APPENDIX A CONNECTION ASSESSMENT

Fortis Broadmoor 420S Upgrades
RP-1597

The attached engineering study report has been prepared by a third party as part of the AESOs 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 proposed connection on the transmission system.

Information regarding the AESO's connection process can be found at: http://www.aeso.ca/8602.html

Date: October 23, 2015

Function	Name	Company	Signature	Date
Engineer	Roul Martin, P. Eng	Alberta Electric System Operator	R. Martin	Nov 6, 2015
Manager, Projects & System Access Studies	Mohamed Kamh, PhD, P. Eng.	Alberta Electric System Operator		Nov 6, 2015

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

2500, 330-5th Avenue SW, Calgary, Alberta T2P 0L4 Phone: 403-539-2450 Fax: 403-539-2949
www.aeso.ca www.poweringalberta.com

ALTALINK
A BERKSHIRE HATHAWAY ENERGY COMPANY

Engineering Study Report

Fortis Broadmoor 420S Upgrades

AESO Project Number: P1597

Revision: 1

Revision Date: 2015-10-22

	Name	Date	Signature
Prepared	Joby Varghese, P. Eng. (AltaLink)	Oct 22, 2015	Joby Varghese
Reviewed/ Approved	Ryan Cui, P. Eng. (AltaLink)	Oct 22, 2015	

PROFESSIONAL ENGINEER ALBERTA
JOBY VARGHESE

Joby Varghese
Oct 22/2015

AltaLink APEGGA Permit Number P-7862

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Executive Summary

Project Overview

Fortis Alberta Inc. (Fortis) submitted a System Access Service Request (SASR) to the Alberta Electric System Operator (AESO) for the addition of a new 25/33/42 MVA 138/25 kV transformer and three 25 kV feeder breakers at the Broadmoor 420S substation in the Sherwood Park area. These proposed upgrades are hereafter called the Project. The Project is required to address capacity and reliability concerns on the distribution system in the Sherwood Park area. Fortis has indicated that they will execute a Demand Transmission Service (DTS) contract at Broadmoor 420S Point of Delivery (PoD) for 53.3 MW upon completion of the Project. The existing DTS contract at Broadmoor 420S is 34.8 MW. The anticipated in-service date of the Project is November 1, 2016.

Existing System

The Project is located in the northeastern section of the Edmonton planning area (Area 60). There are mixed industrial and residential load in the area and is mainly supplied by several 138 kV lines from East Edmonton 38S and Fort Saskatchewan 54S. The existing 500 kV double circuit transmission lines 1206L and 1212L between Ellerslie 89S and Heartland 12S pass through North East Edmonton. The area has encountered a substantial load increase in the past and Fortis has forecasted additional growth in the near future.

Study Summary

This report details the system performance studies undertaken to assess the impact of the Project on the Alberta Interconnected Electric System (AIES).

Power flow results indicate that there are N-1 thermal overloading issues prior to the upgrade of Broadmoor 420S. The single circuit 138 kV lines 731L (Broadmoor 420S to 746L Junction) and 694L (Fort Saskatchewan 54S to Westwood 422S) will be overloaded above their short-term ratings under the contingency of the other circuit. However, studies show that the permanent relocation of the 746L normally open point from 746L8A (located close to the Canadian Liquid Air 337S substation) to the existing 746DL19 (located near the Owens Corning E524S tap on 746L) would eliminate the pre-connection N-1 thermal violations and reduce the severity of the post-connection N-1 thermal violations in the area. With the permanent relocation of the normally open point as previously described, the post-connection N-1 thermal violations can be managed in real-time.

Studies showed that there are no voltage violations. The Project does not significantly alter the short circuit levels in the area.

Recommendation

To mitigate N-1 thermal violations in the area, it is recommended that the existing manually operated switch, 746L8A, be permanently closed and the existing manually operated switch, 746DL19, be permanently open prior to and after the connection of the Project.

1. Introduction

This Customer Connection Engineering Study Report (ESR) documents the results of the studies that were conducted to assess the impact of the proposed upgrades at the Broadmoor 420S substation on the performance of the Alberta Transmission System (ATS).

1.1. Project

1.1.1. Project Overview

Fortis submitted a SASR to the AESO to add a new 25/33/42 MVA 138/25 kV transformer and three 25 kV switchgear at the Broadmoor 420S substation and to increase the existing contract capacity at that Point of Delivery (PoD) substation. The proposed upgrades at the Broadmoor 420S PoD are hereafter called the Project. The Project is required to address the capacity and reliability concerns on the distribution system in the Sherwood Park area per Fortis's Need for Development Sherwood Park Area Upgrade dated October 14, 2014 (hereafter Sherwood Park Upgrade NFD). The existing DTS contract at the Broadmoor 420S substation is 34.8 MW. Fortis has indicated that they will execute a DTS at Broadmoor 420S for 53.3 MW upon completion of this Project. The expected ISD for this project is November 1, 2016.

1.1.2. Load Component

- The expected power factor is 0.9.
- The distribution load in this area consists mainly of urban residential, commercial, and industrial loads.
- DTS request is 53.3 MW by November 1, 2016 at the existing Broadmoor 420S substation.

1.2. Study Scope

1.2.1. Study Objectives

The objectives of the study were the following:

- To assess the impacts of the proposed developments at the Broadmoor 420S substation and its associated load increase on the ATS.
- To identify any system constraints due to the proposed developments and propose mitigation measures, if required, to facilitate the connection.

1.2.2. Study Area

1.2.2.1. Study Area Description

The study area comprises the Edmonton planning area (Area 60), where Broadmoor 420S is located. Currently, the two source substations for the transmission system in North East

Edmonton are East Edmonton 38S and Fort Saskatchewan 54S. The existing 500kV double-circuit transmission lines 1206L and 1212L between the Ellerslie 89S and Heartland 12S pass through North-East Edmonton. A simplified schematic representation of the existing transmission system configuration in North East Edmonton is shown in Figure 1. Figure 1 shows the location of the Broadmoor 420S substation in the study area.

1.2.2.2. Existing Constraints

There are no existing transmission system constraints in the North-East Edmonton area. However, the generation from the Dow Chemical site located to the north of North-East Edmonton in the Saskatchewan area is currently managed in real-time to mitigate outflow thermal violations after N-1 events. The existing constraints in the Fort Saskatchewan Area are managed in accordance with Section 302.1 of the ISO rules, Real Time Transmission Constraint Management (TCM Rule).

1.2.2.3. AESO Long-Term Plans

The following table shows the transmission projects in the Edmonton Planning Region and their anticipated in service time-frames.

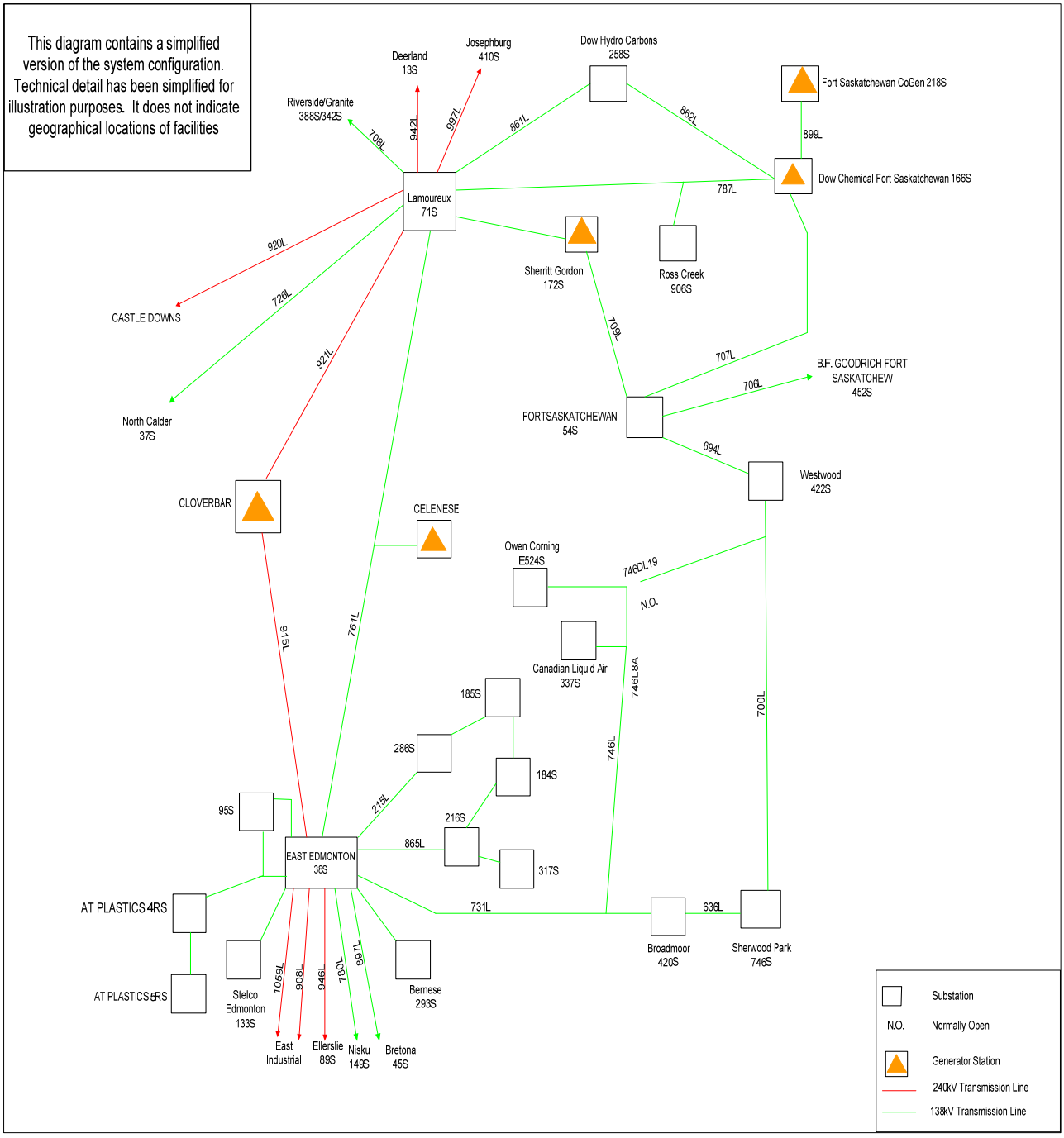
Table 1: Edmonton Region System Development Project list

Edmonton Region System Development Projects	Current AESO Planning Stage	Anticipated In-service Timeframe
Edmonton Region 240kV Line Upgrades (786)	5	By 2016
South and West of Edmonton Transmission Development (850)	4	By 2017
South Central Edmonton Area Transmission Reinforcement (1093)	3	By 2017

As per AESO 2013 Long-term Transmission Plan, the following developments are proposed for construction by 2022:

- New 240/138 kV source substation between Sherwood Park 746S and Fort Saskatchewan 54S.
- A new 240 kV transmission line from Clover Bar E987S to the new substation.

Figure 1: Simplified schematic representation system in the vicinity of the study area



1.2.3. Studies Performed

The following studies were performed for the pre-connection analysis:

- Power Flow analysis (Categories A and B for 2016SP and 2016WP study scenarios).
- Short-Circuit analysis (Category A for 2016WP).

The following studies were performed for the post-connection analysis:

- Power Flow analysis (Categories A and B for 2016SP and 2016WP study scenarios).
- Voltage Stability analysis (Categories A and B for 2016WP study scenario).
- Short-Circuit analysis (Category A for 2016WP and 2024WP study scenarios).

