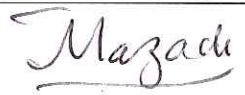


APPENDIX A CONNECTION ASSESSMENT

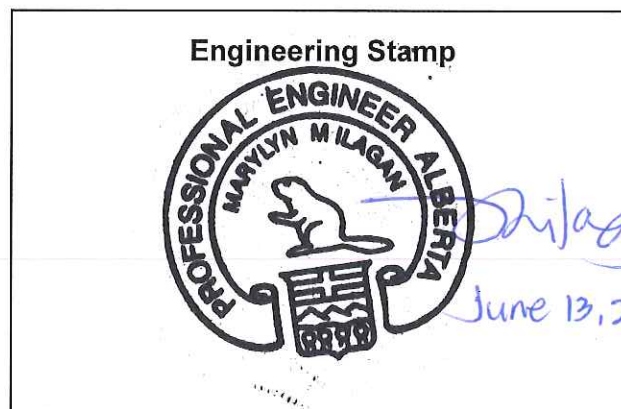
AESO Engineering Connection Assessment

Kirby North Central Processing Facility Connection

AESO Project Number: 1923

Role	Name	Date	Signature
Prepared:	Marylyn Ilagan, P.Eng.	June 13, 2018	
Reviewed/Approved:	Maz Mazadi, PhD., P. Eng.	June 13, 2018	

Version: V1



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P-8200

Note:

The conclusion and recommendations stated in this Report are based on results listed in the Connection Assessment Results report prepared by a third party as part of the AESO's connection process (Attachment A of this report).

The AESO has reviewed the Connection Assessment Results Report, and finds it acceptable for the purpose of assessing potential impacts of the proposed connection on the transmission system.

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Attachment A Engineering Connection Assessment Results

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1. Introduction

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

Attached to this report are the results of the engineering studies (see Attachment A) and the scope and methodology used to perform the studies (see Attachment A1 to Attachment A). These attachments provide details regarding the technical criteria, assumptions, and methods for performing these engineering studies, and the results of the engineering studies.

1.1. Project Overview

Canadian Natural Resources Limited (CNRL) has submitted a request for system access service to the Alberta Electric System Operator (AESO) to connect its approved oil sands recovery facility, called the Kirby North Central Processing Facility (the Facility), in the Conklin area. The Facility will be served by CNRL's approved Margie 1034S substation.

CNRL's request includes a request for a Rate DTS, *Demand Transmission Service*, contract capacity of 29 MW for new system access service in the area, and a request for transmission development (collectively, the Project).

The scheduled in-service date (ISD) for the Project is March 1, 2019.

2. Assessment Scope

2.1. Objectives

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

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

2.2. Study Area

The Study Area for the Project consists of AESO planning areas of Fort McMurray (Area 25) and Athabasca/Lac La Biche (Area 27), including the tie lines connecting these planning areas to the rest of the AIES. All transmission facilities within the Study Area were studied and monitored for violations of the Reliability Criteria (defined in Section 3.1 of Attachment A1).

3. Connection Alternatives

The AESO, in consultation with the legal owners of transmission facilities (TFOs) in the Study Area and the Market Participant, examined three transmission alternatives to meet the Market Participant's request for system access service, as detailed below.

3.1. Connection Alternatives Identified

Alternative 1: Radial Connection to 138 kV Transmission Line 789L

This alternative includes the following developments:

- Add one 138 kV circuit to connect the Margie 1034S substation to the existing 138 kV transmission line 789L approximately 13 km from the existing Winefred 818S substation. To create this radial connection, 789L will be closed at Winefred 818S and opened at the existing Heart Lake 898S substation. This would require the addition of approximately 14 km of 138 kV circuit.
- Add or modify associated equipment as required for the above transmission developments.

Alternative 2: In-and-Out Connection to 240 kV Transmission Line 9L930

This alternative includes the following developments:

- Add two 240 kV circuits to connect the Margie 1034S substation to the existing 240 kV transmission line 9L930 in an in-and-out configuration. This would require the addition of two 240 kV circuits, each approximately 4.5 km in length
- Add or modify associated equipment as required for the above transmission developments.

Alternative 3: Radial Connection to a new 240 kV Switching Station

This alternative includes the following developments:

- Add a 240 kV switching station, including two 240 kV circuit breakers.
- Connect the new 240 kV switching station to the existing 240 kV transmission line 9L930 between Leismer 72S and Heart Lake 898S substations using an in-and-out configuration.
- Connect the Margie 1034S substation to the new 240 kV switching station using a radial configuration. This will require the addition of approximately 4.5 km of 240 kV circuit.

3.2. Connection Alternatives Selected for Further Study

Alternative 1 was selected for further study.

3.3. Connection Alternatives Not Selected for Further Study

Alternative 2 and Alternative 3 would involve more transmission development, and hence overall increased cost, compared to Alternative 1. Therefore, Alternative 2 and Alternative 3 were not selected for further study.

4. Assessment Approach

4.1. Standards, Criteria, and Assumptions

A detailed description of the standards, criteria, and assumptions that were used for the connection assessment can be found in Attachment A1 of Attachment A.

4.2. Studies Performed

The scheduled ISD for the Project is March 1, 2019. Therefore, the studies were performed using the 2019 summer peak (SP), and winter peak (WP) scenarios.

Table 4-1 provides a list of the study scenarios.

Table 4-1: List of the Connection Study Scenarios

Scenario	Year/Season on Load	Condition	Project Load (MW)	Project Generation (MW)	Generation Dispatch Conditions
1	2019 SP	Pre-Project	0	0	Low Cogeneration
2	2019 WP	Pre-Project	0	0	Low Cogeneration
3	2019 SP	Post-Project	29	0	Low Cogeneration
4	2019 WP	Post-Project	29	0	Low Cogeneration

The AESO Planning Region load and generation forecasts used for the connection studies were based on the *AESO 2017 Long-term Outlook (2017 LTO)*.

4.2.1. Power flow studies

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

In addition, power flow studies are also used to identify point of delivery (POD) bus voltage deviations beyond the limits listed in Table 3-1 of Attachment A¹.

Power flow studies were performed for the 2019 SP and 2019 WP pre-Project and post-Project scenarios.

¹ The AESO's desired post-contingency voltage deviations for low voltage busses represent guidelines rather than criteria. A POD bus voltage deviation that exceeds the desired limits shown in Table 3-1 of Attachment A1 does not represent a Reliability Criteria violation. Mitigation measures would not be developed to specifically address POD bus voltage deviations that exceed the desired values in Table 3-1 of Attachment A1.

4.2.2. Voltage Stability Studies

The objective of the voltage stability analysis is to determine the ability of the network to maintain voltage stability at all the busses under Category A and Category B system conditions. The purpose of the voltage stability studies is to assess the ability of the network to maintain voltage stability at all the busses in the system under Category A and Category B system conditions.

Voltage stability studies were performed for the 2019 WP post-Project scenario.

5. Interpretation of Results

The detailed study results are provided in Attachment A.

5.1. Pre-Project Studies Results

Category A condition

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

Category B conditions

No Reliability Criteria violations or POD bus voltage deviations were observed under the Category B condition (i.e., loss of a single system element) for any of the pre-Project scenarios.

5.2. Post-Project Studies Results

Category A condition

No Reliability Criteria violations were observed under the Category A condition for any of the post-Project scenarios.

Category B conditions

No Reliability Criteria violations or POD bus voltage deviations were observed under the Category B condition for any of the post-Project scenarios. The results of the voltage stability studies did not indicate any voltage stability concerns, and the system showed acceptable reactive margin and load transfer capabilities under all studied Category B contingencies.

6. Project Dependencies

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

7. Conclusions and Recommendations

Based on the study results, Alternative 1 is technically viable. The connection assessment did not identify any system performance issues in the pre-Project and post-Project scenarios. The connection of the Project with Alternative 1 will not adversely affect the performance of the AIES.

It is recommended to proceed with the Project using Alternative 1 as the preferred option to respond to the Market Participant's request for system access service. Alternative 1 involves the addition of one 138 kV circuit to radially connect the Margie 1034S substation to the existing 138 kV transmission line 789L.

It is recommended that the conductor to be used for the new 138 kV circuit should have a minimum thermal rating equal to the existing 138 kV transmission line 789L.

Attachment A

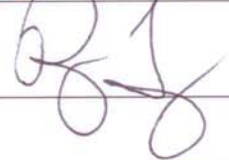
Engineering Connection Assessment Results



Engineering Connection Assessment Results

Kirby North Central Processing Facility Connection

Date: May 18, 2018

Role	Name	Organization	Date	Signature
Prepared:	Lin Li, E.I.T.	PGSC	June 14, 2018	
Reviewed:	Aaron Krush, P. Eng.	PGSC	June 14, 2018	
Approved:	Pung Toy, P. Eng.	PGSC	June 14, 2018	

Version: R1



JUNE 14, 2018

APEGA Permit to Practice: P10933

Suite 506, 100 – 4th Avenue SW
Calgary, Alberta T2P 3N2
www.pgsc.ca

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Attachment A4	Post-Project Voltage Stability P-V Diagrams

1. Introduction

This report presents the results of the engineering studies that were completed by Power Grid Specialists Corp. (the Studies Consultant) to assess the impact of the Project (as defined in Attachment A1: AESO Engineering Connection Assessment Scope) on the performance of the Alberta Interconnected Electric System (AIES). The studies were performed in accordance with Attachment A1, which was prepared by the Alberta Electric System Operator (AESO). The following sections describe the results of the studies.

The power system network analysis tool that was used for the studies in this connection assessment was PSS/E version 33.

2. Pre-Project Study Results

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

2.1. Power Flow Studies

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

2.1.1. 2019 Summer Peak Pre-Project

Category A condition

No Reliability Criteria (as defined in Section 3.1.1 of Attachment A1) violations were observed under the Category A condition.

Category B conditions

No Reliability Criteria violations or voltage deviations beyond the limits listed in Table 3-1 of Attachment A1 (hereafter referred to as, point of delivery (POD) bus voltage deviations) were observed under Category B conditions.

2.1.2. 2019 Winter Peak Pre-Project

Category A condition

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

Category B conditions

No Reliability Criteria violations or POD bus voltage deviations were observed under Category B conditions.

3. Post-Project Study Results

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

3.1. Power Flow Studies

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

3.1.1. 2019 Summer Peak Post-Project

Category A condition

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

Category B conditions

No Reliability Criteria violations or POD bus voltage deviations were observed under Category B conditions.

3.1.2. 2019 Winter Peak Post-Project

Category A condition

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

Category B conditions

No Reliability Criteria violations or POD bus voltage deviations were observed under Category B conditions.

3.2. Voltage Stability Studies

Voltage stability studies were performed for the 2019 WP post-Project scenario. The 6 worst Category B contingencies are reported for each case.

The results did not indicate any voltage stability concerns, and the system showed acceptable reactive margin for all studied Category B conditions.

3.2.1. 2019 Winter Peak Post-Project

Voltage stability analysis was performed for the 2019 WP post-project. The reference load level for the study area (AESO planning area 25 and area 27) is 2481 MW. The minimum incremental load transfer for the Category B contingencies is 5.0% of the reference load or 124.1 MW to meet the voltage stability criteria ($0.05 \times 2481 \text{ MW} = 124.1 \text{ MW}$).

Table 3.2-1 summarizes the voltage stability results for Category A and the worst contingencies for voltage stability transfer margins.

The voltage stability margin was met for all studied conditions. The post-Project voltage stability plots are provided in Attachment A4.¹

Table 3.2-1: Voltage stability results for the 2019 WP Scenario

Studied Contingency (System Element Lost)	From	To	Maximum incremental transfer (MW)	Meets 105% transfer criteria?
None	Category A		1062.5	Yes
951ST1	Thickwood Hills 951S	Thickwood Hills 951S	700.00	Yes
12L45	Thickwood Hills 951S	Livock 939S	700.00	Yes
9L101	Mcclelland 957S	Secord 2005S	718.75	Yes
12L44	Livock 939S	Sunnybrook 510S	693.75	Yes
9900ST4	Kearl 9900S Transformer T4		443.75	Yes
728L	Plamondon 353S	Lac La Biche 157S	868.75	Yes

¹ The voltage stability plots for the Thickwood Hills 951S T1 transformer and 12L45 (Thickwood Hills 951S – Livock 939S) contingencies produce identical results.

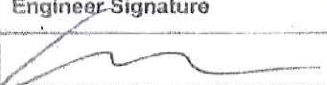
Attachment A1

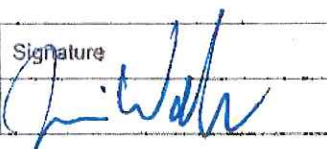
AESO Engineering Connection Assessment Scope

AESO Engineering Connection Assessment Scope

Kirby North Central Processing Facility Connection

AESO Project Number: 1923

Company Name	Engineer Name P.Eng.	Date	Engineer Signature
PGSC (Study Consultant)	Aaron Krush, P.Eng.	May 18, 2018	
AESO (Project Studies Engineer)	Marylyn (Len) Ilagan, P.Eng.	June 5, 2018	

Company Name	Name	Date	Signature
CNRL	Jamie Walker	May 23/18	

Document Release V2

May 16, 2018

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Attachment A1.1 Transmission Planning Criteria – Basis and Assumptions

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1. Introduction

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

1.1. Project

1.1.1. Project Overview

Canadian Natural Resources Limited (CNRL) has submitted a request for system access service to the Alberta Electric System Operator (AESO) to connect its approved oil sands recovery facility, called the Kirby North Central Processing Facility (the Facility), in the Conklin area. The Facility will be served by CNRL's approved Margie 1034S substation.

CNRL's request includes a request for a Rate DTS, *Demand Transmission Service*, contract capacity of 29 MW for new system access service in the area, and a request for transmission development (collectively, the Project).

The scheduled in-service date (ISD) for the Project is March 1, 2019.

1.1.2. Load Component

The Project includes a load component:

- A requested Rate DTS contract capacity of 29 MW at CNRL's proposed Margie 1034S substation.
- Load type is industrial.
- The Facility will include three 5000HP induction motors.

