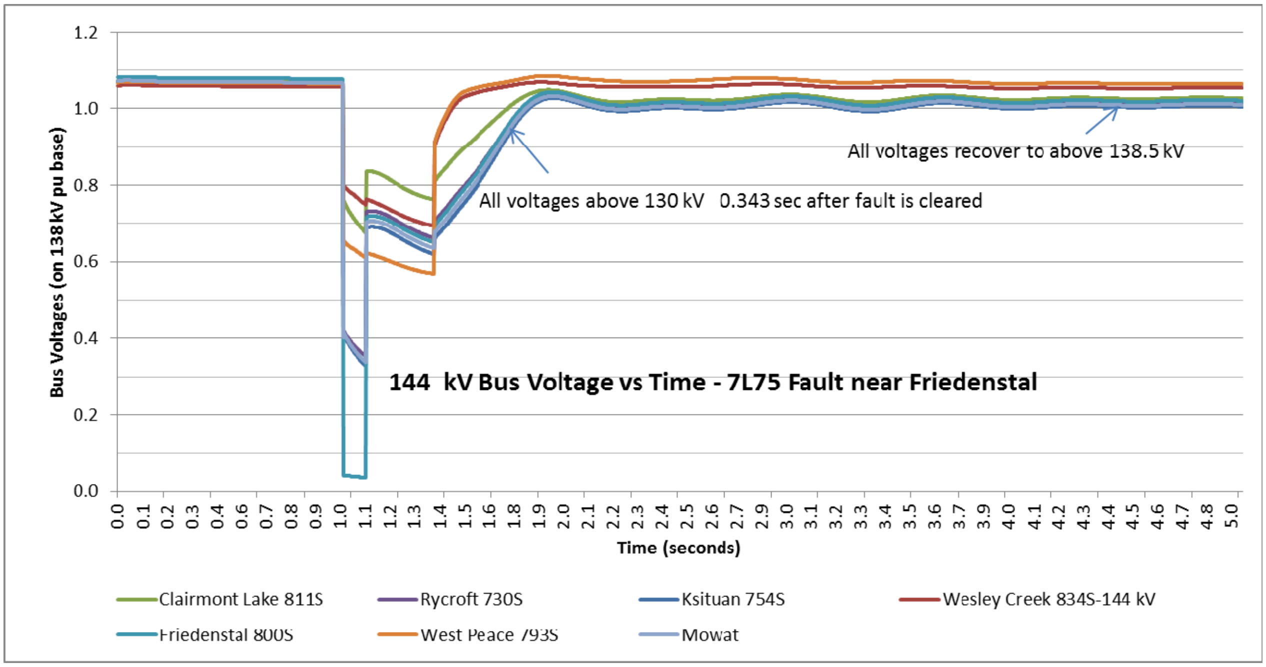


Figure F-6: 7L75 Fault near Friedenstal 800S - 144 kV Bus Voltage vs. Time Curve (Friedenstal bkr opens in 6 cycles and West Peace River in 24 cycles after fault)



Post-Connection: Faults on 7L73

As can be seen in Figure F-7a, faults not cleared quickly enough near Friedenstal 800S by the Rycroft 730S substation protection on 7L73 indicate there are voltage recovery problems with the motor loads in the Rycroft area. Hence, acceleration of the zone 2 clearing time is required at the Rycroft end only on 7L73 for faults close to Friedenstal 800S as shown in Figure F-7b. Figure F-8 shows no issues for voltage recovery for faults near Rycroft 730S.