1.3. Report Overview

The Executive Summary provides a summary of the report and its conclusions and recommendation. Section 1 introduces the Project and summarizes the studies performed. Section 2 describes the applicable standards, system data, and other study assumptions used in this report. Section 3 describes the study methodology. Section 4 discusses the pre-connection assessment of the system. Section 5 presents the connection alternatives considered and studied. Section 6 provides a technical analysis of the connection alternative selected for further study. Section 7 provides the results of the short-circuit analysis. Section 8 discusses project interdependencies. Section 9 presents the summary and conclusions of the study.

2. Criteria, System Data, and Study Assumptions

2.1. Criteria, Standards, and Requirements

2.1.1. 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* (Reliability Criteria)[1] were applied to evaluate system performance under Category A system conditions (i.e., all elements in-service) and following Category B contingencies (i.e., single element outage), prior to and following the studied alternatives. Below is a summary of Category A and Category B system conditions.

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

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

The Alberta Reliability Standards include the Transmission Planning (TPL) standards that specify the desired system performance under different contingency categories with respect to the Applicable Ratings. The transmission system performance under various system conditions is defined in Appendix 1 of the TPL standards. For the purpose of applying the TPL standards to this study, the Applicable Ratings shall mean:

- Seasonal continuous thermal rating of the line's loading limits.
- Highest specified loading limits for transformers.
- For Category A conditions: Voltage range under normal operating condition per AESO Information Document ID# 2010-007RS. For the busses not listed in ID#2010-007RS, Table 2-1 in the Reliability Criteria applies.
- For Category B conditions: The extreme voltage range values per Table 2-1 in the Reliability Criteria.
- Desired post-contingency voltage change limits for three defined post event timeframes as provided in Table 2.

1 Filed under a separate cover

Table 2: 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 Rules

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. 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

2016SP and 2016WPstudy scenarios were considered for the connection studies.

The study cases were developed based on the AESO's published 2014 Planning Base Case Suite. Load and generation information in the study cases were modified to align with the load and generation assumptions described in section 2.2.1 and 2.2.2.

2.2.1. Load Assumptions

Table 3 presents the load conditions and assumptions that were used in the connection studies. The coincident load forecast is based on the AESO 2014 Long Term Outlook (2014 LTO) at the Edmonton Region peak. In this study, the ratio of the active power to reactive power in the study cases was consistent with that in the corresponding AESO Base Cases when modifying the loads. Substation, area, region and AIL load in the study cases were consistent with that in Table 3.

At Broadmoor 420S substation 34.8 MW of load was assumed for pre-connection studies and 53.3 MW load was assumed post connection in accordance with the requested DTS capacity.

Table 3: AESO 2014 LTO Forecasted Load

Substation, Area or Region Name and Season	Forecast Peak Load (MW)	
	2016	
	SP	WP
Westwood 422S	21.6	21.1

Substation, Area or Region Name and Season	Forecast Peak Load (MW)	
	2016	
	SP	WP
Canadian Liquid Air 337S	14.9	14.9
Sherwood Park 746S	46.6	57.6
Owens Corning (Fiberglass) E524S	10.3	8.9
Wetaskiwin (Area 31)	135.9	154.8
Wabamun (Area 40)	162.3	208.0
Edmonton (Area 60)	1917.4	1963.7
Edmonton Region	2215.6	2326.5
AIL w/o Losses	10833.9	12154.4

2.2.2. Generation, HVDC line Flow & Intertie Flow Assumptions

The specific generating units listed in Table 4 were dispatched in the corresponding study case per dispatch given in Table 4. The study was assumed that Dow Gen1 at Dow Chemical Fort Saskatchewan 166S is out-of-service to represent the N-G condition.

Table 4: Local Generators in the Study Cases

Plant Name	Bus Number	Area	Pmax (MW)	2016 SP Generation (MW)	2016 WP Generation (MW)
DOW GEN1 14.400 'G1'	54	33	99.5	0	23
DOW GEN2 14.400 'G2'	454	33	99.5	44	23
SCOTF GT 13.800 'GT'	4185	33	99.4	44	50
AIR LIQC 13.800 'G1'	627	33	96	42	48

Plant Name	Bus Number	Area	Pmax (MW)	2016 SP Generation (MW)	2016 WP Generation (MW)
SCOTF ST 13.800 'ST'	7185	33	95.7	42	48
DOWGTG 9 13.800 'GT'	2031	33	95	21	20
REDW GT 13.800 '1'	3050	33	46	28	30
DOWSTG 9 14.700 'ST'	2030	33	45.5	12	12
SKARO_G1 13.800 'G1'	1732	33	45	0	0
SKARO_G2 13.800 'G2'	2732	33	45	0	0
SKARO_G3 13.800 'G3'	3732	33	45	0	0
SKARO_G4 13.800 'G4'	4732	33	45	0	0
SHELL C1 13.800 '1'	19834	33	18	0	0
SHERRITT 4.1600 '3'	4062	33	3.2	0	0
SHERRITT 4.1600 '1'	4062	33	2.7	0	0
SHERRITT 4.1600 '2'	4062	33	2.7	0	0
Heartland 400SG1*	2786	33	281	0	0
Heartland 400SG2*	2788	33	185	0	0

The HVDC power orders are stated below in Table 5 for the study cases. These power order settings represent the minimum loss operating point.

Table 5: Summary of system project assumptions for connection studies

Study Case	WATL Power Order (MW)	EATL Power Order (MW)
2016SP-Pre Project	0	-250
2016SP-Post Project	0	-250
2016WP-Pre Project	0	-250
2016WP-Post Project	0	-250

The Intertie points are deemed to be electrically remote to have an effect on the assessment of the proposed load addition

2.3. System Projects

The system development project listed in Table 6 was included in the 2016 summer and winter peak (2016 SP and 2016 WP) study cases.

Table 6: Summary of system project assumptions for connection studies

Project Number	Project Name	Projected In-service Date
786	Edmonton Region 240kV Line Upgrades	2016

2.4. Customer Connection Projects

No other customer projects were considered for the study.

2.5. Ratings and Shunt Elements

The key transmission lines, transformers and shunt elements in the study area and its vicinity including their ratings are listed in Tables 7 to 9.

Table 7: Summary of Transmission Line Ratings

Facility	From	To	Summer (MVA)	Winter (MVA)
138 kV 897L	East Edmonton 38S	Bretona 45S	85	90
138 kV 780L	East Edmonton 38S	Nisku 149S	98	132
138 kV 865L	East Edmonton 38S	Knightsbridge 216S	119	146
138 kV 215L	East Edmonton 38S	Yasa 286S	120	146
138 kV 694L	Fort Saskatchewan 54S	Westwood 422S	119	146

Facility	From	To	Summer (MVA)	Winter (MVA)
138 kV 700L	Westwood 422S	JCT. 746L	119	146
138 kV 700L	Sherwood Park 746S	JCT. 746L	119	146
138 kV 636L	Sherwood Park 746S	Broadmoor 420S	119	146
138 kV 731L	East Edmonton 38S	JCT. 746L	172	212
138 kV 731L	JCT. 746L	Broadmoor 420S	119	146
240 kV 761L	East Edmonton 38S	JCT 761AL	98	132
240 kV 1059L	East Edmonton 38S	JCT EP 1059AL	499**	499*
240 kV 908L	East Edmonton 38S	JCT 908AL	505	648
240 kV 946L	East Edmonton 38S	Ellerslie 89S	494	499*
240 kV 915L	East Edmonton 38S	Clover Bar 987S	492	499*

*Limited by CT at East Edmonton.

** Limited by other terminal equipment at East Edmonton.

Table 8: Summary of Transformer Ratings

Station Name and Number	Transformer	MVA Rating
East Edmonton 38S	2 × 240/138 kV (T1 and T4)	2 × 337
	2 × 138/25 kV (T2 and T3)	2 × 93.3

Table 9: Summary of Shunt Elements in the Study Area

Substation Name and Number	Nominal Bus Voltage (kV)	Capacitors	
		Number of Switched Shunt Blocks	Total at nominal voltage (MVAR)
Fort Saskatchewan 54S	138	1	48.91
East Edmonton 38S	138	2	97.82
Nisku 149S	138	1	30
Acheson 305S	138	1	24.46
Jasper	240	1	105.31
Rossdale	69	2	95.5
Cloverbar	69	1	31.57
Stelco Edmonton 133S	34.5	2	46.8
North Red Deer 217S	138	1	48.91
Benalto 17S	240	1	110.82

Substation Name and Number	Nominal Bus Voltage (kV)	Capacitors	
		Number of Switched Shunt Blocks	Total at nominal voltage (MVAR)
Joffre 535S	138	1	50
Union Carbideprentiss 276S	138	1	50
Ellis 332S	138	1	25

2.6. Voltage Profile Assumptions

General Operating Practice – Voltage Control ID # 2010-007RS was used to establish normal system (i.e. pre-contingency) voltage profiles for all area buses prior to commencing the study. Table 10 provides a list of operating voltages for the key buses in the study area and its vicinity.

Table 10: Operating Voltages at the Key Nodes in the Vicinity of the Study Area

Substation	Nominal Voltage (kV)	Minimum Operating Limit (kV)	Desire Range (kV)	Maximum Operating Limit (kV)
Nisku 149S	138	124	135-145	150
Acheson 305S	138	138	138-144	145
Leduc 325S	138	124	135-145	150
Stony Plain 434S	138	124	135-145	150
East Camrose 285S	138	124	135-145	150
North Calder 37S	138	137	138-144	145
	240	240	244-255	260
Buford 538S	138	124	135-145	150
Bigstone 86S	138	135	141-145	145
	240	(see ID 2010-007R)	243-253	260
Fort Saskatchewan 54S	138	124	135-145	150
East Edmonton 38S	240	240	240-253	255
	138	139	139-144	145
Wabamun 19S	240	250	250-258	260
	138	140	140-144	145
Nelson Lake 429S	138	124	135-145	150

3. Study Methodology

3.1. Study Objectives

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

- To assess the impacts of the proposed developments at the Broadmoor 420S substation and its associated load increase on the Alberta Transmission System.
- To identify any system constraints due to the proposed developments and propose mitigation measures to facilitate the development, if required.

3.2. Study Scenarios

Detailed studies were conducted using the study scenarios summarized in Table 11 to investigate the pre and post-connection system performance. The pre-connection system is defined as the 2016 system configuration prior to the Broadmoor 420S substation upgrade.

Table 11: Study Scenarios for Power Flow, Voltage Stability and Short Circuit Studies

Scenario	Study case / Connection status	Power Flow	Voltage Stability	Short Circuit
1	2016SP (Pre-Connection)	Yes	No	No
2	2016WP (Pre-Connection)	Yes	No	Yes
3	2016SP (Post-Connection)	Yes	No	No
4	2016WP (Post-Connection)	Yes	Yes	Yes
5	2024WP (Post-Connection)	No	No	Yes

3.3. Connection Studies Carried Out

The following studies were performed for the pre-connection analysis:

- Power Flow analysis (Categories A and B for 2016SP and 2016WP study scenarios).
- Short-Circuit analysis (Category A for 2016WP)

The following studies were performed for the post-connection analysis:

- Power Flow analysis (Categories A and B for 2016SPand 2016WP study scenarios).
- Voltage Stability analysis (Categories A and B for 2016WP study scenario).
- Short-Circuit analysis (Category A for 2016WP and 2024WP study scenarios).