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 are as follows:

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

1.2.2. Study Area

1.2.2.1. Study Area Description

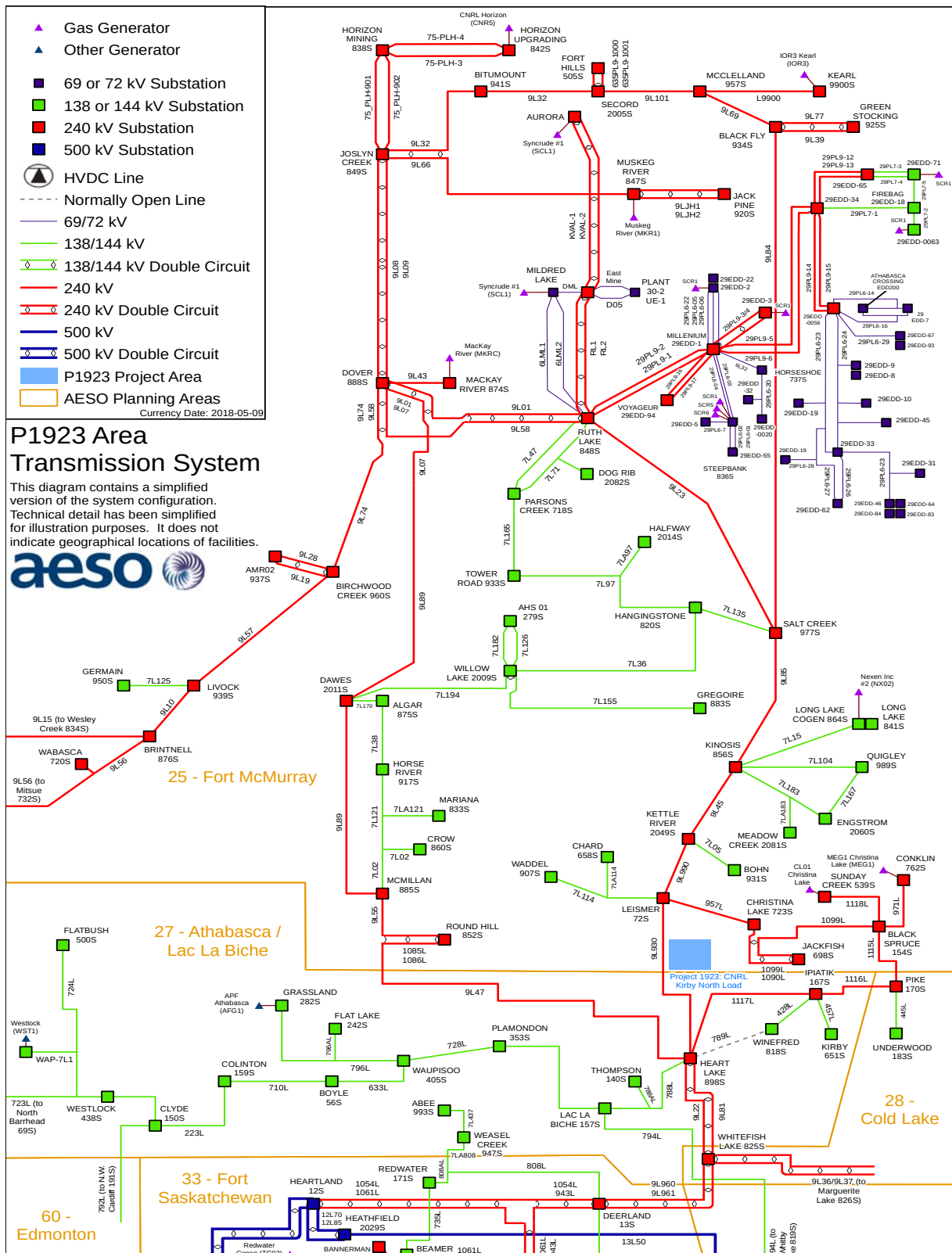
Geographically, the Project is located in the AESO Fort McMurray planning area (Area 25), which is part of the AESO Northeast Planning Region.

From a transmission system perspective, the southeast part of the Fort McMurray area (Area 25) has several substations such as Christina Lake 723S, Jackfish 698S, Black Spruce 154S, Sunday Creek 539S, Pike 170S, Underwood 183S and Ipiatik Lake 167S that are being supplied from the 240 kV transmission line 957L from Leismer 72S substation and the 240 kV transmission line 1117L from Heart Lake 898S substation. The 138 kV loads at the Winefred 818S and Kirby 651S substations located in the adjacent Athabasca/Lac La Biche area (Area 27) are being supplied from the Ipiatik Lake 167S substation.

The Study Area for the Project consists of the AESO planning areas of Fort McMurray (Area 25) and Athabasca/Lac La Biche (Area 27), including the tie lines connecting these planning areas to the rest of the AIES. All transmission facilities within the Study Area will be studied and monitored for violations of the Reliability Criteria (as defined in Section 3.1).

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

Figure 1-1: Existing Study Area Transmission System



1.2.2.2. Existing Constraints

The existing constraints in the Study Area are managed in accordance with the procedures set out in Section 302.1 of the ISO rules, *Real Time Transmission Constraint Management* (TCM Rule). There are a number of existing constraints in the Study Area that are mitigated by a remedial action schemes (RAS).

The following mitigation is used to manage constraints in the area:

1. RAS 155: Kearl voltage stability mitigation

1.2.3. Studies Performed

The following engineering studies are required for the pre-Project scenarios:

- Power flow studies

The following engineering studies are required for the post-Project scenarios:

- Power flow studies
- Voltage stability studies

2. Connection Alternative to be Studied

The following Alternative will be studied.

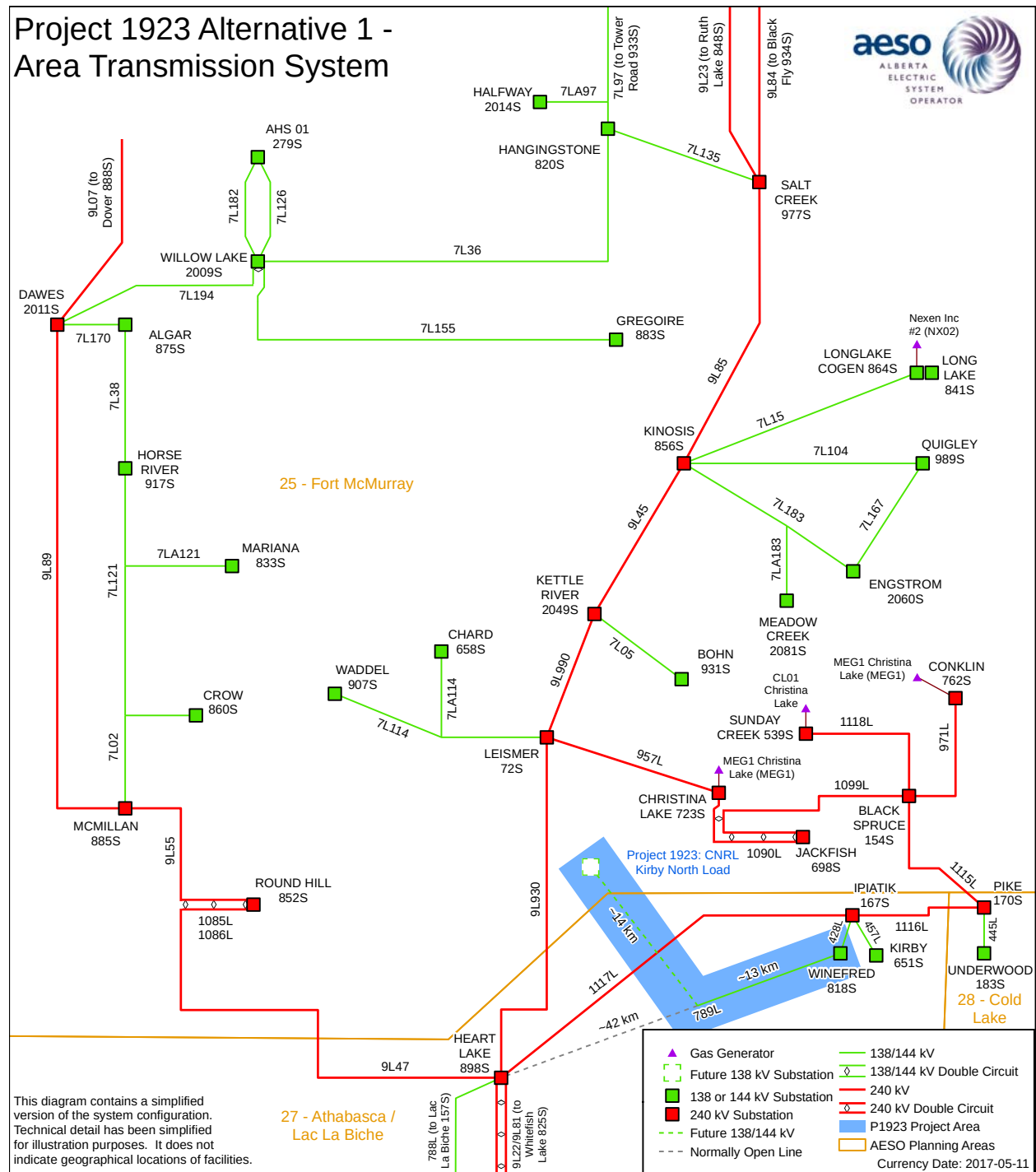
Alternative 1: Radial Connection to 138 kV Transmission Line 789L

This alternative includes the following developments:

- Add one 138 kV circuit to connect the Margie 1034S substation to the existing 138 kV transmission line 789L approximately 13 km from the existing Winefred 818S substation. To create this radial connection, 789L will be closed at Winefred 818S and opened at the existing Heart Lake 898S substation. This would require the addition of approximately 14 km of 138 kV circuit.
- Add or modify associated equipment as required for the above transmission developments.

Figure 2-1 shows the proposed Project connection.

Figure 2-1: Proposed Project Connection



3. Criteria, System Data, and Study Assumptions

3.1. Criteria, Standards, and Requirements

3.1.1. Transmission Planning Standards and 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, the Reliability Criteria) will be applied to evaluate system performance under Category A system conditions (i.e., all elements in-service) and following Category B (i.e., single element outage), prior to and following the studied alternatives. Below is a summary of Category A and Category B system conditions.

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

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

The TPL standards, TPL-001-AB-0 and TPL-002-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 conditions: Voltage range under normal operating condition should follow the AESO Information Document ID #2010-007RS, *General Operating Practices – Voltage Control* (ID #2010-007RS). For the busses not listed in ID #2010-007RS, Table 2-1 in the *Transmission Planning Criteria – Basis and Assumptions* applies.

¹ Please refer to Attachment A1.1

- For Category B condition: 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 3-1.

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

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

3.1.2. ISO Rules and IDs

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

The TCM Rule will be followed in setting up the study scenarios and assessment of the impact of the Project. In addition, due regard will be given to the AESO's *Connection Study Requirements and the AESO's Generation and Load Interconnection Standard*.

3.2. Study Scenarios

The scheduled ISD for the Project is March 1, 2019. Therefore, the studies will be performed using the 2019 summer peak (SP) and 2019 winter peak (WP) scenarios, as shown in Table 3-2.

Table 3-2: List of the Connection Study Scenarios

Scenario	Year/Season Load	Condition	Project Load (MW)	Project Generation (MW)	Generation Dispatch Conditions
1	2019 SP	Pre-project	0	0	Low Cogeneration
2	2019 WP	Pre-Project	0	0	Low Cogeneration
3	2019 SP	Post-project	29	0	Low Cogeneration
4	2019 WP	Post-Project	29	0	Low Cogeneration

3.3. Load and Generation Assumptions

3.3.1. Load Assumptions

The AESO planning area and planning region load forecasts used for this connection study are shown in Table 3-3 and are based on the *AESO 2017 Long-term Outlook* (2017 LTO) at Northeast Planning Region Peak. For the studies, when POD loads for the Alberta internal load (AIL) are modified to align with the load forecast from the 2017 LTO, the active power to reactive power ratio in the base case scenarios will be maintained.

Table 3-3: Forecast Area Load (2017 LTO at Northeast Planning Region Peak)

AESO Planning Region/Area Name	Forecast Peak Load (MW)	
	2019 Summer Peak (SP)	2019 Winter Peak (WP)
Fort McMurray (Area 25)	1942	2261
Northeast Region	2741	3146

Notes:

- The Northeast Region comprises the following AESO planning areas: 25, 27 and 33.

3.3.2. Generation Assumptions

The dispatch assumptions used for the existing generating units in the vicinity of the Study Area are presented in Table 3-4. The studies will assume low cogeneration dispatch conditions.

The MEG Conklin Christina Lake generating unit 1 was determined to be the critical generator, and will be modelled as being offline to simulate the N-G condition in all the study scenarios.

Table 3-4: Existing Generation (MW) in the Study Area

Unit Name	AESO Planning Area	Bus Number	MC (MW)	2019 SP Unit Net Generation ^a (MW)	2019 WP Unit Net Generation ^a (MW)
CNRL Horizon	25	18264_G1 19264_5 2268_G2	195.06	141	170
MEG Conklin Christina Lake	25	2405_1 3405_2	82.5 71.6	N-G ^b 37.2	N-G ^b 58.2
MacKay River	25	18274_1	185	147	187
Nexen Longlake	25	11241_G3 11241_G4 12249_G2 13249_G1	183	71	110
Syncrude	25	16233_12 17209_G3 17210_G4 17233_11 18206_2 18207_1 18209_G2 18210_G5 19209_G1 19210_G6	592.1	285	329
Firebag Suncor - Millennium	25	17297_G3 19297_1 18297_1 3273_G7 16297_G4 16219_G3 18208_G5 19208_G6 18218_G2 16218_G1 18223_G4	926.4	489	630
IOL Kearl	25	1695_ST	86	58	70
Muskeg River	25	10236_1 12236_2	202	88	168
Fort Hills	25	14781_G1 14782_G2	199.93	132	156
Christina Lake	25	4379_539S_G1 4380_539S_G2	100	70	84
DAPP (Westlock)	27	14_G1	17	9	13
AltaGas Bantry/AltaGas Parkland (ALPAC)	27	2392_1 2392_2 2392_3 2392_4	139.6	49	58

^a "Unit Net Generation" refers to gross generating unit output (MW) less unit service load.