Figure F-7a: 7L73 Fault near Friedenstal 800S - 144 kV Bus Voltage vs. Time Curve (Friedenstal bkr opens in 6 cycles and Rycroft in 24 cycles after fault)

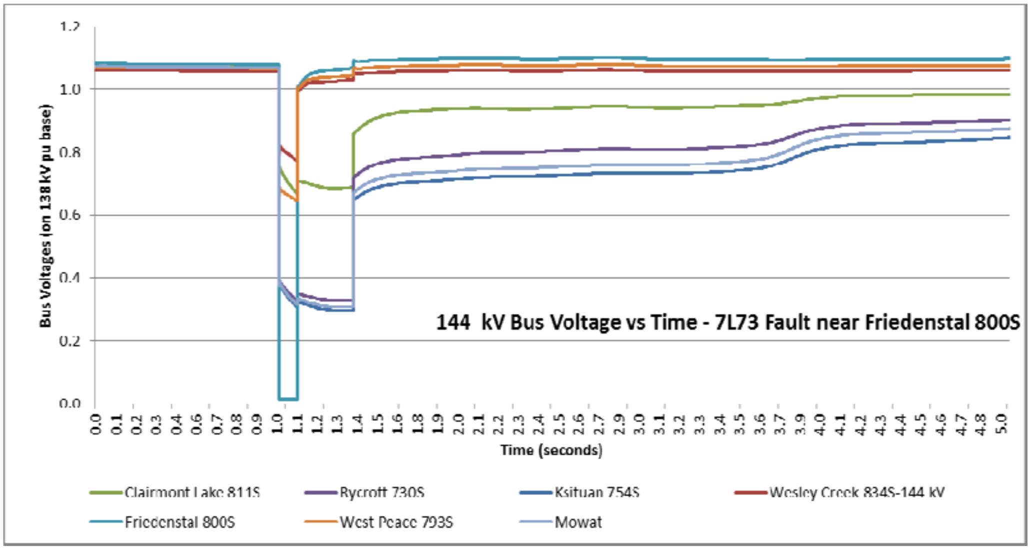


Figure F-7b: 7L73 Fault near Friedenstal 800S - 144 kV Bus Voltage vs. Time Curve (Friedenstal bkr opens in 6 cycles and Rycroft in 18 cycles after fault)