3.4. Power Flow Analysis

Power flow studies were performed in accordance with the TPL-001-AB-0 and TPL-002-AB-0 for Category A and B events, respectively. Power flow studies were carried out using study scenario 1 and 2 for the pre-connection system and study scenarios 3, and 4 for the post-connection system. Transformer tap and switched shunt controls were locked and continuous shunt control was enabled when performing Category B power flow analysis.

The Category B contingency list consists of the following:

- 761L (East Edmonton 38S to Lamoureux 71S)
- 915L (East Edmonton 38S to Cloverbar E987S)
- 731L (East Edmonton 38S to Broadmoor 420S)
- 780L (East Edmonton 38S to Nisku 149S)
- 1059L (East Edmonton 38S to Lambton E803S)
- 908L (East Edmonton 38S to Ellerslie 89S)
- 946L (East Edmonton 38S to Ellerslie 89S)
- 897L (East Edmonton 38S to Bretona 45S)
- East Edmonton 38S T1
- East Edmonton 38S T4
- 694L (Fort Saskatchewan 54S to Westwood 422S)
- 700L (Westwood 422S to Sherwood Park 746S)
- 636L (Broadmoor 420S to Sherwood Park 746S)
- 920L (North Calder 37S to Castle Downs 557S to Lamoureux 71S)
- 921L (Clover Bar E987S to Lamoureux 71S)

All transmission facilities 138 kV and above in the study area and ties with the surrounding planning areas were monitored when performing power flow studies.

PSS/E 33 contingency power flow analysis function was used as the study tool.

3.5. Voltage Stability (PV) Analysis

Voltage stability (PV) analysis was performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology. The reference load level was the 2016 forecasted winter peak load for the study area.

PV curves were developed for a selected set of critical Category B contingencies in the study area. The voltage stability analysis was performed using the PV method as follows:

- Increasing the load in the study area (Area 60) and increasing generation in an area remote from the study area (area 25[2]). P/Q ratio was maintained constant while scaling the area load. The 25 kV load buses of the existing T1 and proposed T2 at the Broadmoor 420S substation were monitored and their voltages plotted versus the incremental change in the study area load.

2 The AESO Base Cases divide area 25 into three subareas. These areas are 58 (Dover), 59 (Ruth Lake) and 61 (Christina Lake). When area 25 is referenced in this document it relates to all three of these subareas in the cases (58, 59, and 61).

- Discrete switched capacitors and reactors, LTC transformers and phase shifting transformers were locked.

Results are provided for the Category A condition and the top five worst case Category B contingencies as identified by the studies.

PSS/E 33 PV analysis function was used as the study tool.

3.6. Short-Circuit Analysis

For the short-circuit analysis, all generators in and around the study area were switched on to evaluate the maximum fault current under three-phase faults and single-line-to-ground faults.

Short circuit analysis was performed for the pre-project system using study scenario 2 and study scenario 4 for the post project system. The future 10 years post project short circuit analysis was performed using the study scenario 5.

Maximum short circuit levels were provided for the following substations in the study area:

- Broadmoor 420S
- Sherwood Park 746S
- Canadian Liquid Air 337S
- East Edmonton 38S
- Fiberglass (Owens Corning) E524S

PSS/E 33 automatic sequencing fault calculation function was used as the study tool.

4. Pre-Connection System Assessment

4.1. Pre-Connection Power Flow Analysis

The pre-connection system is defined as the 2016 system configuration without the Broadmoor 420S substation upgrades. The steady-state performance of the pre-connection system was assessed using the 2016SP and 2016WP study scenarios. The power flow analyses were based on the TPL standards, System Data and Study Assumptions as described in Section 2.

4.1.1. 2016SP Scenario

The steady state performance of the system under normal conditions (Category A) and single contingency (Category B) were assessed using the 2016SP scenario 1 with the pre-connection system configuration. The results of the power flow analysis are summarized in Table 12 and illustrated in the cross referenced single line diagrams in Attachment A.

(A) System Normal Results (Category A):

No thermal or voltage violations were observed for the 2016SP scenario 1 with the pre-connection system configuration.

(B) Single Element Contingency Results (Category B):

No voltage violations were observed for the 2016SP scenario 1 with the pre-connection system configuration but some thermal violations were observed as can be seen in table 12 below.

Table 12: 2016SP Pre-connection Study Results

Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment A
N-0: Normal Operation	None	--		None	A-1
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to 746L Junction	113%	116/136	None	A-2
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	116%	119/139	None	A-3
	781L Lamoureux 71S to Sherritt 172S	99%	143/144		
	700L Westwood 422S to 746L Junction	97%	119/114		

4.1.2. 2016WP Scenario

The steady state performance of the system under normal conditions (Category A) and single contingency (Category B) were assessed using the 2016WP scenario 2 with the pre-connection system configuration. The results of the power flow analysis are summarized in Table 13 and illustrated in the cross referenced single line diagrams in Attachment A.

(A) System Normal Results (Category A):

No thermal or voltage violations were observed for the 2016WP scenario 2 with the pre-connection system configuration.

(B) Single Element Contingency Results (Category B):

No voltage violations were observed for the 2016WP scenario 2 with the pre-connection system configuration but some thermal violations were observed as can be seen in table 13 below.

Table 13: 2016WP Pre-connection Study Results

Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment A
N-0: Normal Operation	None	--	-	None	A-4
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to the Junction	-	-	None	A-5
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	100%	146/146	None	A-6

5. Connection Alternatives

5.1. Overview

Five alternatives were explored by Fortis to address the capacity and reliability concerns on the distribution system in the Sherwood Park area and to address the existing and future DFO's reliability need at this area[3]. Fortis had already ruled out load shifting alternative due to technical concerns. The other four alternatives are described below:

- **Alternative 1 – Upgrades at the Broadmoor 420S Substation**

  In this alternative, a new 25/33/42MVA LTC transformer and three new 25kV feeder breakers would be installed at the Broadmoor 420S substation. A 138 kV bus tie breaker would also be added at the Broadmoor 420S substation to address Fortis' reliability requirement. The 138 kV bus tie breaker is not required for system reliability. Per the Sherwood Park Upgrade NFD this alternative would address the distribution concerns in the Sherwood Park area and was selected by Fortis as the preferred alternative for the Project.

- **Alternative 2 – Upgrades at the Sherwood Park 746S Substation**

  This alternative would include adding a new source transformer at the Sherwood Park 746S substation, and would also require expansion of the substation site. This would result in a higher capital cost relative to the preferred alternative.

- **Alternative 3 – Upgrades at the East Edmonton 38S Substation**

  This alternative would include adding a new source transformer at the East Edmonton 38S substation, and would also require expansion of the substation site. This would result in a higher capital cost relative to the preferred alternative.

- **Alternative 4 – Upgrades at the Bretona 45S Substation**

  This alternative would include adding a new source transformer at the Bretona 45S substation and adding three distribution lines that are approximately three times longer than those contemplated in the preferred alternative. This would result in a higher capital cost relative to the preferred alternative.

5.2. Connection Alternatives Evaluated

Alternative 1 was identified by Fortis as the preferred system development to address the capacity and reliability concerns in the Sherwood Park area. Based on Fortis detailed overview at the Broadmoor 420S PoD, this alternative would offload existing feeders, thereby making the distribution system capable of accommodating additional future load.

Alternative 2, 3 and 4 would require additional facility development and hence result in significantly higher capital cost relative to alternative 1.

3 Fortis has provided a detail overview of distribution need in this area in their document titled Need for Development Sherwood Park Area Upgrade, filed under a separate cover.

Alternative 1 was identified as the preferred option to address the DFO's need on the basis of assessments performed on the distribution network in the vicinity of Sherwood Park area and distribution cost estimates conducted by Fortis. Figure 2 shows the details of the alternative 1.

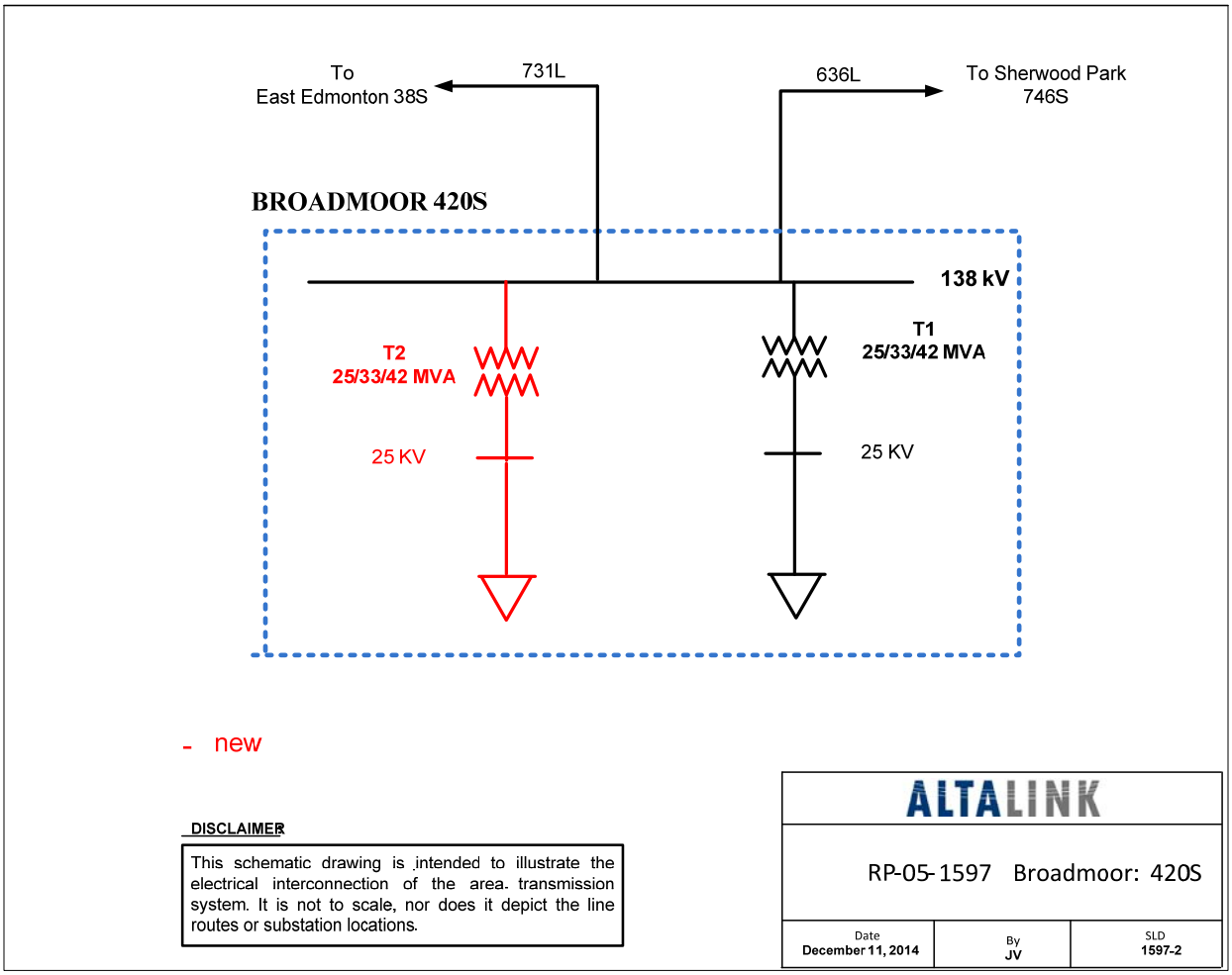
5.2.1. Connection Alternatives Selected for Further Studies

Alternative 1 was selected for detailed technical studies to assess the impact of the proposed upgrades and DTS of 53.3MW at the Broadmoor 420S PoD on the performance of the AIES.