^b "N-G" indicates the critical generating unit that is assumed by the AESO to be offline to test the N-G contingency condition

3.3.3. Intertie Flow Assumptions

The British Columbia-Alberta (BC-AB), Saskatchewan-Alberta (SK-AB), and Montana-Alberta (MATL) interties power flows are expected to have no material impact on the connection

assessment for the Project. Therefore, the intertie flows will be assumed to be the same as the AESO planning base cases and will not be adjusted for the studies.

3.3.4. HVDC Power Order

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

3.4. System Projects

The system projects that have approvals and/or are under construction are outlined in Table 3-5. These transmission developments in the Study Area will be considered in-service for the studies.

Table 3-5: Summary of System Projects Included in the Study Cases

AESO Project No.	AESO Project Name and Description	Scheduled In-Service Date
1655	Sunnybrook and Livock Interconnection with Fort McMurray West 500kV Transmission Facilities Development of transmission facilities at the existing Livock 939S substation and existing Sunnybrook 510S substation to integrate the Fort McMurray West 500 kV transmission line (see Project 1590 below).	Q4 2018
1186	Thickwood Hills 240 kV Transmission Development and Reactive Power Reinforcement The construction of a new 240 kV switching substation to be designated as Thickwood Hills 951S and its associated 240kV line terminations on 9L07 and 9L01.	Q1 2019
1590	Fort McMurray West 500 kV Transmission Project Thickwood – Livock – Sunnybrook 500 kV transmission line	Q3 2019

3.5. Connection Projects

No connection projects will be included in the study scenarios.

3.6. Facility Ratings and Shunt Elements

The legal owners of transmission facilities (TFOs) provided the thermal ratings assumptions for the existing transmission lines in the Study Area. Table 3-6 shows the normal and emergency ratings for the key transmission lines in the Study Area, which will be used to perform the engineering studies.

Table 3-6: Summary of Key Transmission Line Ratings in the Study Area

Line ID	Line Description	Voltage Class (kV)	Normal Rating (MVA)		Emergency Rating (MVA)	
			Summer	Winter	Summer	Winter
728L	Plamondon 353S – Lac La Biche 157S	138	72	72	95	100
728L	Plamondon 353S – Waupisoo 405S	138	72	72	95	100
788L	Lac La Biche 157S – 788AL Tap	138	119	146	131	161
794L / 7L94	Lac La Biche 157S – Whitby Lake 819S	138	85	90	94	99
428L	Winefred 818S – Ipiatik Lake 167S	138	121	149	133	164
788L	Heart Lake 898S – 788AL Tap	138	119	146	131	161
9L930	Heart Lake 898S – Leismer 72S	240	519L	663L	592L	716L
9L47	Heart Lake 898S – Round Hill 852S	240	550L	702L	627L	759L
9L22	Heart Lake 898S – Whitefish Lake 825S	240	498CT	498CT	498CT	498CT
9L81	Heart Lake 898S – Whitefish Lake 825S	240	498CT	498CT	498CT	498CT
1117L	Heart Lake 898S – Ipiatik Lake 167S	240	931	1117	1024	1210
957L	Leismer 72S – Christina Lake 723S	240	594	713	654	773
9L990	Leismer 72S – Kettle River 2049S	240	519L	663L	592L	716L
1090L	Christina Lake 723S – Jackfish 698S	240	594	713	654	773
971L	Conklin 762S – Black Spruce 154S	240	624	764	749	917
1099L	Jackfish 698S – Black Spruce 154S	240	624	764	749	917
1118L	Sunday Creek 539S – Black Spruce 154S	240	647	802	776	962
1115L	Black Spruce 154S – Pike 170S	240	931	1117	1024	1210
1116L	Pike 170S – Ipiatik Lake 167S	240	931	1117	1024	1210
457L	Kirby 651S – Ipiatik Lake 167S	138	121	149	133	164
789L	Winefred 818S – 789L Tap	138	86	91	95	100
789L	Heart Lake 898S – 789L Tap	138	86	91	95	100
789L	789L Tap – New Margie 1034S (P1923)	138	120	148	132	163
1086L	Heart Lake 898S – Round Hill 852S	240	603	723	663	784
9L47	Heart Lake 898S – Round Hill 852S	240	550L	702L	627L	759L

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

The TFOs provided the details of the substation transformers in the Study Area. The key transformers in the Study Area are shown in Table 3-7.

Table 3-7: Summary of Key Transformer Ratings in the Study Area

Substation Name and Number	Transformer ID	Transformer Voltages (kV)	Transformer Rating (MVA)
Heart Lake 898S	898S 902T	240/144	H-X is 120/160/200 MVA (240-144 kV) H-Y is 40/53.3/66.7 MVA with the Y winding used as a reactor bus
Leismer 72S	72S T1	240/25	25/33/42
	72S T2	240/144	240/320/400
Pike 170S	170S T1	240/144	120/160/200
	170S T2	240/144	120/160/200
Ipiatik Lake 167S	167S T2	240/144	120/160/200

The TFOs provided the details of the shunt elements in the Study Area. The key shunt elements in the Study Area are shown in Table 3-8.

Table 3-8: Summary of Key Shunt Elements in the Study Area

Substation Name and Number	Voltage Class (kV)	Capacitors			Reactors		
		Number of Switched Shunt Blocks	Total at Nominal Voltage (MVar)	Status in Study (on or off)	Number of Switched Shunt Blocks	Total at Nominal Voltage (MVar)	Status in Study (on or off)
Boyle 56S	138	1	14.95	Switch as required	-	-	Switch as required
Winefred 818S	138	1	9.98		-	-	
		1	14.05		-	-	
		1	18.04		-	-	
Waupisoo 405S	138	1	16.20		-	-	
		1	19.93		-	-	
Heart Lake 898S		-	-		1	20	
Lac La Biche 157S	138	1	10.80		-	-	
Leismer 72S	138	2	27.08		-	-	
Kinosi 856S	138	2	27.55		-	-	
Salt Creek 977S	240	-	-		1	34.96	
Thickwood Hills 951S	240	1	200		1	100	

3.7. Voltage Profile Assumption

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

4. Study Methodology

4.1. Engineering Studies to be Performed

The engineering studies to be performed for this connection assessment are identified in Table 4-1.

Table 4-1: Summary of Engineering Studies Performed

Scenario No. and Name		System Conditions	Load Flow	Voltage Stability
1	2019 SP Pre-project	Category A and Category B	X	
2	2019 WP Pre-Project	Category A and Category B	X	
3	2019 SP Post-Project	Category A and Category B	X	
4	2019 WP Post-Project	Category A and Category B	X	X

4.2. Power Flow Studies

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

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

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

The scenarios are to be studied as shown in Table 4-1.

4.2.1. Contingencies to be Studied

Power flow studies will be performed for all Category B contingencies in the Study Area.

4.3. Voltage Stability Studies

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

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

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

Typically, voltage stability studies are carried out assuming the worst case loading scenarios. The voltage stability analysis will be performed by increasing load in Fort McMurray (Area 25) and Athabasca/Lac La Biche area (Area 27), and generation will be correspondingly increased in Wabamun (Area 40).

Results will be provided for the Category A condition and the top six worst case contingencies under Category B conditions as identified by the voltage stability studies. The results are to clearly identify whether or not the applicable criteria are met.

5. Mitigation Measures

5.1. Development

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

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

- Consult with the AESO to propose changes, if any, to the connection alternatives that could remove the requirement for a RAS.
- Consult with the AESO to study modifications to existing and/or planned RASs, proposed by the AESO, to ensure the coordination of existing protection schemes with the addition of any proposed protection schemes.
- Consult with the AESO to identify and study new RASs, if any, that may be required to ensure post-Project system reliability is maintained.

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

Attachment A1.1

Transmission Planning Criteria- Basis and Assumptions (Reliability Criteria)

1. Introduction

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

2. Transmission Reliability Standards and Criteria¹

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

1. TPL-001-AB-0: System Performance Under Normal Conditions

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

2. TPL-002-AB-0: System Performance Following Loss of a Single BES Element

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

3. TPL-003-AB-0: System Performance Following Loss of Two or More BES Elements

Category C events result in the loss of two or more bulk electric system elements (sequential, N-1-1 or concurrent, N-2) under specified fault conditions and include both normal and delayed fault clearing. All of the system limits for Category A and B events apply with the exception that planned and controlled loss of firm load, firm transfers and/or generation is acceptable provided there is no cascading.

4. TPL-004-AB-0: System Performance Following Extreme BES Events

Category D represents a wide variety of extreme, rare and unpredictable events, which may result in the loss of load and generation in widespread areas. The system may not be able to reach a new stable steady state, which means a blackout is a possible outcome. The AESO needs to evaluate these events, at its discretion, for risks and consequences prior to creating mitigation plans.

5. FAC-014-AB-2: Establishing and Communicating System Operating Limits

The AESO is required to establish system operating limits where a contingency is not mitigated through construction of transmission facilities.

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

2.1 Thermal Loading Criteria

The AESO Thermal Loading Criteria require that the continuous thermal rating of any transmission element is not exceeded under normal and post-contingency operating conditions. Thermal limits are assumed to be 100% of the respective normal summer and winter ratings. Emergency limits are not considered in the planning evaluations.

2.2 Voltage Range and Voltage Stability Criteria

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

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

Nominal Voltage	Extreme Minimum	Normal Minimum	Normal Maximum	Extreme Maximum
500	475	500	525	550
240	216	234	252	264
260 (Northeast & Northwest)*	234	247	266	275
144	130	137	151	155
138	124	135	145	150
72	65	68.5	75.5	79
69	62	65.5	72.5	76

Table 2-2: Voltage Stability Criteria

Performance Level	Disturbance (1)(2)(3)(4) Initiated by: Fault or No fault DC Disturbance	MW Margin (P-V method) (5)(6)(7)	MVAr Margin (V-Q method) (6)(7)
A	Any element such as: One Generator One Circuit One Transformer One Reactive Power Source One DC Monopole	$\geq 5\%$	Worst Case Scenario(8)
B	Bus Section	$\geq 5\%$	50% of Margin Requirement

Performance Level	Disturbance (1)(2)(3)(4) Initiated by: Fault or No fault DC Disturbance	MW Margin (P-V method) (5)(6)(7)	MVAr Margin (V-Q method) (6)(7)
			in Level A
C	Any combination of two elements such as: A Line and a Generator A Line and a Reactive Power Source Two Generators Two Circuits Two Transformers Two Reactive Power Sources DC Bipole	$\geq 2.5\%$	50% of Margin Requirement in Level A
D	Any combination of three or more elements. i.e.: Three or More Circuits on ROW Entire Substation Entire Plant Including Switchyard	> 0	> 0

2.3 Transient Stability Analysis Assumptions

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

Table 2-3: Fault Clearing Times

Nominal	Near End	Far End
kV	Cycles	Cycles
500	4	5
240	5	6
144/138	6	8

with telecommunications		
144/138	6	30
without telecommunications		

Table 2-4: Stuck Breaker Clearing Times for Lines

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

Table 2-5: Stuck Breaker Clearing Times for Transformers

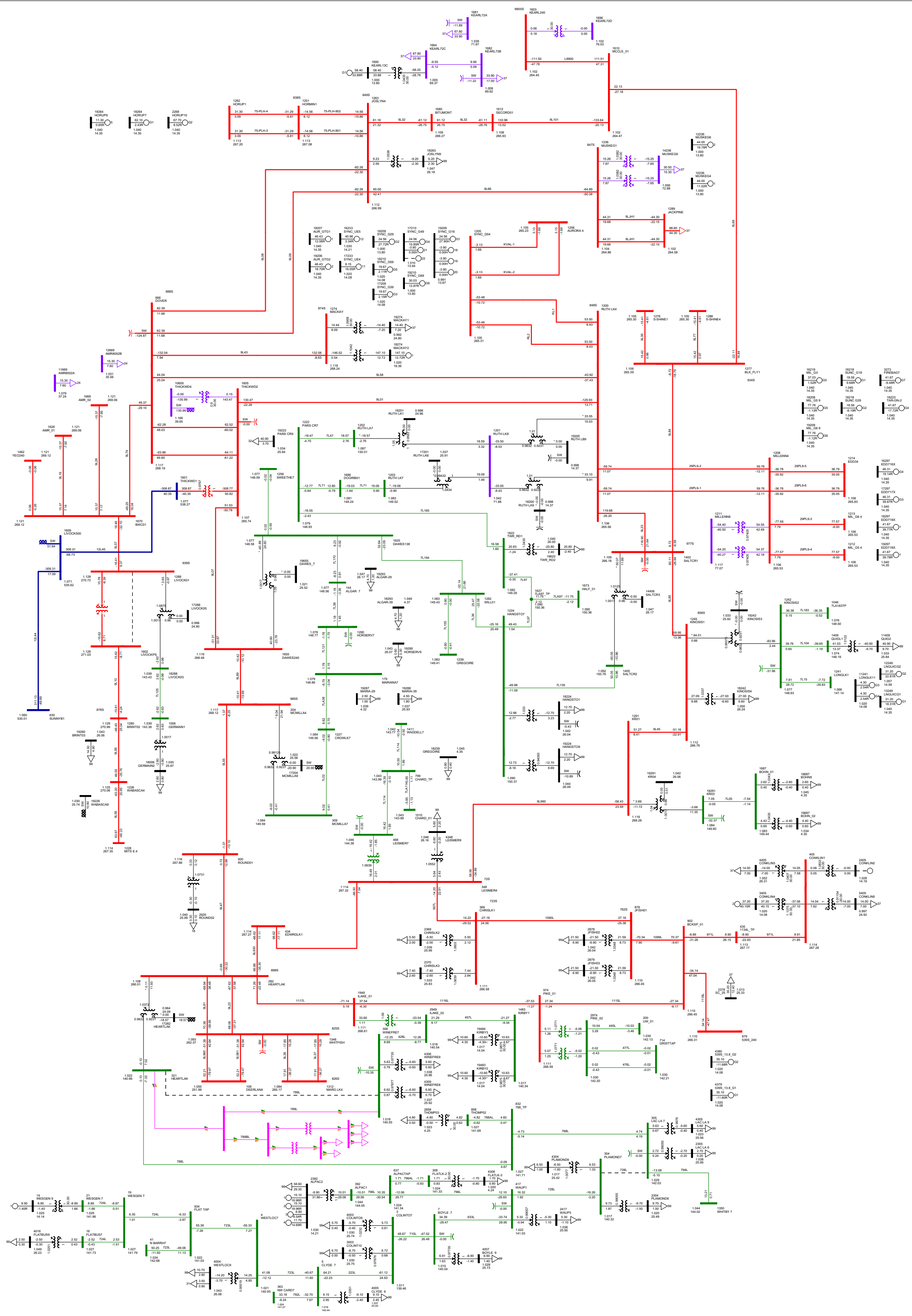
Fault Clearing Time (Cycles)						Fault Clearing Time (Cycles)					
240/138 kV						500/240 kV					
Fault on 240 kV Side			Fault on 138 kV Side			Fault on 500 kV Side			Fault on 240 kV Side		
240 kV Side	138 kV Side	2 nd Ckt (for Breaker Fail)	138 kV Side	240 kV Side	2 nd Ckt (for Breaker Fail)	500 kV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