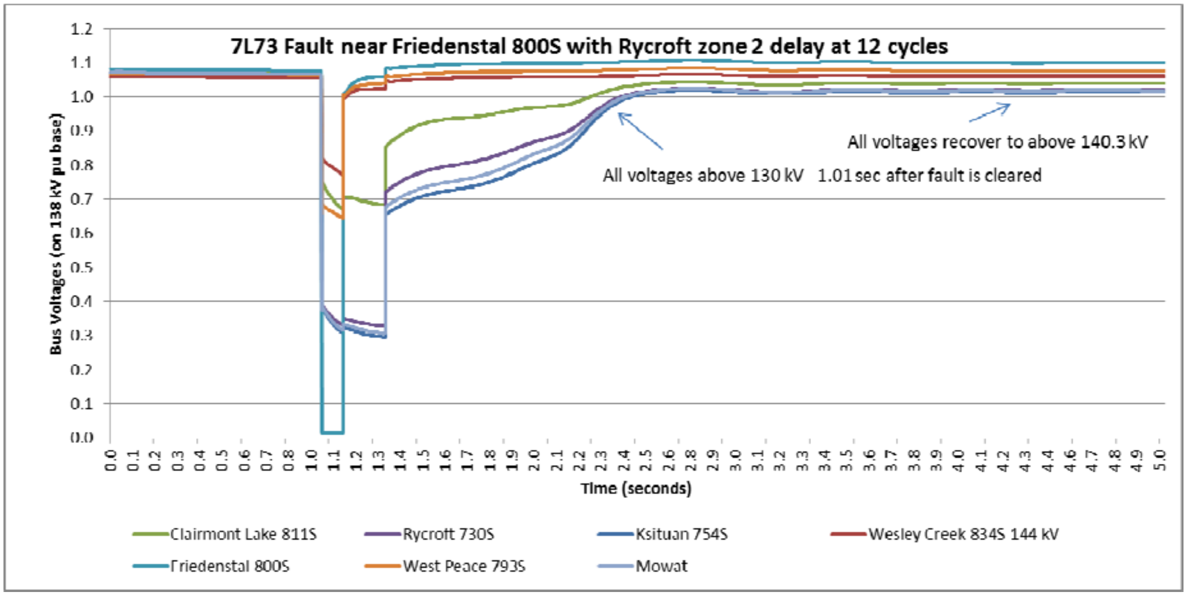
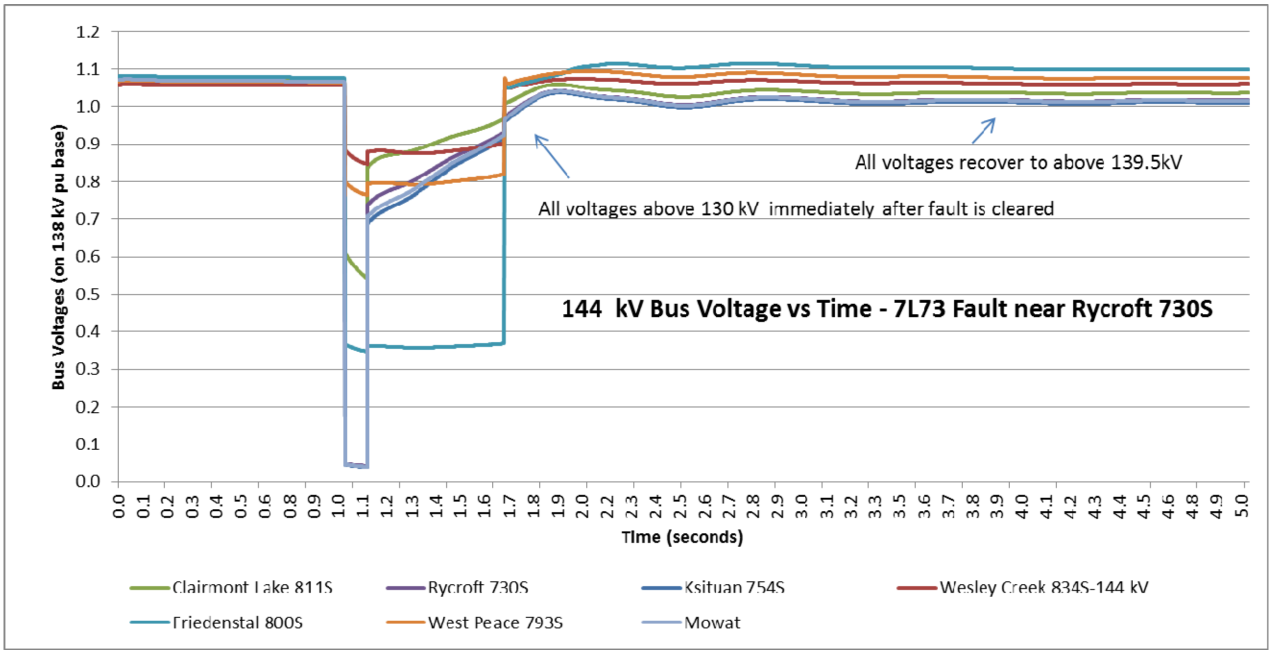


Figure F-8: 7L73 Fault near Rycroft 730S - 144 kV Bus Voltage vs. Time Curve (Rycroft bkr opens in 6 cycles and Friedenstal in 42 cycles after fault)



Recommendations after Voltage Recovery Transient Analysis

For the worst contingencies identified by the power flow and PV analysis, transient voltage recovery testing provided the following recommendations:

- 7L68 (Rycroft 730S to Clairmont Lake 811S) requires teleprotection to ensure all faults are cleared within 8 cycles. (Accelerated zone 2 clearing was investigated but voltage recovery could not be achieved for faults near the Clairmont Lake 811S terminal end. The critical clearing time identified for voltage recovery was 9 cycles requiring teleprotection grade telecommunications to be installed on 7L68.)
- 7L75 (West Peace River 793S to Friedenstal 800S) requires accelerated zone 2 clearing time at Friedenstal 800S to ensure the critical clearing time of 18 cycles is achieved for faults near West Peace River 793S.
- 7L73 (Rycroft 730S to Friedenstal 800S) requires accelerated zone 2 clearing time at Rycroft 730S to ensure the critical clearing time of 18 cycles is achieved for faults near Friedenstal 800S.