5.2.2. Connection Alternatives Not Selected for Further Studies

Alternative 2, 3 and 4 were not selected for further studies.

Figure 2: Alternative 1 – Preferred Alternative



6. Technical Analysis of the Connection Alternatives

The recommended alternative was modeled and studied using 2016SP and 2016WPsystem conditions, similar to the studies for the pre-connection system described in Section 4 above. The additional load associated with the proposed connection was also modeled in the study cases. The study results are summarized in the subsections that follow.

6.1. Preferred Alternative

6.1.1. Power Flow Analysis

The post-connection system is defined as the 2016 system configuration with the proposed Broadmoor 420S substation upgrades. The steady-state performance of the post-connection system was assessed under the 2016SP and 2016WPstudy scenarios. The power flow analyses were based on the TPL standards, System Data and Study Assumptions as described in Section 2.

6.1.1.1. 2016SP Scenario

The steady state performance of the system under normal conditions (Category A) and single contingency (Category B) were assessed using the 2016SP scenario 3 with post-connection (Broadmoor 420S substation upgrades). The results of the power flow analysis are summarized in Table 14 and illustrated in the cross referenced single line diagrams in Attachment B.

(A) System Normal Results (Category A):

No thermal or voltage violations were observed for the 2016SP scenario 3 with the post-connection system configuration.

(B) Single Element Contingency Results (Category B):

No voltage violations were observed for the 2016SP scenario 3 with the post-connection system configuration but thermal violations that were observed as can be seen in Table 14 below. The pre and post connection N-1 percentage thermal loadings are compared in Table 14.

Table 14: 2016SP Post-connection Study Results

Contingency	Thermal Overloads	% of Loading Pre/Post Connection	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment B
N-0: Normal Operation	None	--	-	None	B-1

N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to 746L Junction	113%/129%	119/156	None	B-2
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	116%/133%	119/160	None	B-3
	781L Lamoureux 71S to Sherritt 172S	99%/105%	143/153		
	700L Westwood 422S to 746L Junction	97%/115%	119/134		

6.1.1.2. 2016WP Scenario

The steady state performance of the system under normal conditions (Category A) and single contingency (Category B) were assessed using the 2016WP scenario 4 with post-connection (Broadmoor 420S substation upgrades). The results of the power flow analysis are summarized in Table 15 and illustrated in the cross referenced single line diagrams in Attachment B.

(A) System Normal Results (Category A):

No overloads or voltage violations were observed for the 2016WP scenario 4 with the post-connection system configuration.

(B) Single Element Contingency Results (Category B):

No voltage violations were observed for the 2016WP scenario 4 with the post-connection system configuration but overloads were observed as can be seen in table 15 below.

Table 15: 2016WP Post-connection Study Results

Contingency	Thermal Overloads	% of Loading Pre/Post Connection	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment B
N-0: Normal Operation	None	--		None	B-4
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to the Junction	97%/110%	146/163	None	B-5
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	100%/115%	146/168	None	B-6
	700L Westwood 422S to 746L Junction	85%/100%	146/146		

6.1.2. Voltage Stability Analysis

Voltage stability analysis was performed using the 2016WP scenario to investigate the system active power margins after the proposed development under Category A conditions and following Category B contingency conditions. The sink sub-system is defined as the load in the AESO planning area Edmonton (Area 60). A total load of 1963.7 MW for 2016WP in the study area was considered as the reference load level. The source system was formed by the generation in the planning area 25. The 25 kV load buses at the existing T1 and new T2 transformers at Broadmoor 420S substation were monitored and their voltages plotted versus the incremental change in the study area load. The PV analysis confirms that there is no voltage stability violation after the connection of the proposed development. The Edmonton area voltage stability margins under Category A and Category B system conditions are listed in Table 16. The PV plots are presented in Attachment C.

Table 16: P-V Analysis-2016WP Post-Connection

Operation Conditions	2016WP Forecasted load (MW)	105% Margin (MW)	Meets Voltage Criteria?
N-0: Normal Operation	1963.7	2061.9	YES
N-1: 636L Broadmoor 420S to Sherwood Park 746S	1963.7	2061.9	YES
N-1: 694L Fort Saskatchewan 54S to Westwood 422S	1963.7	2061.9	YES
N-1: 700L Westwood 422S to Sherwood Park 746S	1963.7	2061.9	YES
N-1: 731L East Edmonton 38S to Broadmoor 420S	1963.7	2061.9	YES
N-1: 761L East Edmonton 38S to Lamoureux 71S	1963.7	2061.9	YES

6.2. Mitigation Measure (Permanently Re-locating the Normally Open point)

6.2.1. Power Flow Analysis

The steady-state performance of the post-connection system was assessed using the 2016SP and 2016WP study scenarios and incorporating the permanent relocation the normally open point from 746L8A (located close to the Canadian Liquid Air 337S substation) to 746DL19 (located near the Owens Corning E524S tap on 746L).

6.2.1.1. 2016SP Scenario

The steady state performance of the system under normal conditions (Category A) and single contingency (Category B) were assessed using the post-connection 2016SP study scenario 3 and incorporating the relocation of the normally open point. The results of the power flow analysis are summarized in Table 17 and illustrated in the cross referenced single line diagrams in Attachment D.

(A) System Normal Results (Category A):

No thermal or voltage violations were observed for the 2016SP scenario 3 with the post-connection system configuration and relocation of the normally open point.

(B) Single Element Contingency Results (Category B):

No voltage violations were observed for the 2016SP scenario 3 with the post-connection system configuration and relocation of the normally open point but thermal violations were observed as can be seen in table 17 below.

Table 17: 2016SP Post-connection Study Results

Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment D
N-0: Normal Operation	None	--	-	None	D-1
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to 746L Junction	105%	119/127	None	D-2
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	108%	119/130	None	D-3
	781L Lamoureux 71S to Sherritt 172S	--	--		
	700L Westwood 422S to 746L Junction	--	--		
N-1: 781L Lamoureux 71S to Sherritt 172S	707L Fort Saskatchewan 54S to Dow Chemical 166S	--	--	None	D-4

6.2.1.2. 2016WP Scenario

The steady state performance of the system under normal conditions (Category A) and single contingency (Category B) were assessed using the post-connection 2016WP scenario 4 and incorporating the relocation of the normally open point. The results of the power flow analysis are summarized in Table 18 and illustrated in the cross referenced single line diagrams in Attachment D.

(A) System Normal Results (Category A):

No overloads or voltage violations were observed for the 2016WP scenario 4 with the post-connection system configuration and the relocation of the normally open point.

(B) Single Element Contingency Results (Category B):

No thermal No voltage violations were observed for the 2016WP scenario 4 with the post-connection system configuration and the relocation of the normally open point.

Table 18: 2016WP Post-connection Study Results

Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment D
N-0: Normal Operation	None	--	--	None	D-5
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to the Junction	--	--	None	D-6
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	--	--	None	D-7
	700L Westwood 422S to 746L Junction	--	--		

6.3. Conclusions

Power flow results indicate that there are pre-connection N-1 thermal violations prior to the upgrade of Broadmoor 420S. The 138 kV lines 731L (Broadmoor 420S to 746L Junction) and 694L (Fort Saskatchewan 54S to Westwood 422S) will be overloaded under the contingency of the other circuit in the pre-connection system. These thermal violations are above the short-term ratings of the lines. However, studies show that the permanent relocation of the 746L normally open point from 746L8A (located close to the Canadian Liquid Air 337S substation) to the existing 746DL19 (located near the Owens Corning E524S tap on 746L) would eliminate the pre-connection N-1 thermal violations and reduce the severity of the post-connection N-1 thermal violations in the area. With the permanent relocation of the normally open point as previously described, the post-connection N-1 thermal violations are below the short-term ratings of the lines and can be managed in real-time.

Voltage stability analysis (PV) results indicate that the voltage stability margins of the Edmonton area system, with the proposed upgrades in Broadmoor 420S substation, meet the Reliability Criteria.

7. Short-Circuit Analysis

7.1. Pre-Connection

Short circuit studies[4]were performed using the 2016WP scenario to determine the fault levels in the system before the upgrades at the Broadmoor 420S substation. Single phase and three phase fault currents were calculated at the Broadmoor 420S and other nearby 138 kV substations. These results are shown in Table 19.

Table 19: Summary of Short-Circuit Current Levels – Pre-Connection (Year 2016WP)

Substation	Base Voltage (kV)	Pre-Fault Voltage (kV)	Pre-Fault Voltage (pu)	3-Phase Fault (kA)	1-Phase Fault (kA)	Positive Sequence Impedance (R1+jX1)	Positive Sequence Impedance (p.u.)	Zero Sequence Impedance (R0+jX0)	Zero Sequence Impedance (p.u.)
Sherwood Park 746S	138	140.1	1.015	14.34	9.59	1.926+ j5.323	0.01011+ j0.02795	3.210+ j13.724	0.01686+ j0.07207
Canadian Liquid Air 337S	138	139.3	1.01	7.24	4.37	4.214+ j10.327	0.02213+ j0.05423	8.343+ j32.079	0.04381+ j0.16845
East Edmonton 38S	240	249.4	1.039	25.03	18.53	1.334+ j5.618	0.00232+ j0.00975	2.495+ j11.586	0.00433+ j0.02012
	138	141.4	1.025	22.33	17.94	0.998+ j3.530	0.00524+ j0.01853	1.046+ j6.267	0.00549+ j0.03291
Fiberglass E524S	138	139.4	1.01	7.62	4.62	4.004+ j9.821	0.02103+ j0.05157	7.882+ j30.313	0.04139+ j0.15918
Broadmoor 420S	138	140.8	1.02	17.74	12.84	1.348+ j4.398	0.00708+ j0.02309	1.935+ j9.671	0.01016+ j0.05078

4 Short circuit current calculation is based on modeling information provided to the AESO by third parties. Short circuit estimation is subject to change. The information provided in this study is not intended to be used as the sole source of information for electrical equipment specification and the design of public or worker safety-grounding systems.

7.2. Post-Connection

Short circuit studies[5] were performed using the 2016WP and 2024WP scenarios to determine the fault levels in the system after the connection of the proposed upgrades at the Broadmoor 420S substation. The short circuit results are shown in Table 20 and Table 21.