Attachment A2

Pre-Project Power Flow Diagrams

Table A2-SP-Pre: List of 2019SP Pre Project Load Flow Diagrams

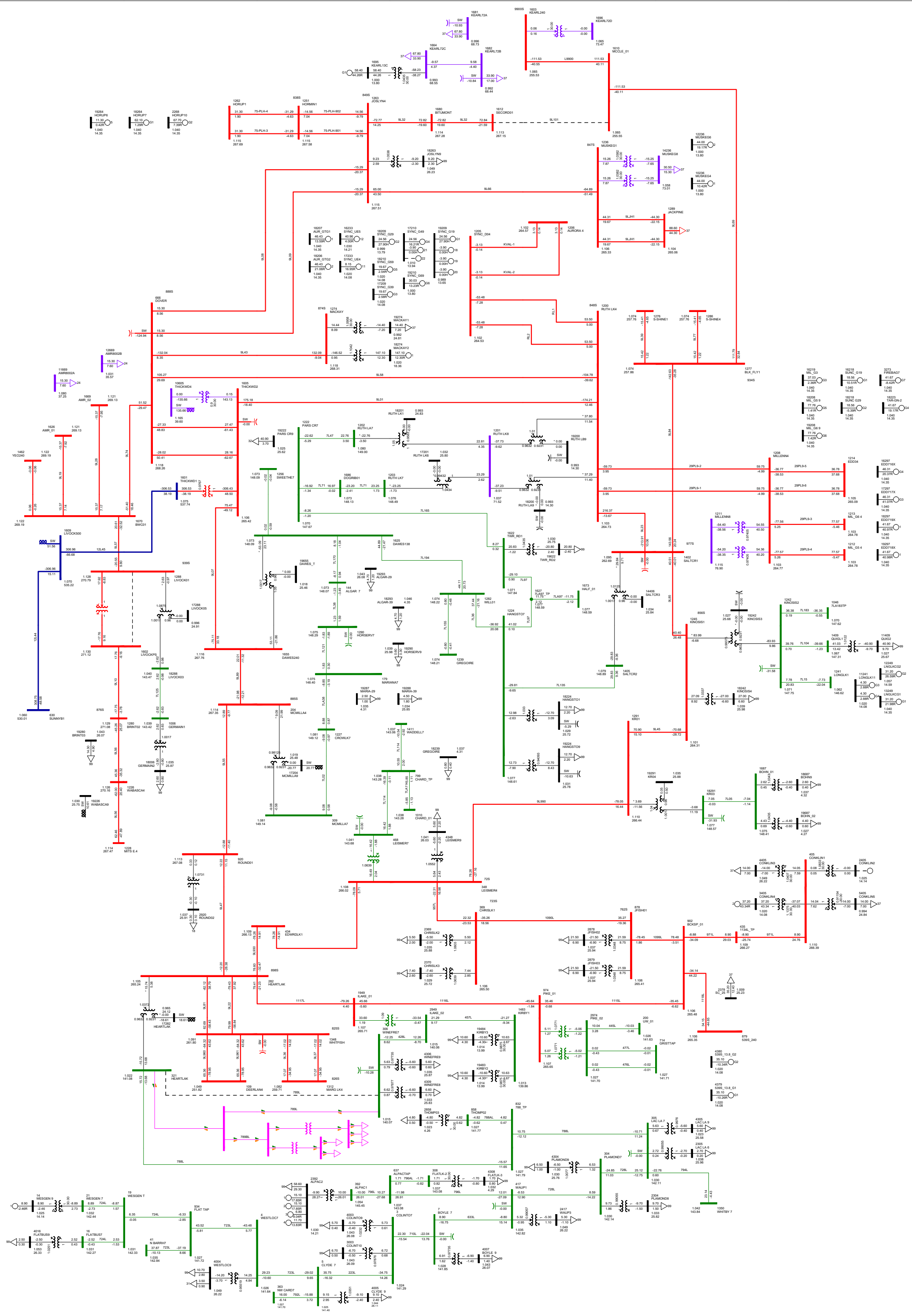
Figure	Category	Contingency
A2-SP-Pre-1	A (N-0)	System Normal
A2-SP-Pre-2	B (N-1)	728L Plamondon 353S - Lac La Biche 157S
A2-SP-Pre-3	B (N-1)	9L101 Mcclelland 957S - Secord 2005S
A2-SP-Pre-4	B (N-1)	12L45 Thickwood Hills 951S - Livock 939S
A2-SP-Pre-5	B (N-1)	12L44 Livock 939S - Sunnybrook 510S
A2-SP-Pre-6	B (N-1)	T4 Kearl 9900S Transformer
A2-SP-Pre-7	B (N-1)	T1 Thickwood Hills 951S Transformer



A2-SP-Pre-2

2015SP PRE CASE
728L PLAMONDON 353S - LAC LA BICHE 157S CONTINGENCY
THU, APR 19 2018 15:59

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

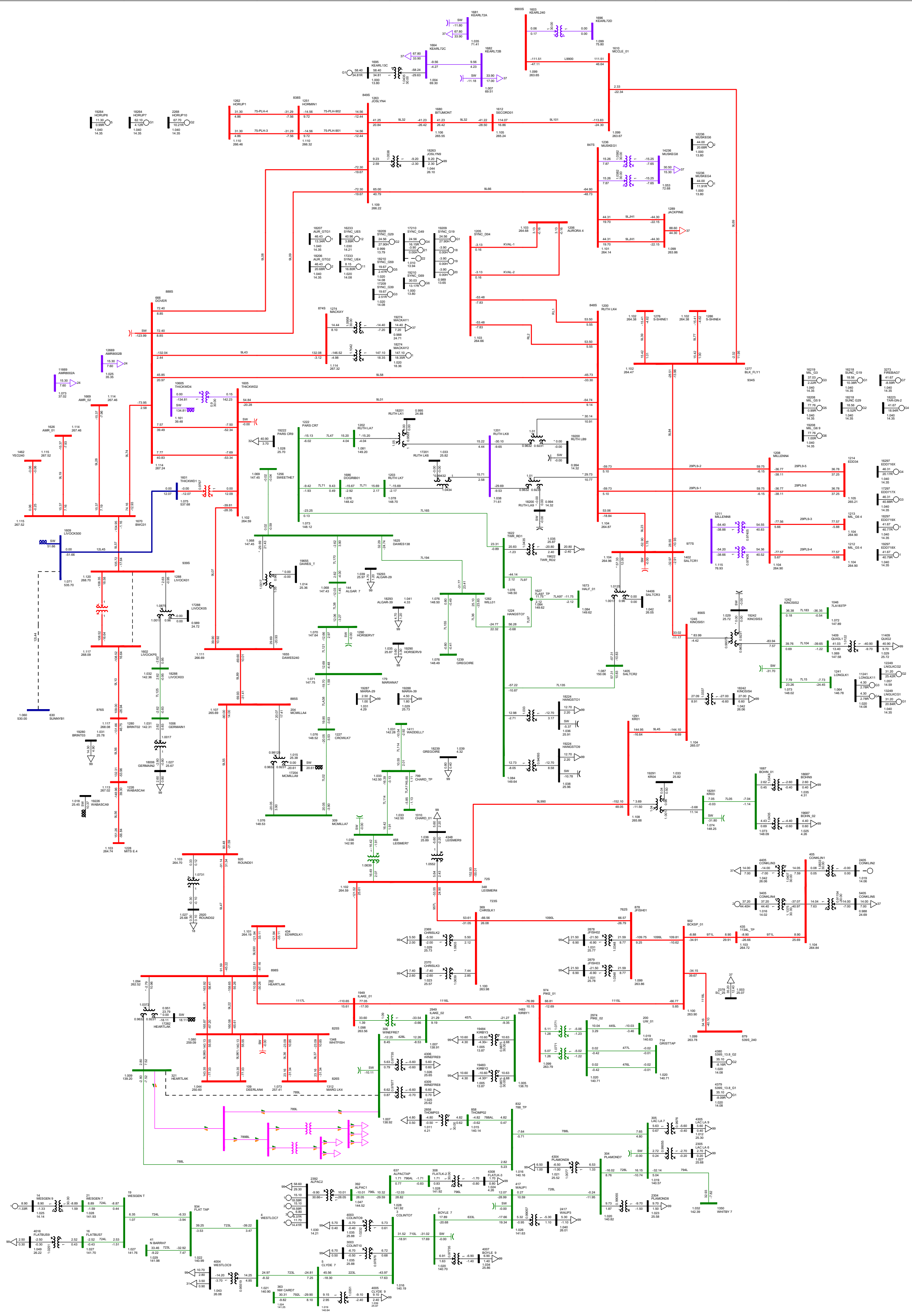


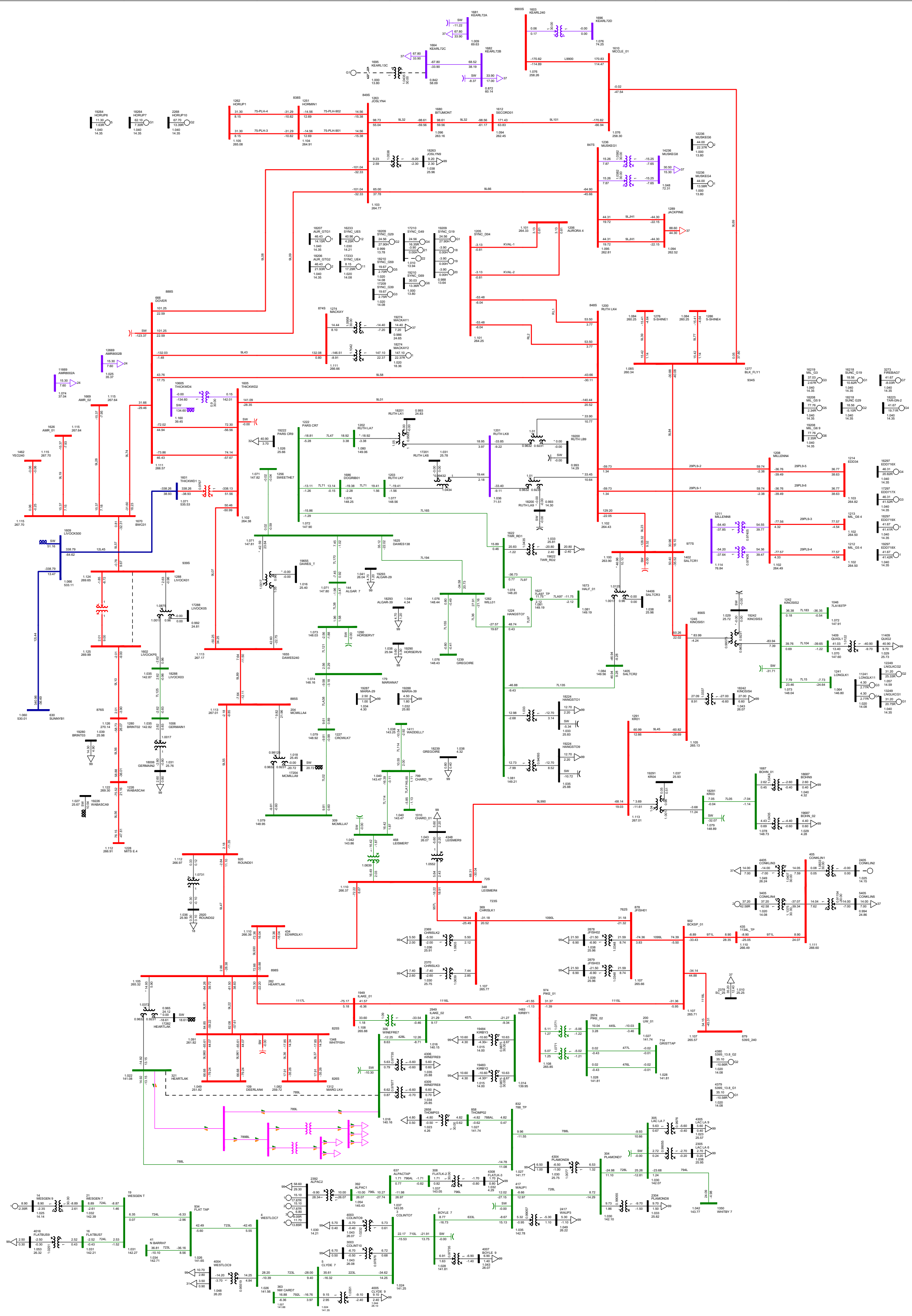
2019SP PRE CASE
12L45 THICKWOOD HILLS 951S - LIVOCK 939S CONTINGENCY
THU, APR 19 2018 15:05