Table 20: Summary of Short-Circuit Current Levels – Post-Connection (Year 2016WP)

Substation	Base Voltage (kV)	Pre-Fault Voltage (kV)	Pre-Fault Voltage (pu)	3-Phase Fault (kA)	1-Phase Fault (kA)	Positive Sequence Impedance (R1+jX1)	Positive Sequence Impedance (p.u.)	Zero Sequence Impedance (R0+jX0)	Zero Sequence Impedance (p.u.)
Sherwood Park 746S	138	140	1.015	14.35	9.64	1.935+ j5.315	0.01016+ j0.02791	3.191+ j13.594	0.01676+ j0.07138
Canadian Liquid Air 337S	138	139.3	1.01	7.24	4.38	4.219+ j10.323	0.02215+ j0.05421	8.336+ j32.017	0.04377+ j0.16812
East Edmonton 38S	240	249.5	1.04	25.03	18.57	1.335+ j5.620	0.00232+ j0.00976	2.481+ j11.531	0.00431+ j0.02002
	138	141.4	1.024	22.35	18.03	1.004+ j3.525	0.00527+ j0.01851	1.041+ j6.204	0.00547+ j0.03258
Fiberglass E524S	138	139.4	1.01	7.62	4.62	4.009+ j9.817	0.02105+ j0.05155	7.875+ j30.252	0.04135+ j0.15885
Broadmoor 420S	138	140.7	1.019	17.75	12.96	1.360+ j4.386	0.00714+ j0.02303	1.908+ j9.490	0.01002+ j0.04983

5 Short circuit current calculation is based on modeling information provided to the AESO by third parties. Short circuit estimation is subject to change. The information provided in this study is not intended to be used as the sole source of information for electrical equipment specification and the design of public or worker safety-grounding systems.

Table 21: Summary of Short-Circuit Current Levels – Post-Connection (Year 2024WP)

Substation	Base Voltage (kV)	Pre-Fault Voltage (kV)	Pre-Fault Voltage (pu)	3-Phase Fault (kA)	1-Phase Fault (kA)	Positive Sequence Impedance (R1+jX1)	Positive Sequence Impedance (p.u.)	Zero Sequence Impedance (R0+jX0)	Zero Sequence Impedance (p.u.)
Sherwood Park 746S	138	140.8	1.02	17.23	10.05	1.391+ j4.508	0.00730+ j0.02367	3.350+ j14.448	0.01759+ j0.07587
Canadian Liquid Air 337S	138	140.1	1.016	9.1	4.73	2.991+ j8.374	0.01571+ j0.04397	8.423+ j32.489	0.04423+ j0.17060
East Edmonton 38S	240	242.9	1.012	35.05	20.34	0.713+ j3.937	0.00124+ j0.00684	2.854+ j12.349	0.00495+ j0.02144
	138	142.7	1.034	23.47	16.97	0.761+ j3.426	0.00399+ j0.01799	1.263+ j7.405	0.00663+ j0.03889
Fiberglass E524S	138	140.2	1.016	9.71	5.02	2.778+ j7.865	0.01459+ j0.04130	7.962+ j30.723	0.04181+ j0.16133
Broadmoor 420S	138	141.7	1.027	19.5	12.75	1.055+ j4.062	0.00554+ j0.02133	2.123+ j10.627	0.01115+ j0.05580

8. Project Interdependencies

Studies and the assumptions made regarding the proposed transmission developments described herein are consistent with the AESO's long-term transmission system plans for the region. Future AESO needs identification documents in the Edmonton Region will assume the proposed transmission development in-service for the date specified, unless new information indicates otherwise.

9. Summary and Conclusion

Fortis submitted a SASR to the AESO to add a new 25/33/42 MVA 138/25 kV transformer and three 25 kV switchgear at the Broadmoor 420S substation and to increase the existing contract capacity at that Point of Delivery (PoD) substation. The proposed upgrades at the Broadmoor 420S PoD are required to address the capacity and reliability concerns on the distribution system in the Sherwood Park area per Fortis's Need for Development Sherwood Park Area Upgrade dated October 14, 2014. The existing DTS contract at the Broadmoor 420S substation is 34.8 MW. Fortis has indicated that they will execute a DTS at Broadmoor 420S for 53.3 MW upon completion of this Project. The expected ISD for this project is November 1, 2016.

The proposed alternative is for the upgrades at Broadmoor 420S that includes the installation of a new 25/33/42 MVA LTC transformer and three new 25 kV feeder breakers. A 138 kV bus-tie breaker is required at Broadmoor 420S to address Fortis' reliability requirement (not required for transmission system reliability).

This ESR details the studies undertaken to assess the impacts of the requested DTS increase and proposed upgrades at the Broadmoor 420S substation on the ATS. Power flow and short-circuit studies were performed for the system prior to and following the proposed developments to identify any system constraints. Voltage stability studies were also performed following connection of the proposed development.

Power flow results indicate that there are N-1 thermal overloading issues prior to the upgrade of Broadmoor 420S. The single circuit 138 kV lines 731L (Broadmoor 420S to 746L Junction) and 694L (Fort Saskatchewan 54S to Westwood 422S) will be overloaded above their short-term ratings under the contingency of the other circuit. However, studies show that the permanent relocation of the 746L normally open point from 746L8A (located close to the Canadian Liquid Air 337S substation) to the existing 746DL19 (located near the Owens Corning E524S tap on 746L) would eliminate the pre-connection N-1 thermal violations and reduce the severity of the post-connection N-1 thermal violations in the area. With the permanent relocation of the normally open point as previously described, the post-connection N-1 thermal violations can be managed in real-time.

Voltage stability analysis results indicate that the voltage stability margins of the Edmonton area system, with the proposed upgrades in Broadmoor 420S substation, meet the Reliability Criteria. The proposed developments have minimal impact on the short circuit levels in the area.

It is recommended that the existing manually operated switch, 746L8A, be permanently closed and the existing manually operated switch, 746DL19, be permanently open prior to and after the connection of the Project.

ATTACHMENT A

Pre - Connection: Power Flow Analysis

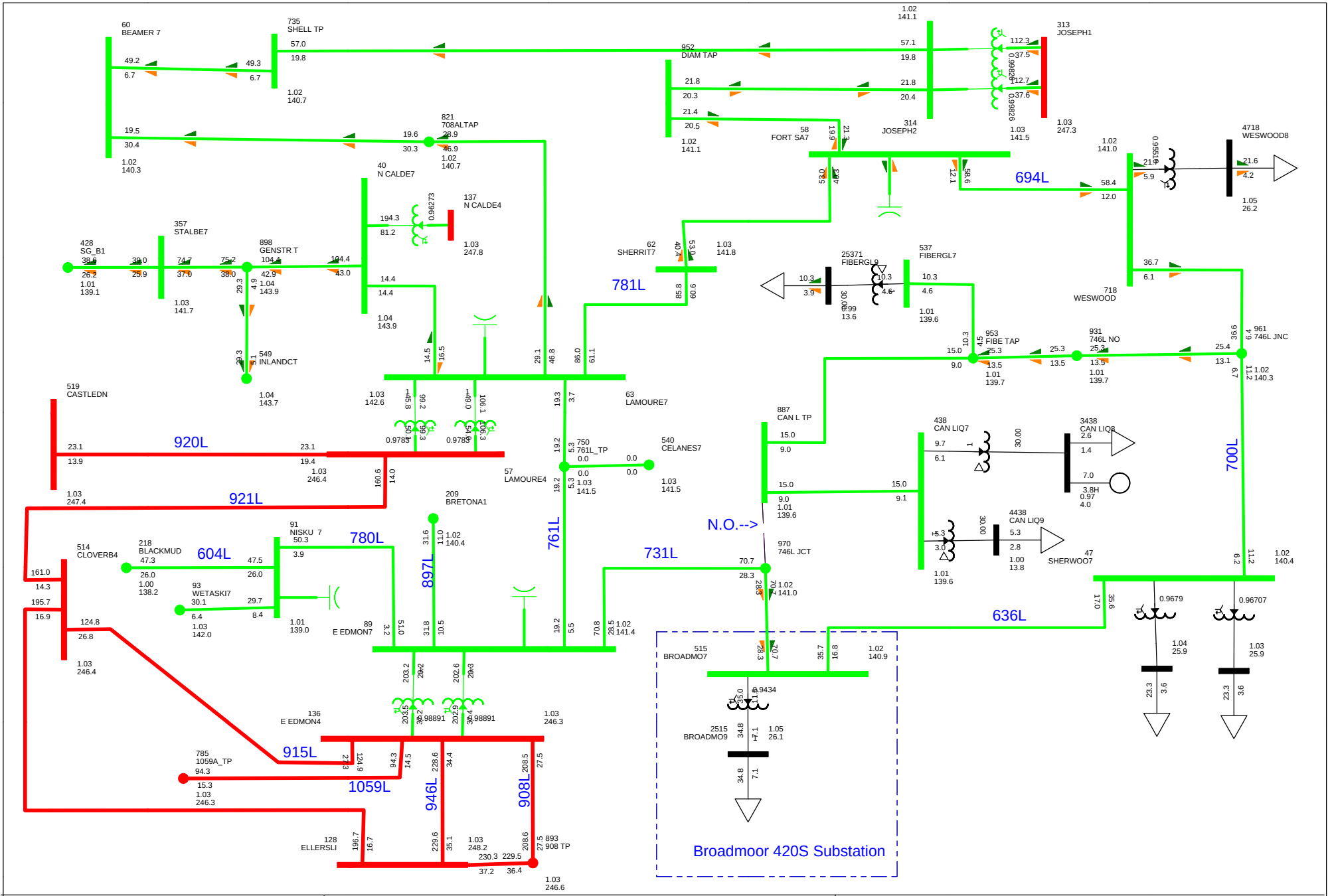
Before the Broadmoor Substation Upgrade

Table 1: 2016SP Pre-connection Study Results

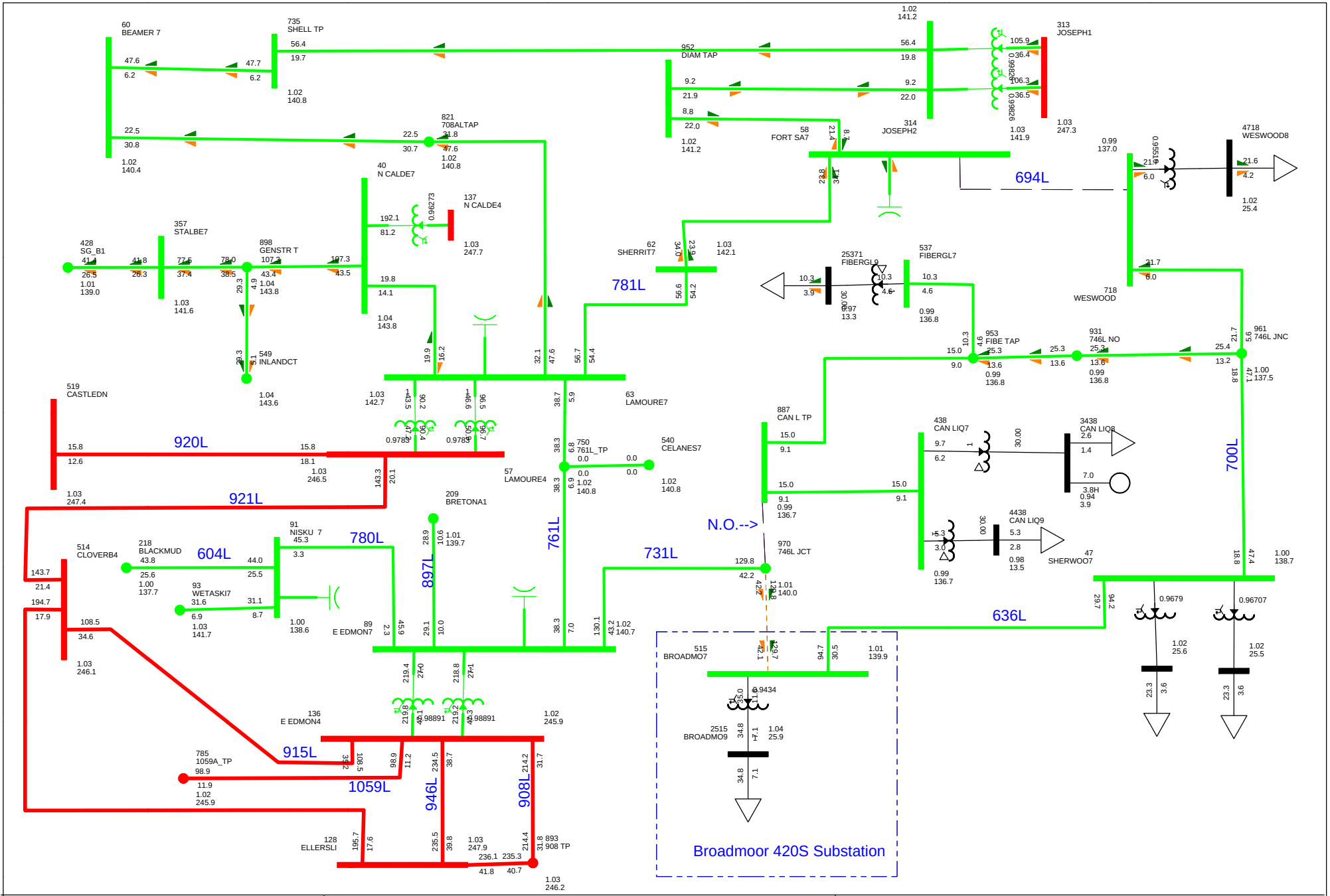
Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment A
N-0: Normal Operation	None	--		None	A-1
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to 746L Junction	113%	116/136	None	A-2
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	116%	119/139	None	A-3
	781L Lamoureux 71S to Sherritt 172S	99%	143/144		
	700L Westwood 422S to 746L Junction	97%	119/114		

Table 2: 2016WP Pre-connection Study Results

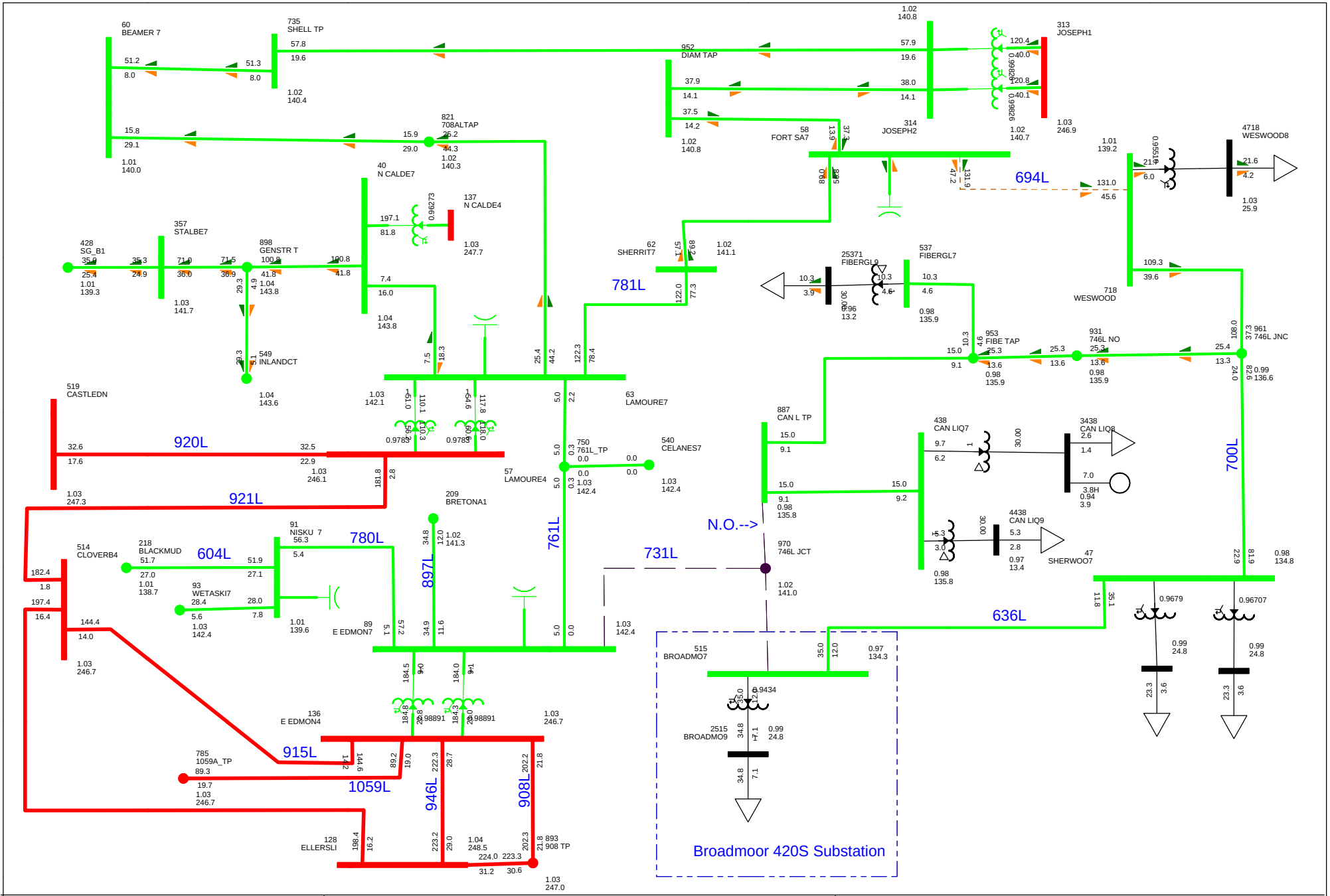
Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment A
N-0: Normal Operation	None	--	-	None	A-4
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to the Junction	-	-	None	A-5
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	100%	146/146	None	A-6



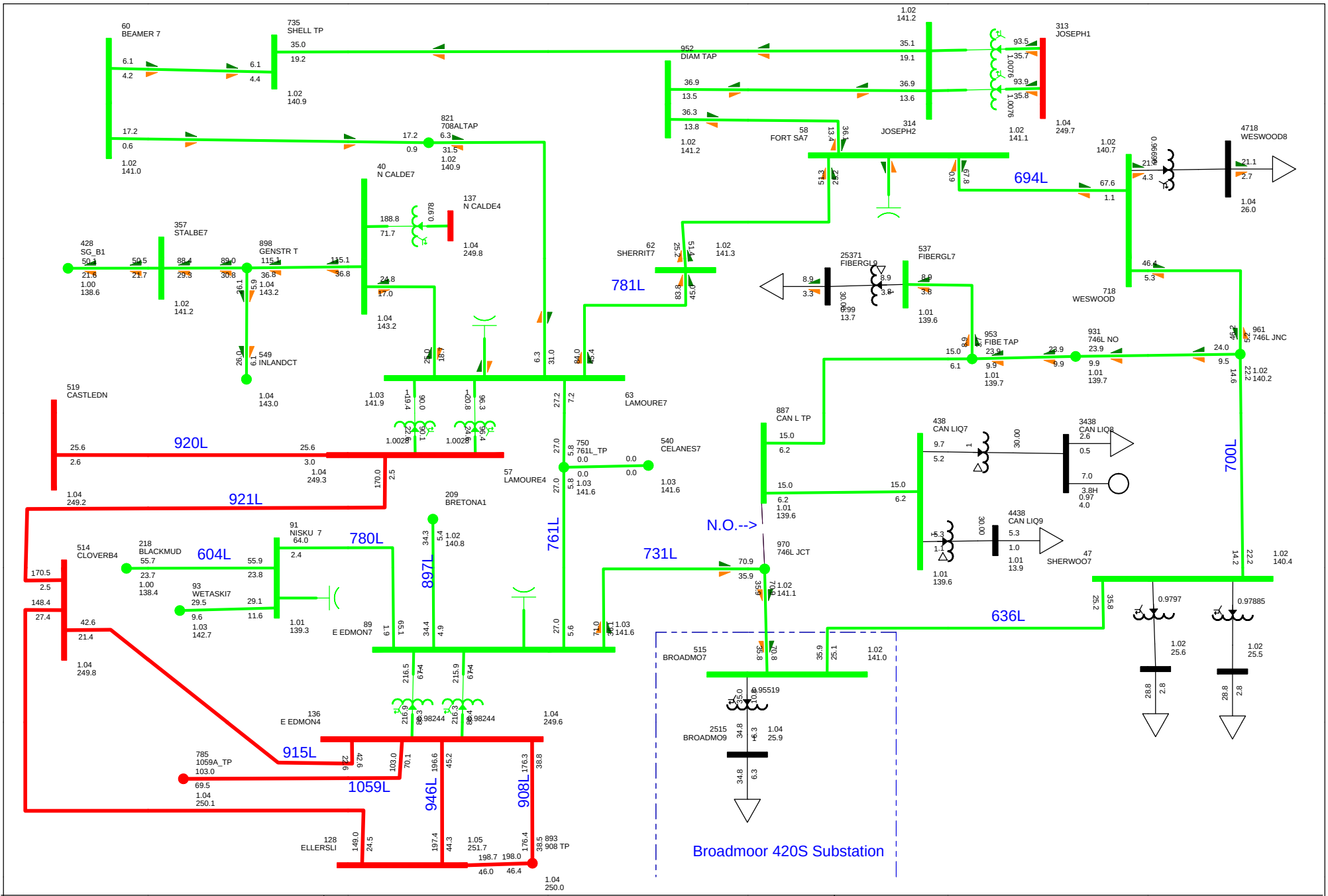
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S PRE-CONNECTION - DIAGRAM A-1 N-0: NORMAL OPERATION WED, APR 29 2015 11:15	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