A2-SP-Pre-4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A

kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000





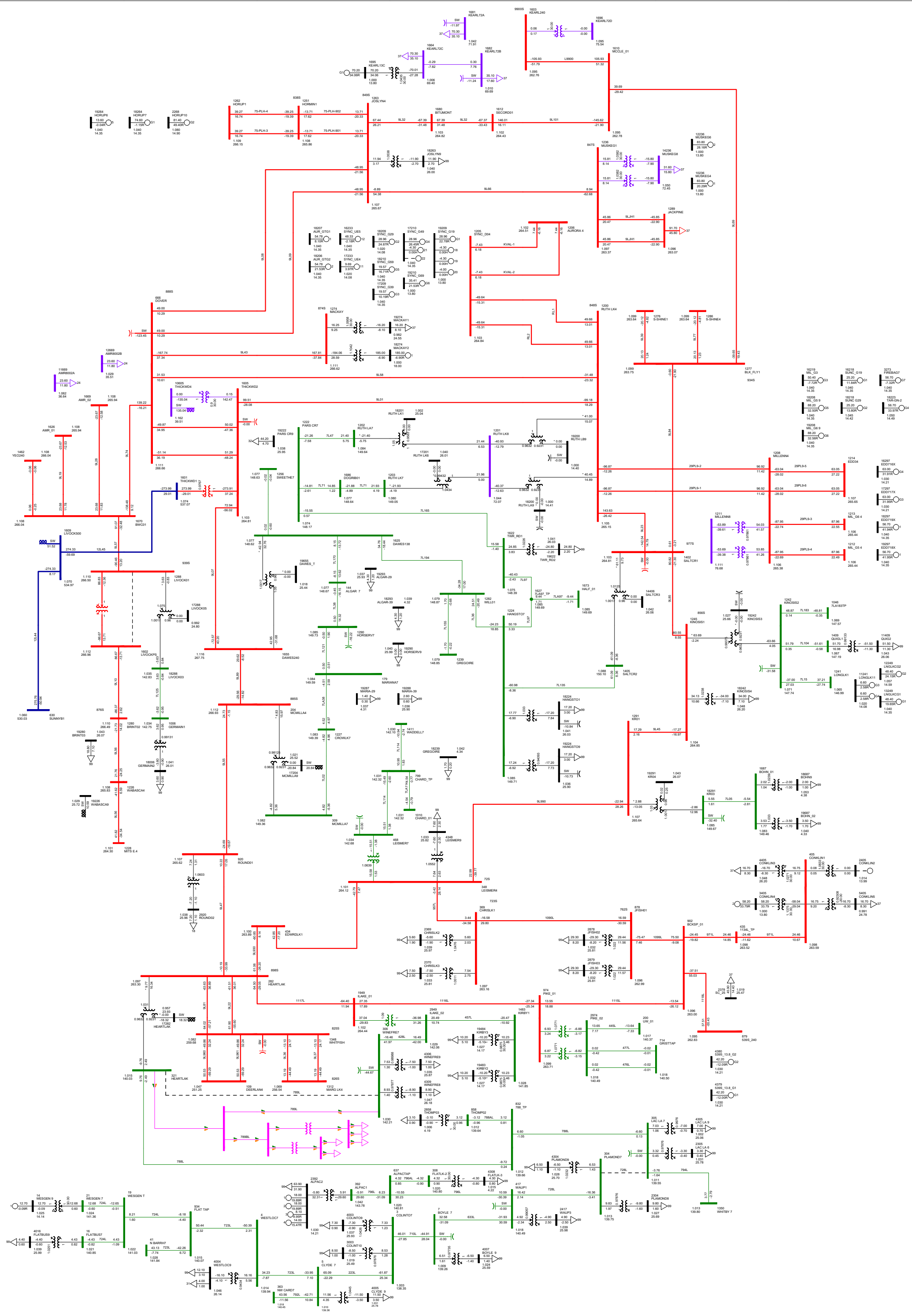
2015SP PRE CASE
T4 KEARL 9900S TRANSFORMER CONTINGENCY
THU, APR 19 2018 15:05

A2-SP-Pre-6

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

Table A2-WP-Pre: List of 2019WP Pre Project Load Flow Diagrams

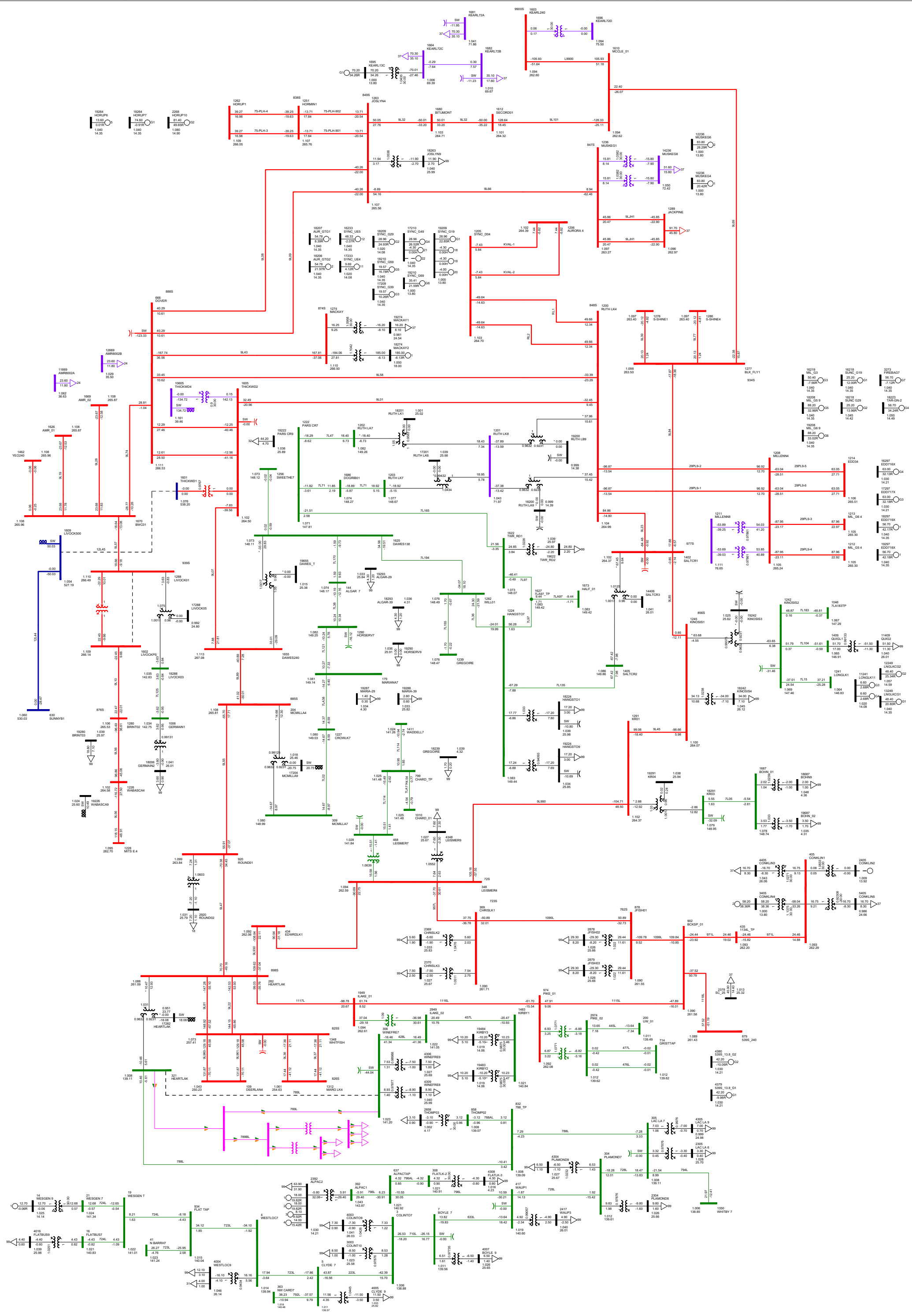
Figure	Category	Contingency
A2-WP-Pre-1	A (N-0)	System Normal
A2-WP-Pre-2	B (N-1)	728L Plamondon 353S - Lac La Biche 157S
A2-WP-Pre-3	B (N-1)	9L101 Mcclelland 957S - Secord 2005S
A2-WP-Pre-4	B (N-1)	12L45 Thickwood Hills 951S - Livock 939S
A2-WP-Pre-5	B (N-1)	12L44 Livock 939S - Sunnybrook 510S
A2-WP-Pre-6	B (N-1)	T4 Kearl 9900S Transformer
A2-WP-Pre-7	B (N-1)	T1 Thickwood Hills 951S Transformer



2019WP PRE CASE
728L PLAMONDON 353S - LAC LA BICHE 157S CONTINGENCY
THU, APR 19 2018 15:59

A2-WP-Pre-2

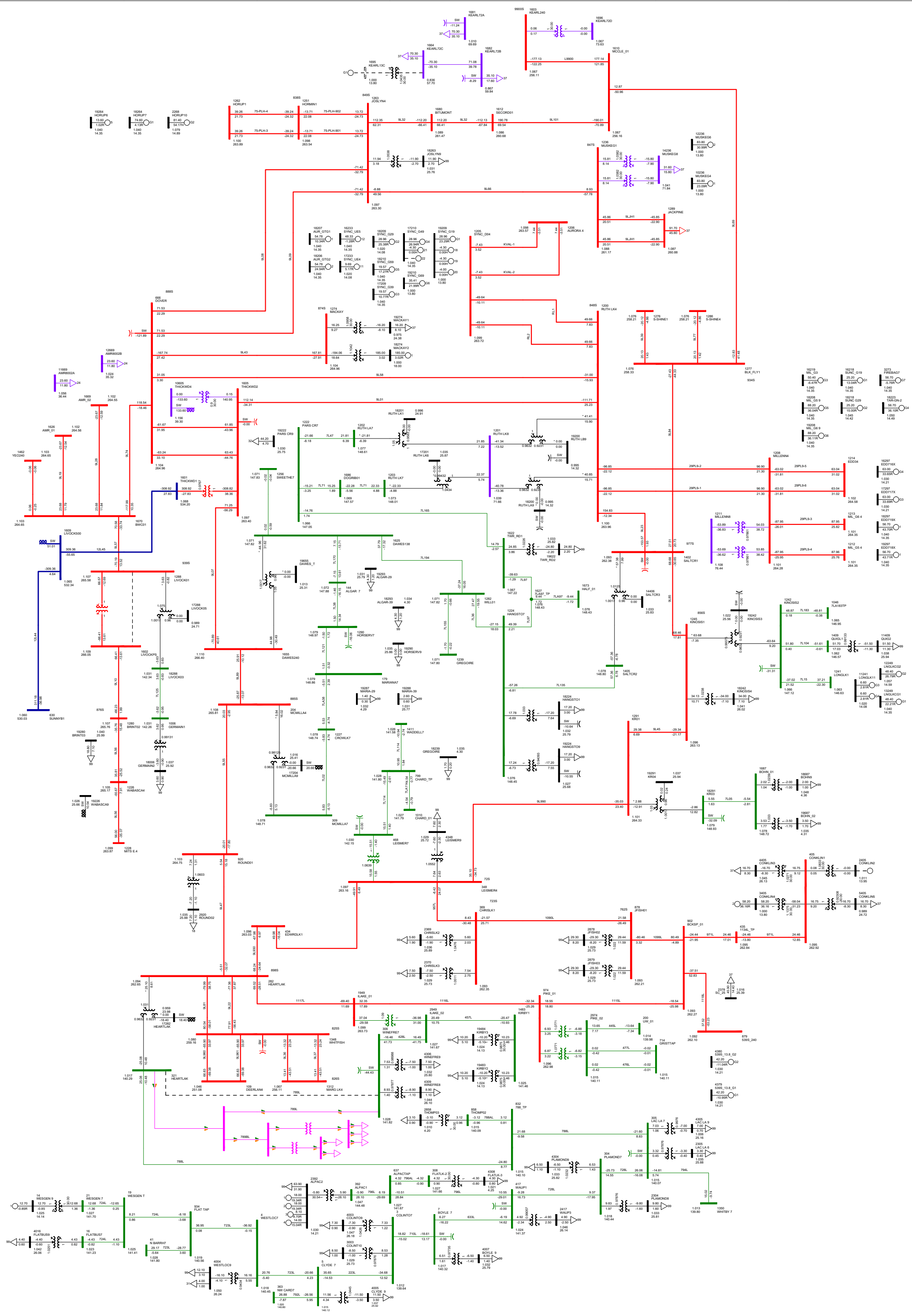
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2019WP PRE CASE
12L45 THICKWOOD HILLS 951S - LIVOCK 939S CONTINGENCY
THU, APR 19 2018 15:07

A2-WP-Pre-4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2019WP PRE CASE
T4 KEARL 99005 TRANSFORMER CONTINGENCY
THU, APR 19 2018 15:07