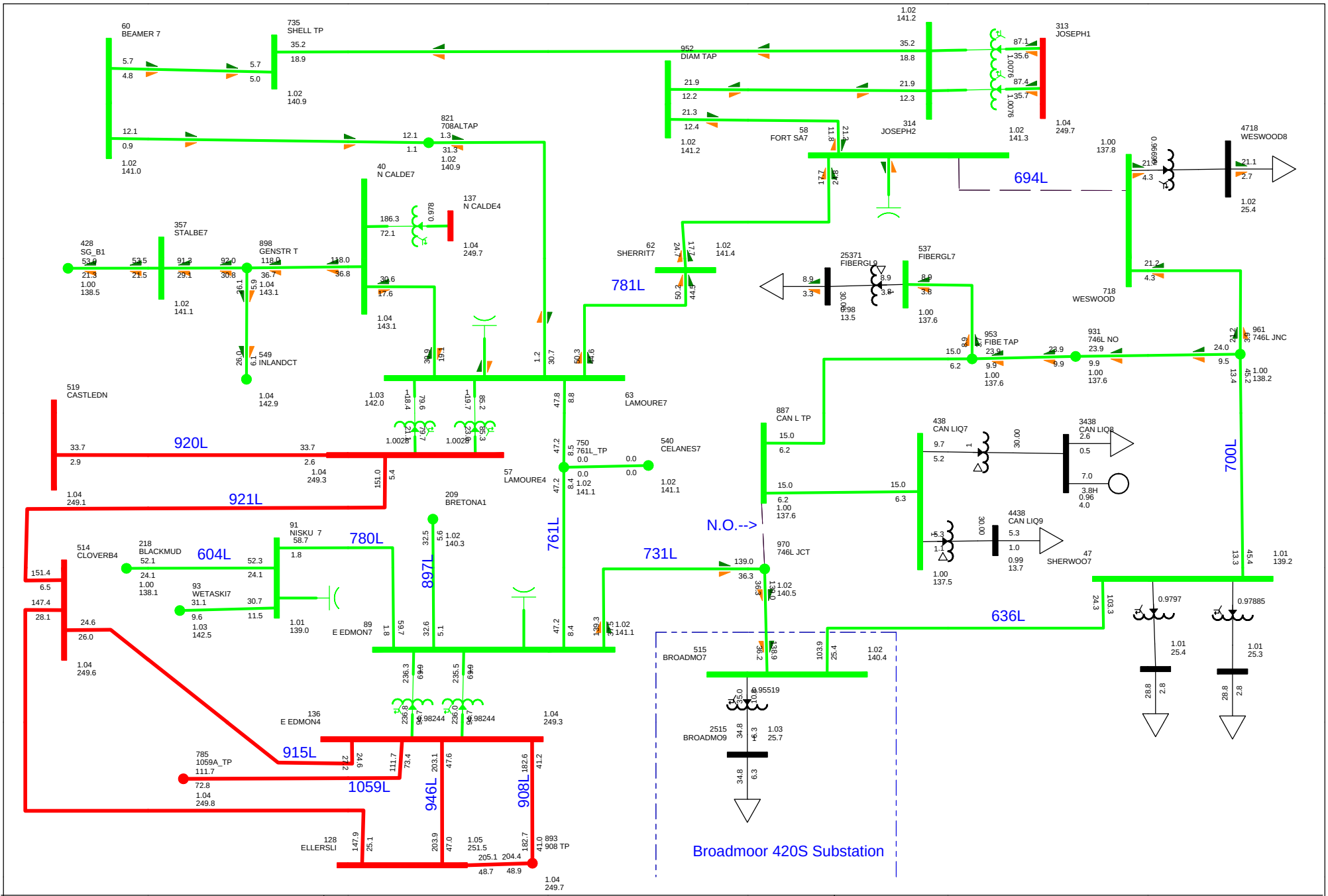
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S PRE-CONNECTION - DIAGRAM A-2 N-1: 694L FORT SASKATCHEWAN 54S WESTWOOD 422S WED, APR 29 2015 11:15	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 SP	BROADMOOR 420S PRE-CONNECTION - DIAGRAM A-3 N-1: 731L BROADMOOR 420S TO EAST EDMONTON 38S WED, APR 29 2015 11:15	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S PRE-CONNECTION - DIAGRAM A-4 N-0: NORMAL OPERATION WED, APR 29 2015 11:18	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

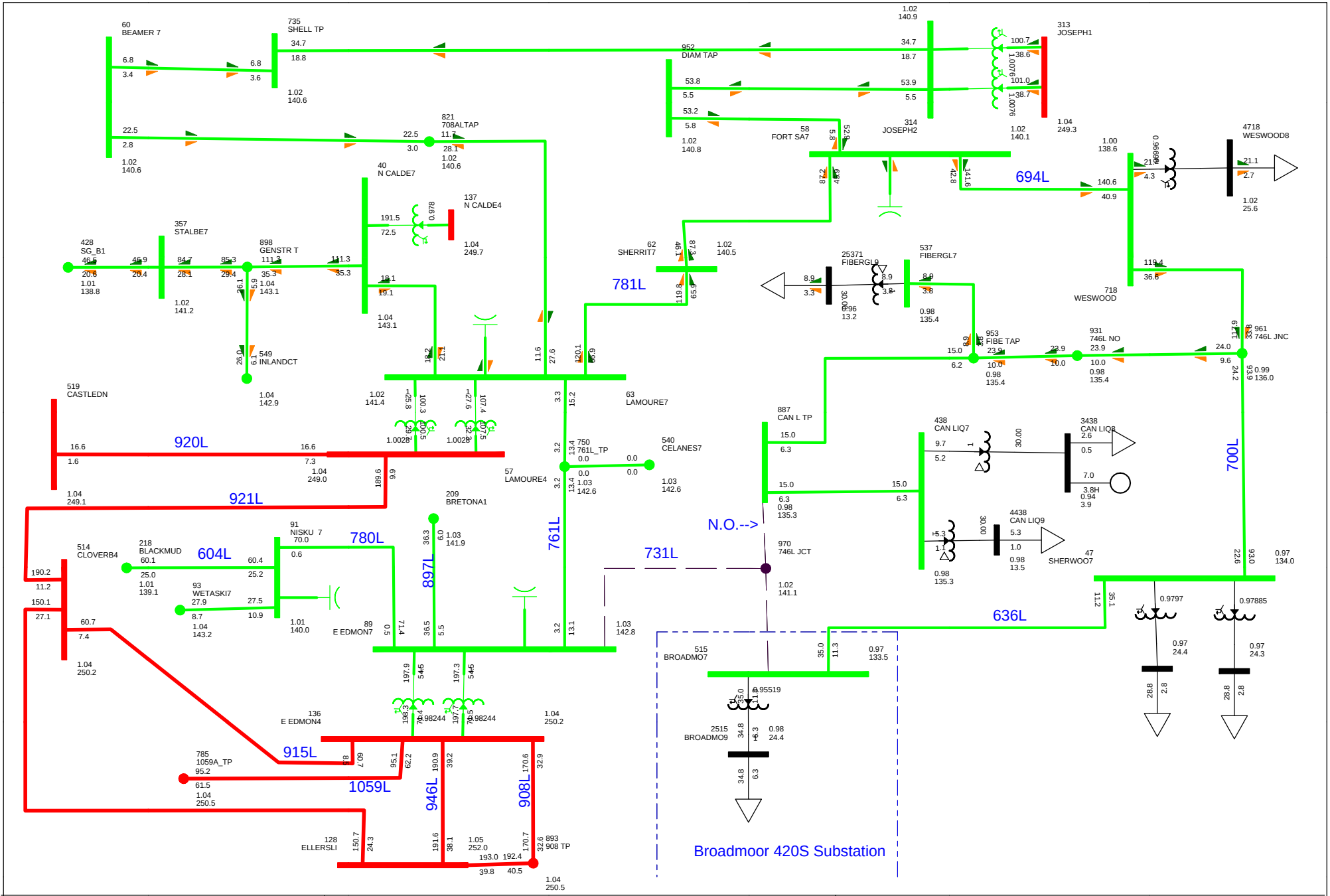


Broadmoor 420S Substation

2016 WP

BROADMOOR 420S PRE-CONNECTION - DIAGRAM A-5
N-1: 694L FORT SASKATCHEWAN 54S WESTWOOD 422S
WED, APR 29 2015 11:18

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.105OV 0.899UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S PRE-CONNECTION - DIAGRAM A-6 N-1: 731L BROADMOOR 420S TO EAST EDMONTON 38S WED, APR 29 2015 11:18	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

ATTACHMENT B

Post - Connection: Power Flow Analysis

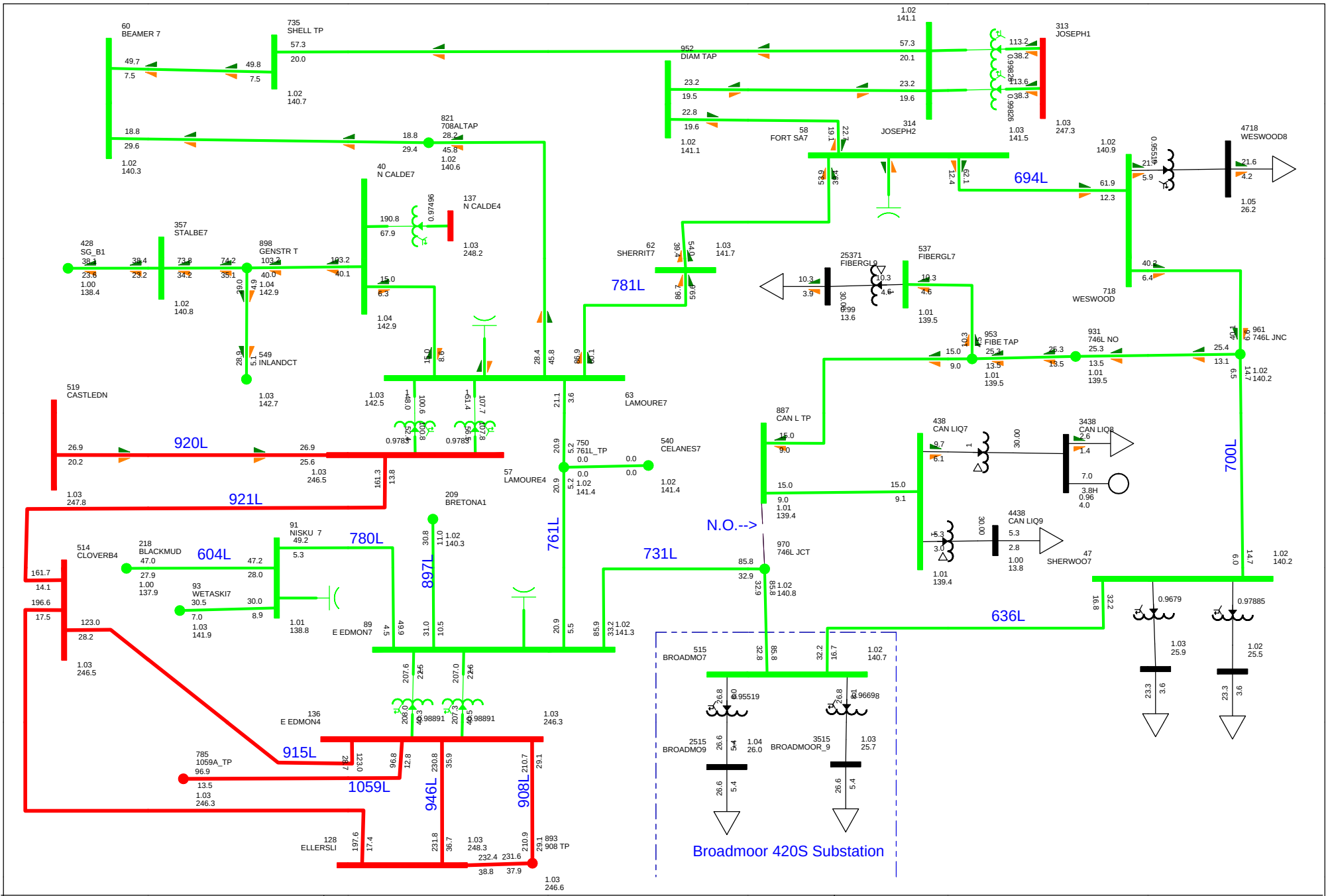
After the Broadmoor Substation Upgrade (2016)