A2-WP-Pre-6

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

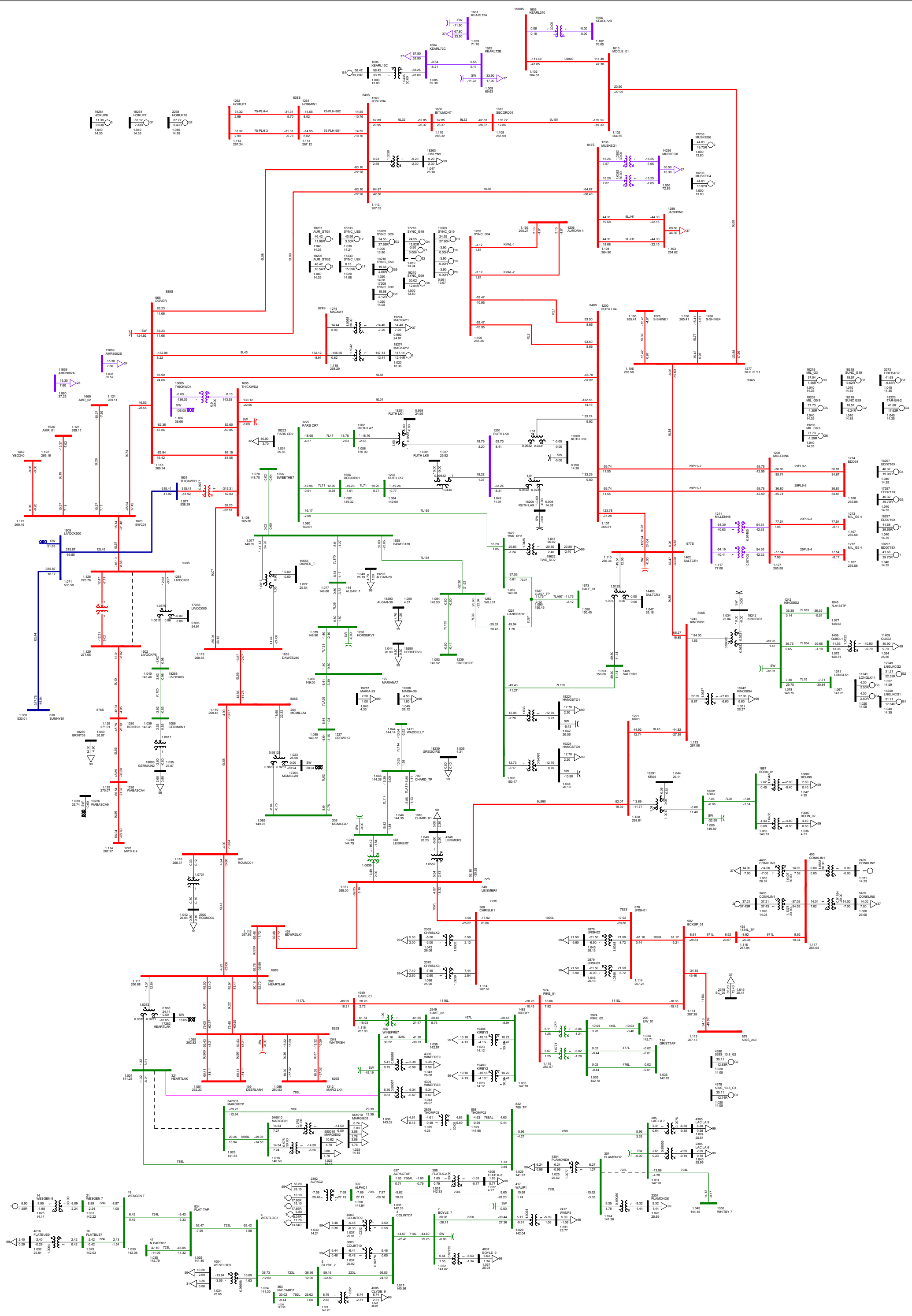


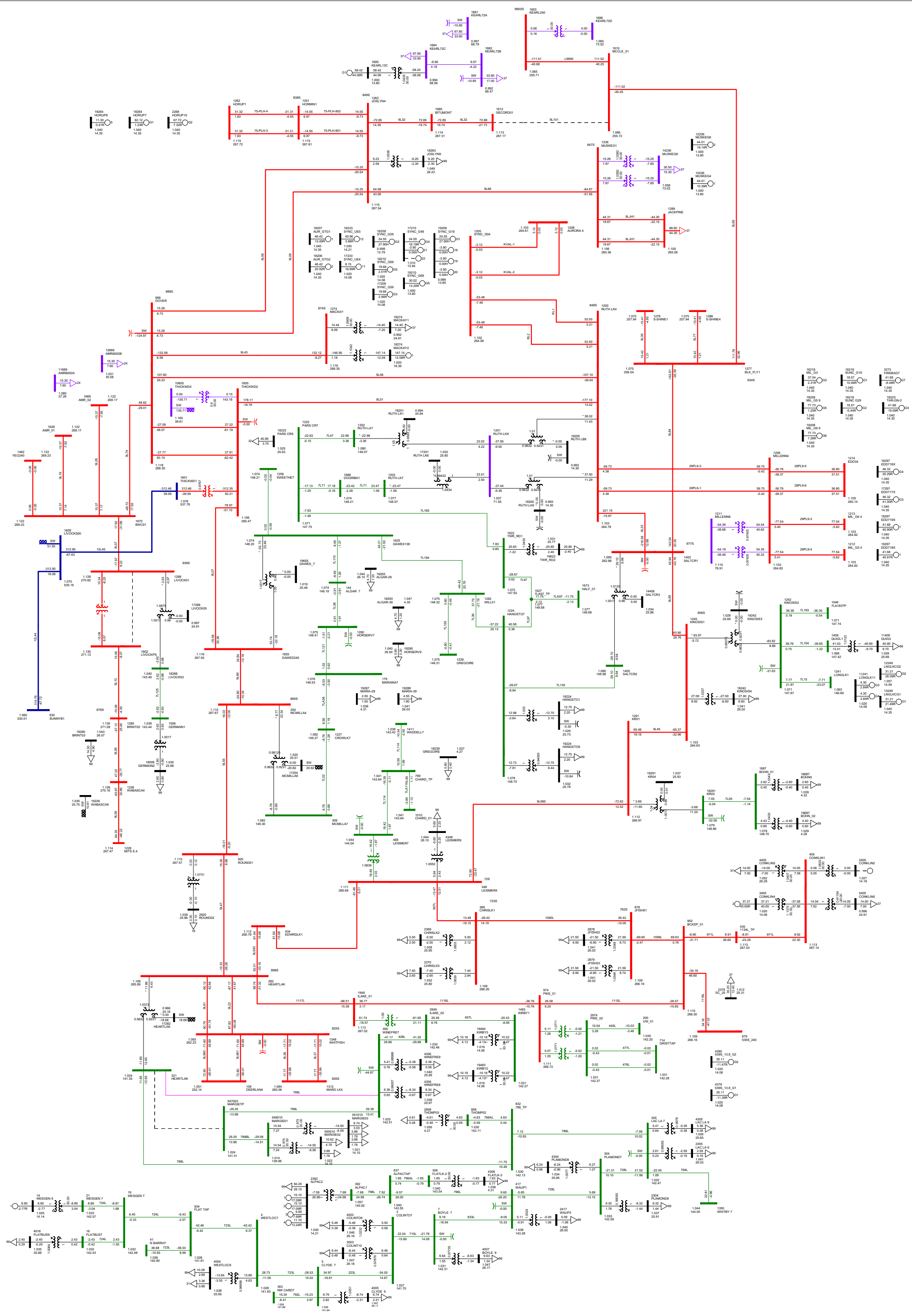
Attachment A3

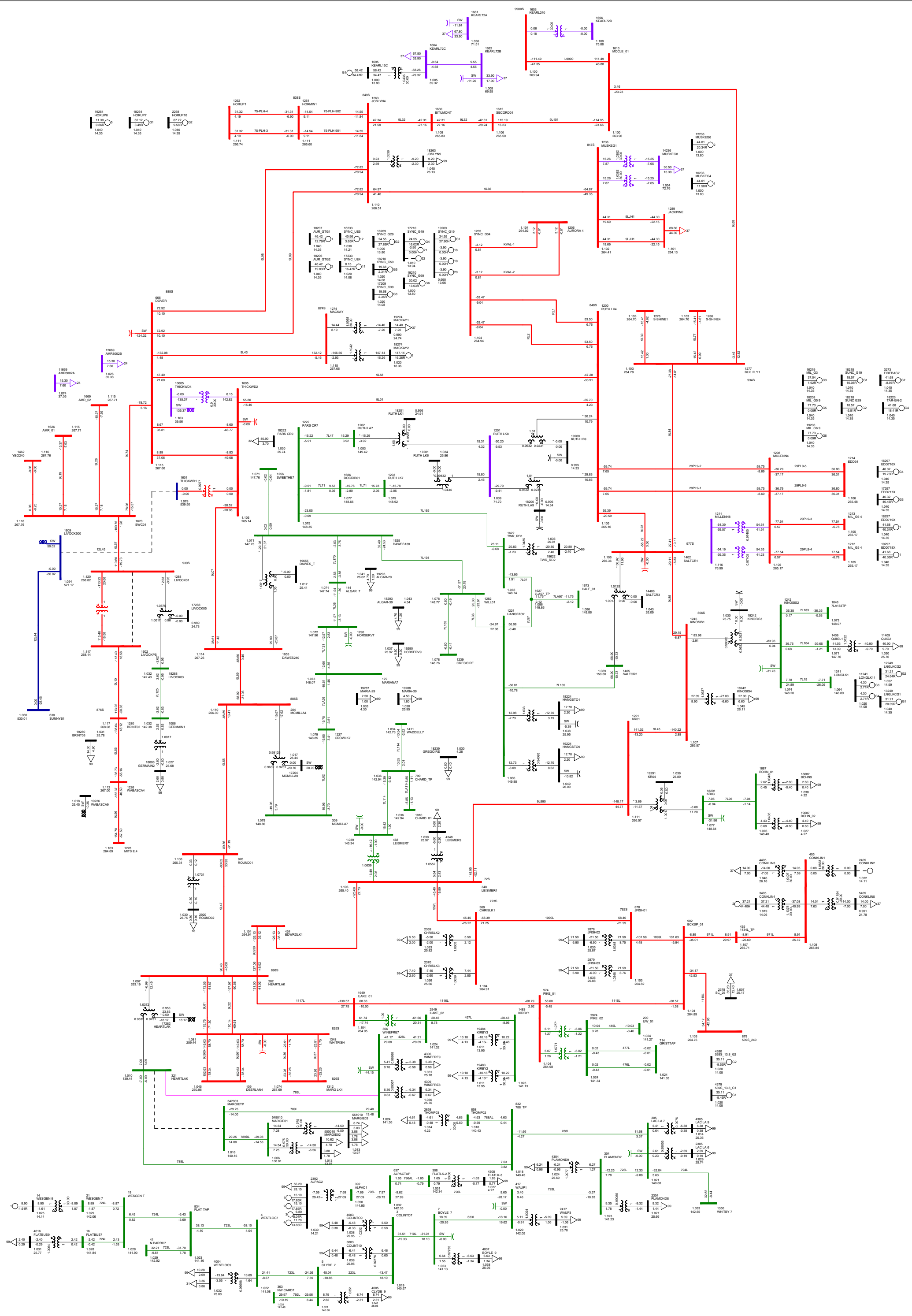
Post-Project Power Flow Diagrams

Table A3-SP-Post: List of 2019SP Post Project Load Flow Diagrams

Figure	Category	Contingency
A3-SP-Post-1	A (N-0)	System Normal
A3-SP-Post-2	B (N-1)	728L Plamondon 353S - Lac La Biche 157S
A3-SP-Post-3	B (N-1)	9L101 Mcclelland 957S - Secord 2005S
A3-SP-Post-4	B (N-1)	12L45 Thickwood Hills 951S - Livock 939S
A3-SP-Post-5	B (N-1)	12L44 Livock 939S - Sunnybrook 510S
A3-SP-Post-6	B (N-1)	T4 Kearl 9900S Transformer
A3-SP-Post-7	B (N-1)	T1 Thickwood Hills 951S Transformer



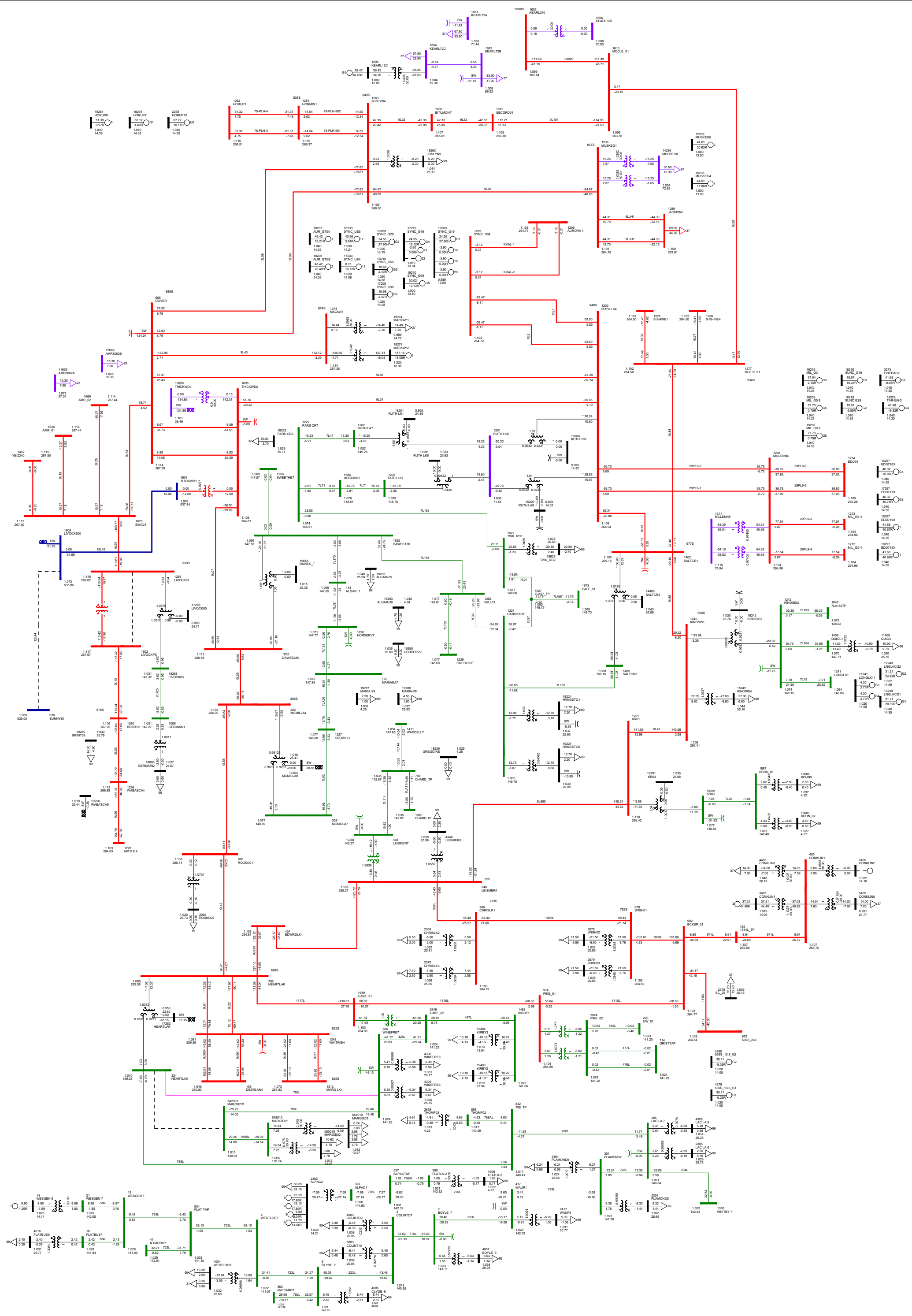




2019SP POST CASE
12L45 THICKWOOD HILLS 951S - LIVOCK 939S CONTINGENCY
THU, APR 19 2018 15:09

A3-SP-Post-4

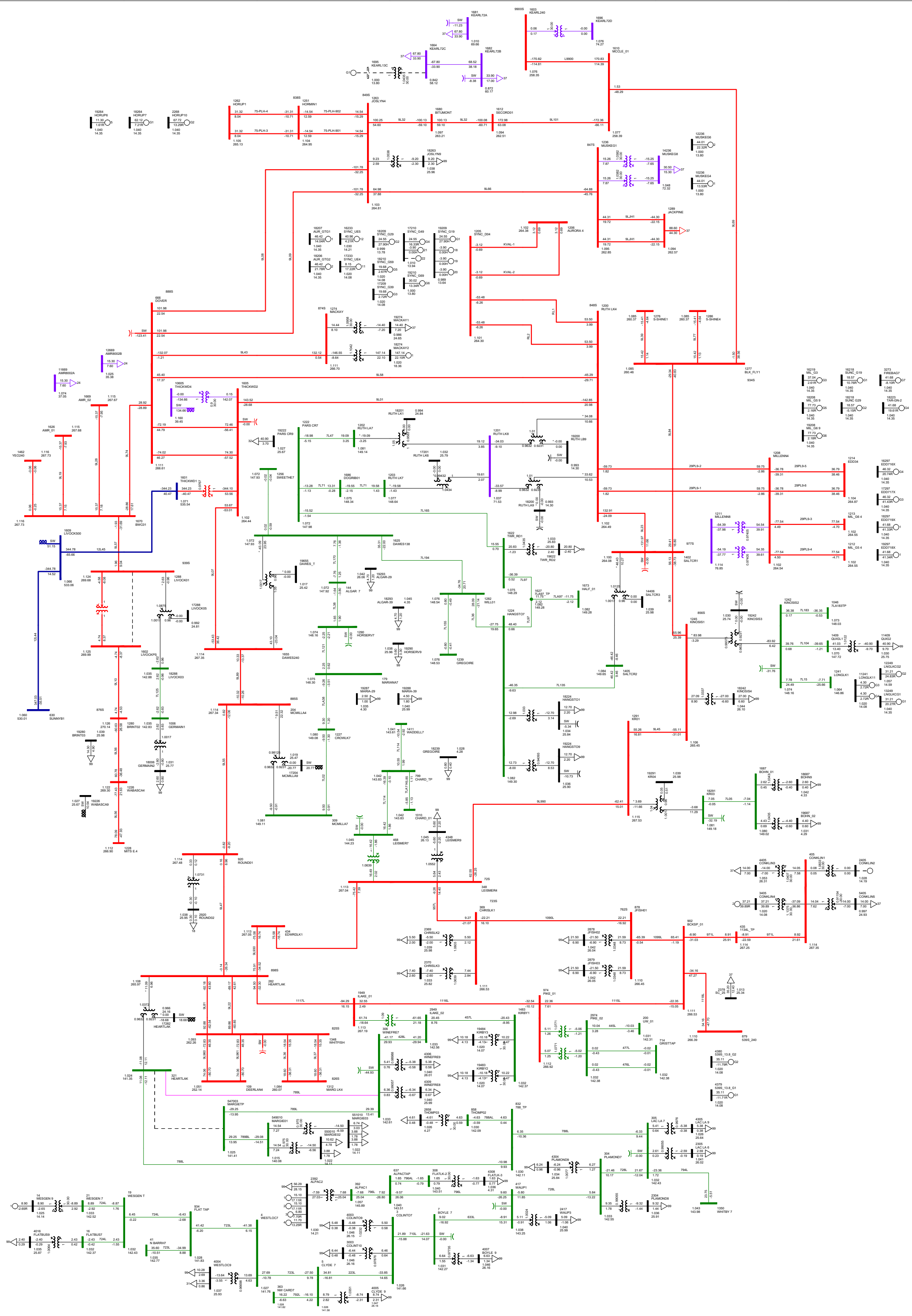
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2019SP POST CASE
12L44 LIVOCK 939S - SUNNYBROOK 510S CONTINGENCY
THU, APR 19 2018 15:09

A3-SP-Post-5

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2015SP POST CASE
T4 KEARL 9900S TRANSFORMER CONTINGENCY
THU, APR 19 2018 15:10

A3-SP-Post-6

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

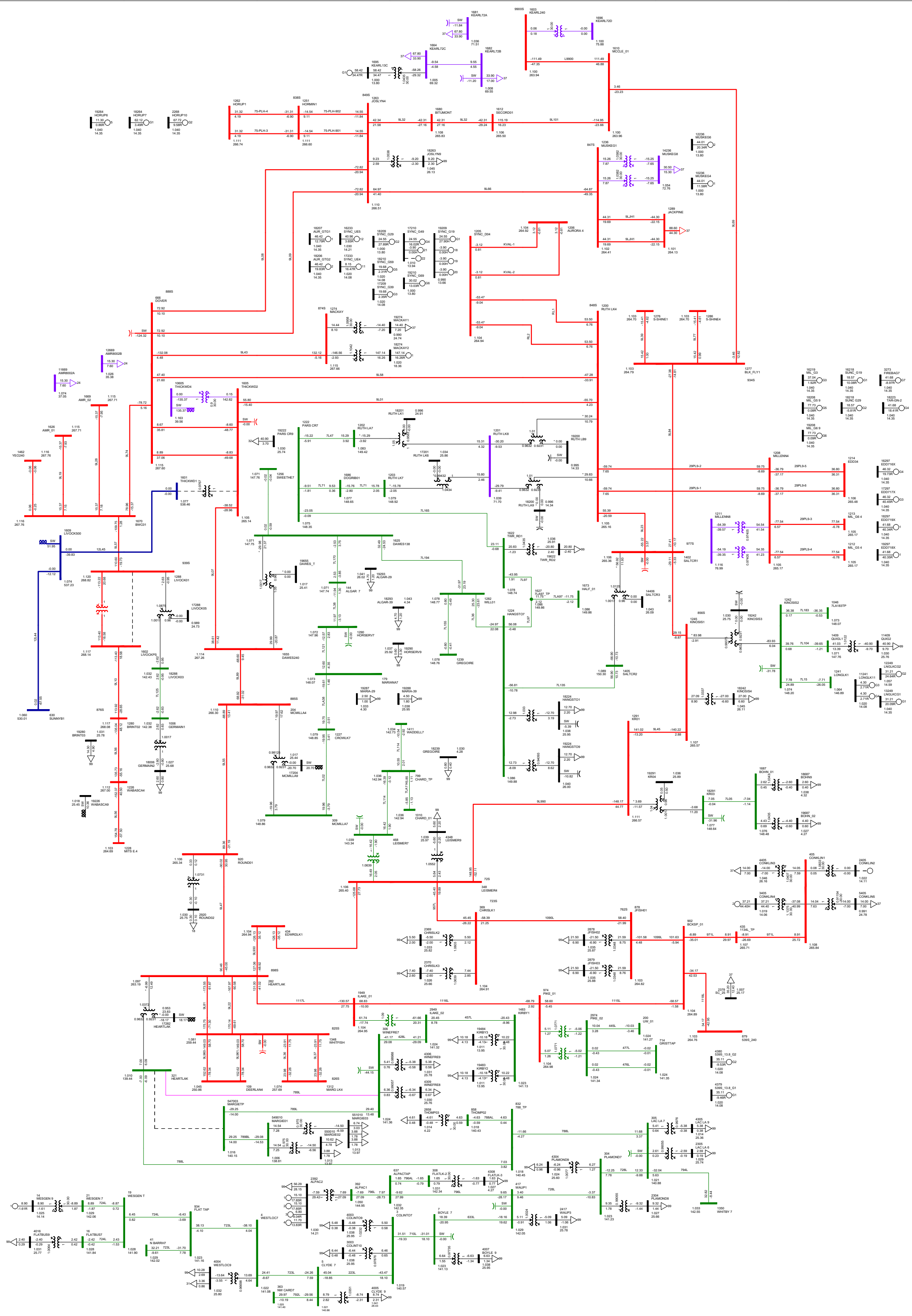
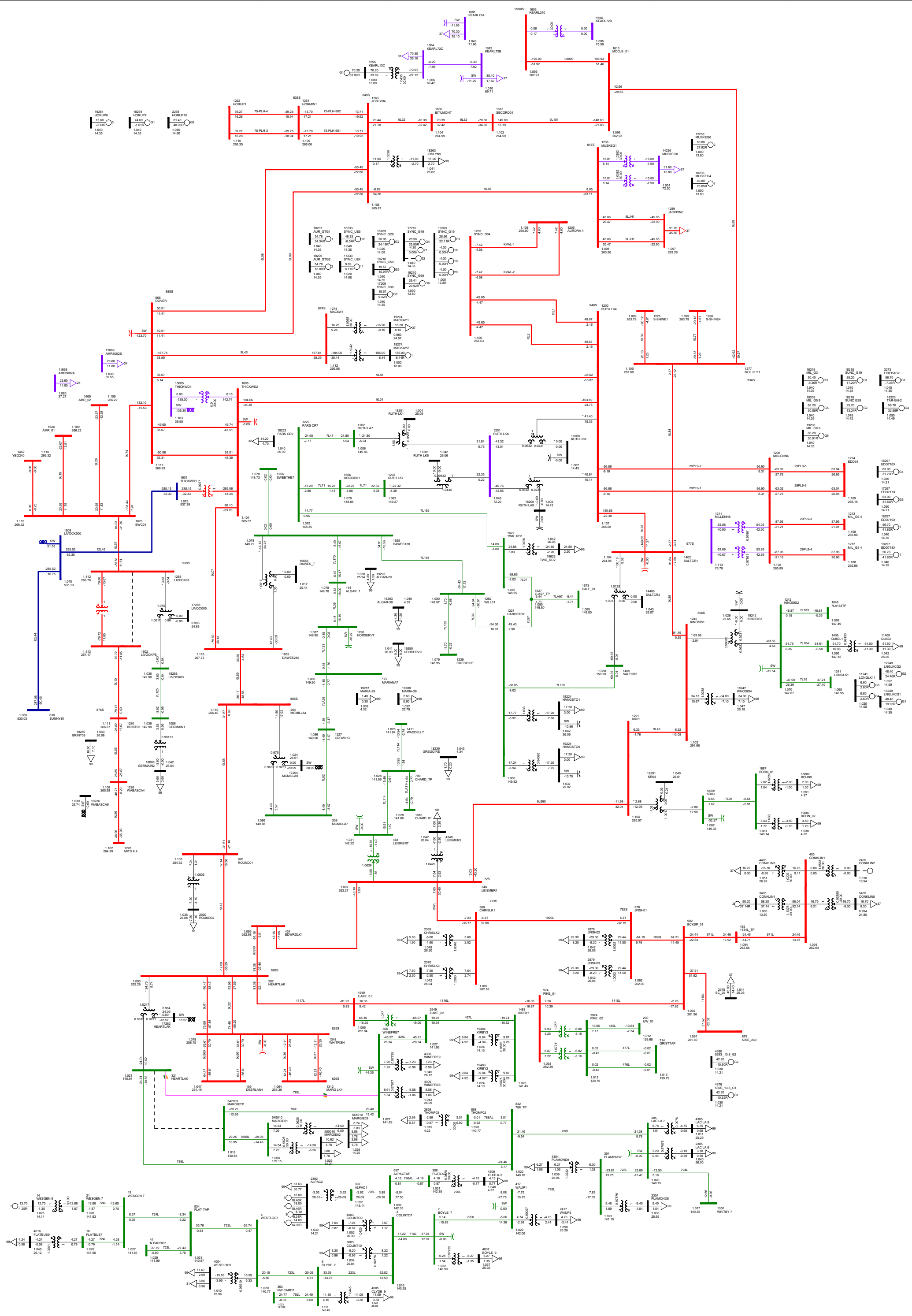


Table A3-WP-Post: List of 2019WP Post Project Load Flow Diagrams

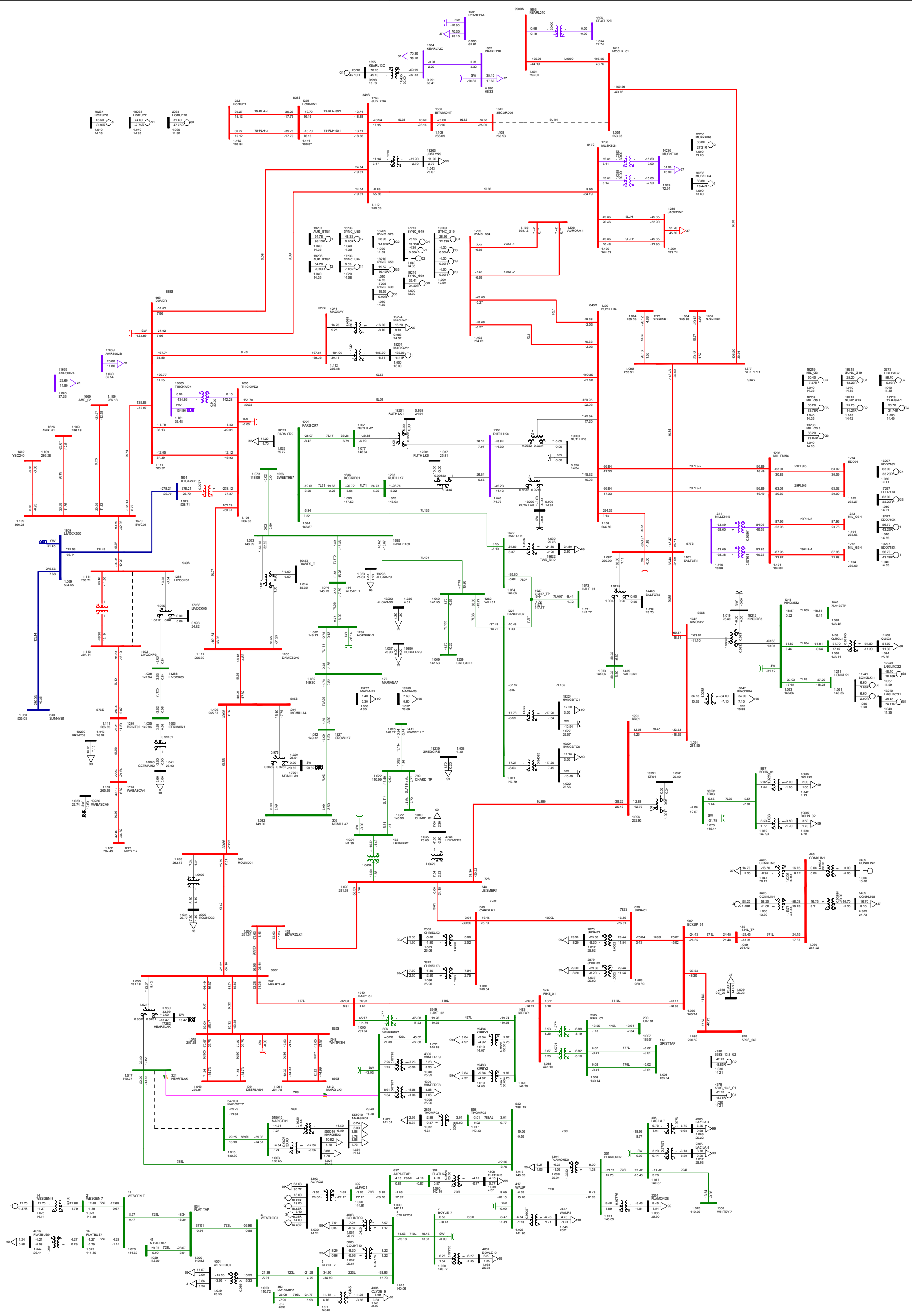
Figure	Category	Contingency
A3-WP-Post-1	A (N-0)	System Normal
A3-WP-Post-2	B (N-1)	728L Plamondon 353S - Lac La Biche 157S
A3-WP-Post-3	B (N-1)	9L101 McClelland 957S - Secord 2005S
A3-WP-Post-4	B (N-1)	12L45 Thickwood Hills 951S - Livock 939S
A3-WP-Post-5	B (N-1)	12L44 Livock 939S - Sunnybrook 510S
A3-WP-Post-6	B (N-1)	T4 Kearl 9900S Transformer
A3-WP-Post-7	B (N-1)	T1 Thickwood Hills 951S Transformer



2019WP POST CASE
N.O. SYSTEM NORMAL
THU, APR 19 2018 15:11

A3-WP-Post-1

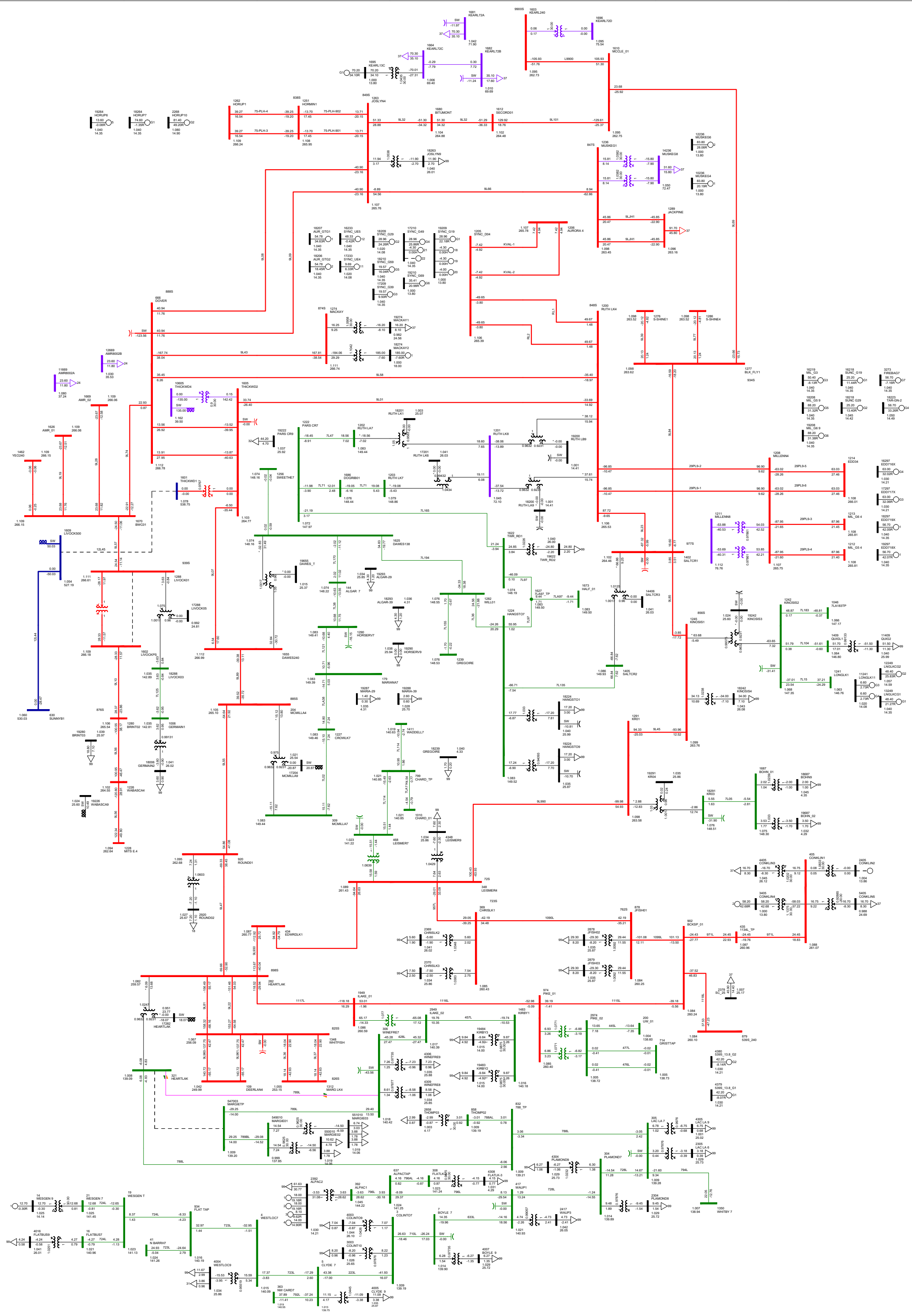
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2019WP POST CASE
9L101 MCCLELLAND 957S - SECOND 2005S CONTINGENCY
THU, APR 19 2018 15:11

A3-WP-Post-3

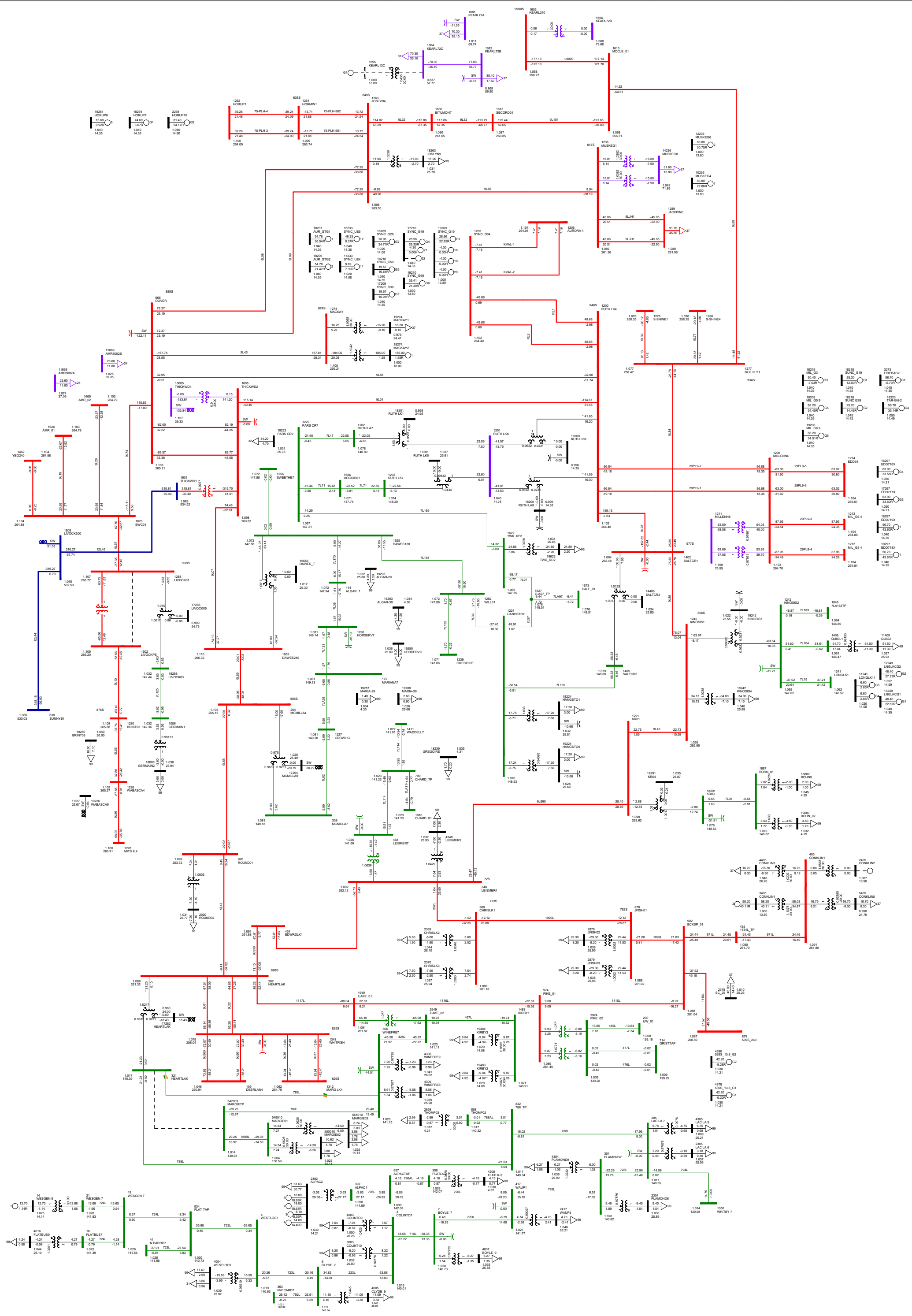
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2019WP Post Case
12L45 THICKWOOD HILLS 951S - LIVOCK 939S CONTINGENCY
THU, APR 19 2018 15:11

A3-WP-Post-4

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



2019WP POST CASE
T4 KEARL 99005 TRANSFORMER CONTINGENCY
THU, APR 19 2018 15:12

A3-WP-Post-6

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

Attachment A4

Post-Project Voltage Stability Diagrams

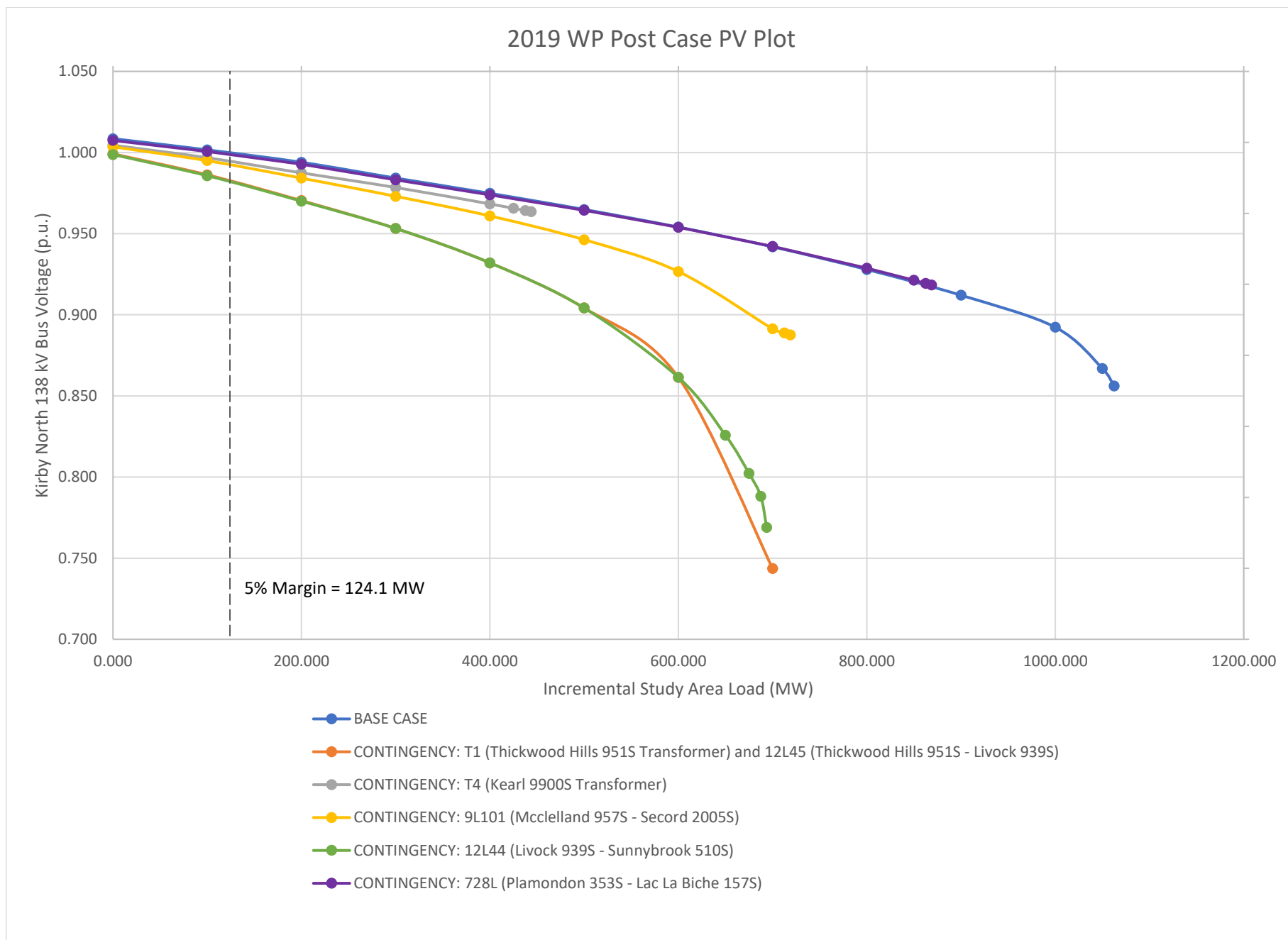


Figure A4-1