Table 1: 2016SP Post-connection Study Results

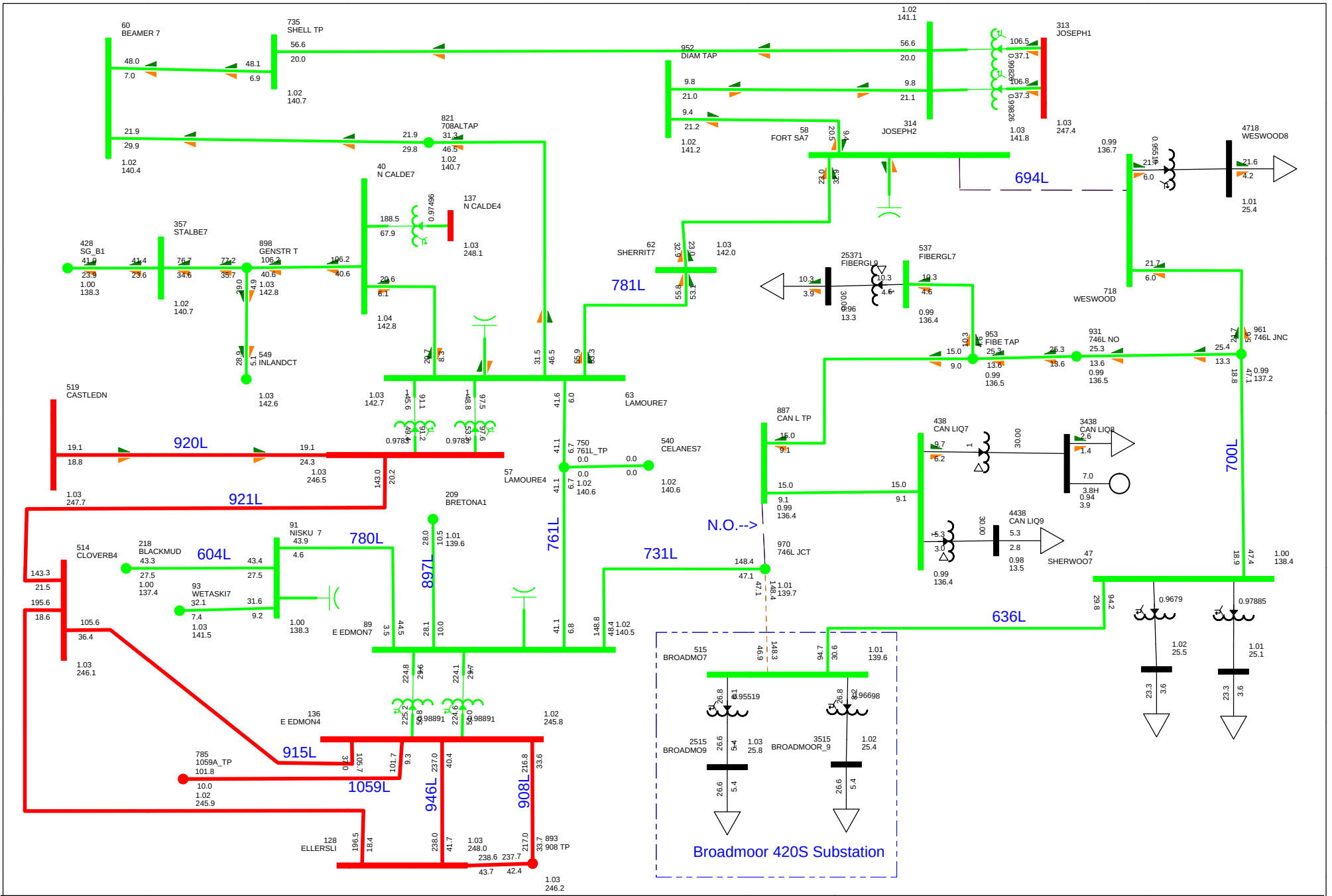
Contingency	Thermal Overloads	% of Loading Pre/Post	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment B
N-0: Normal Operation	None	--	-	None	B-1
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to 746L Junction	113%/129%	119/156	None	B-2
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	116%/134%	119/160	None	B-3
	781L Lamoureux 71S to Sherritt 172S	99%/105%	143/153		
	700L Westwood 422S to 746L Junction	97%/115%	119/134		

Table 2: 2016WP Pre-connection Study Results

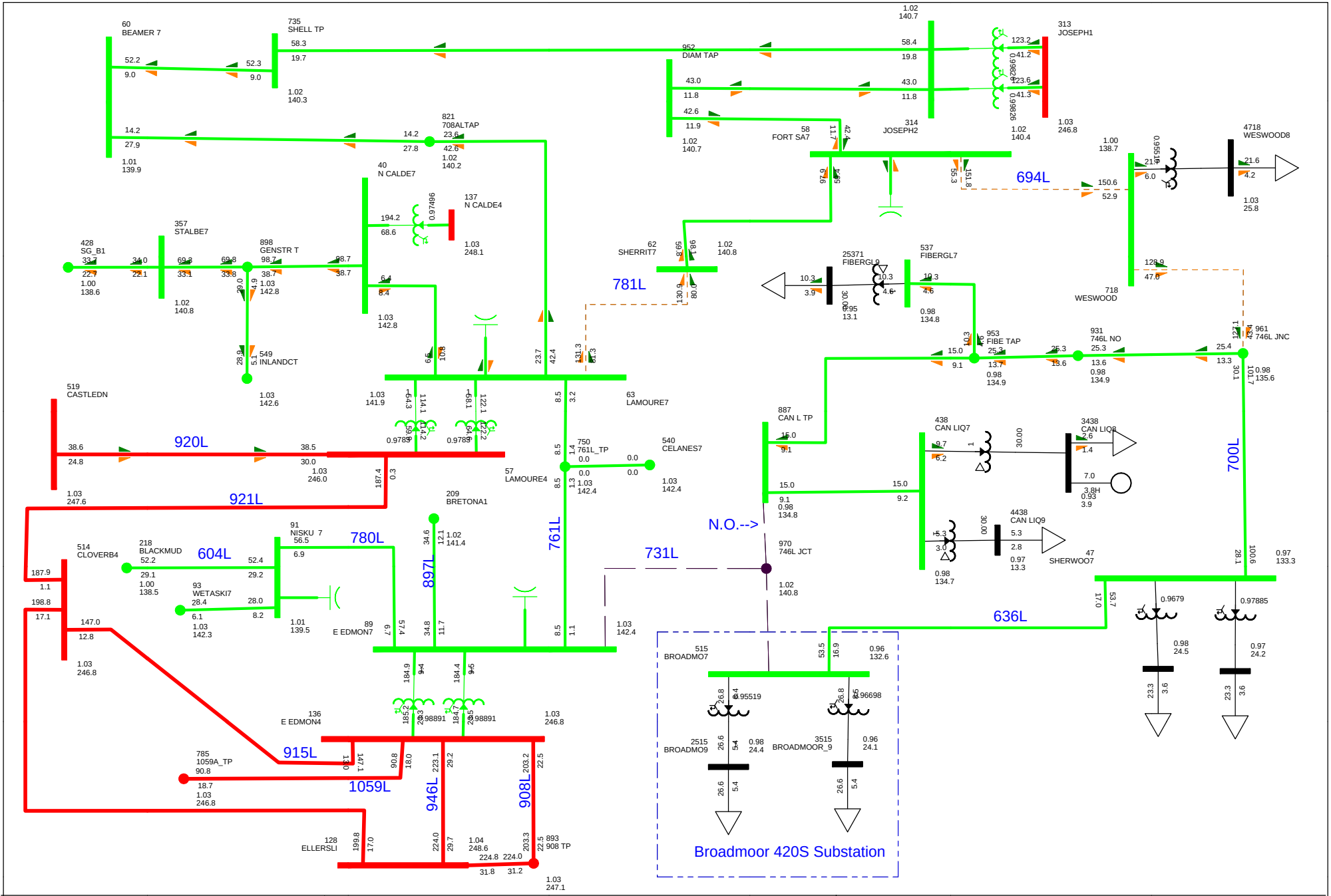
Contingency	Thermal Overloads	% of Loading Pre/Post	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment B
N-0: Normal Operation	None	--		None	B-4
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to the Junction	97%/110%	146/163	None	B-5
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	100%/115%	146/168	None	B-6
	700L Westwood 422S to 746L Junction	85%/100%	146/146		



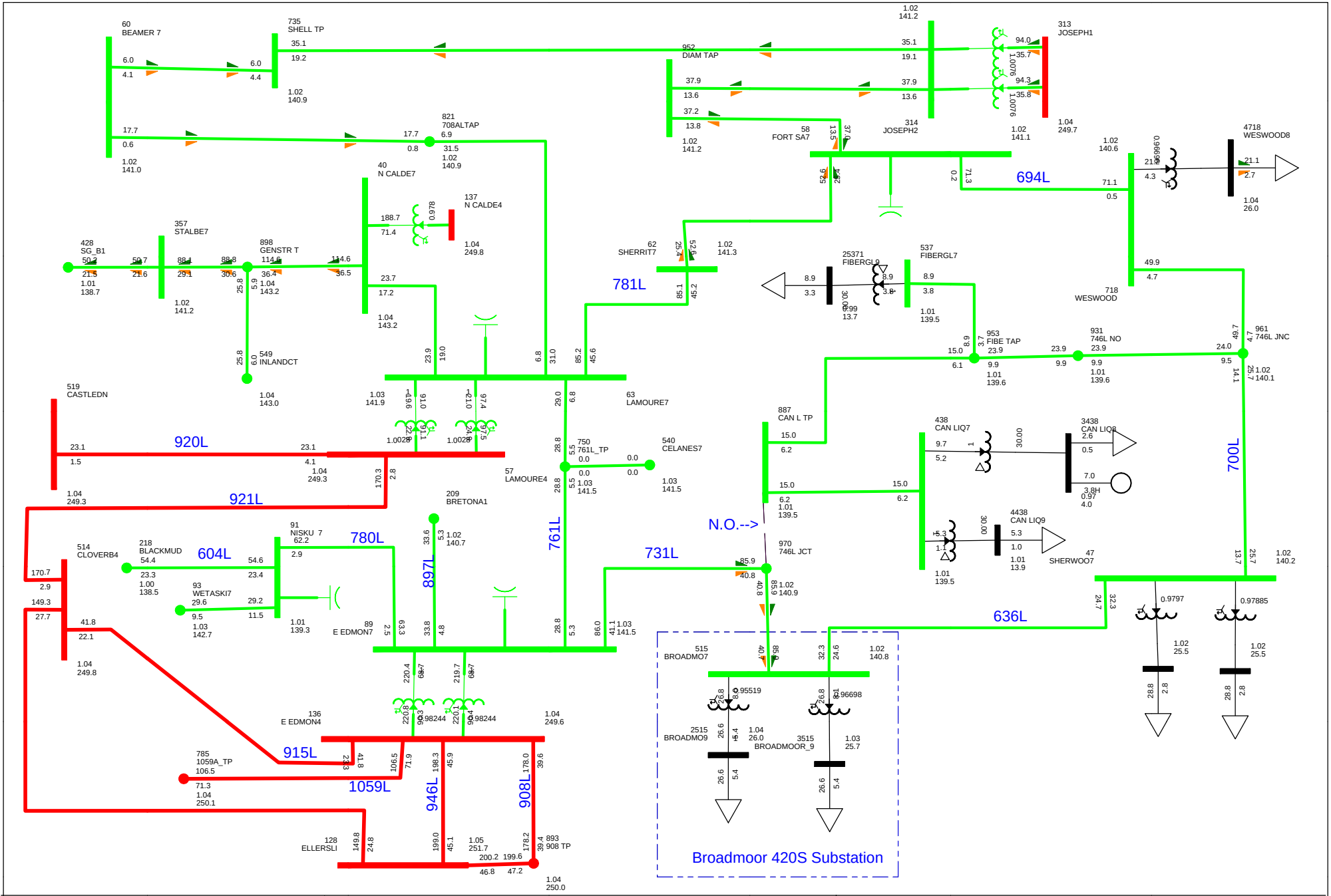
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM B-1 N-0: NORMAL OPERATION WED, APR 29 2015 11:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



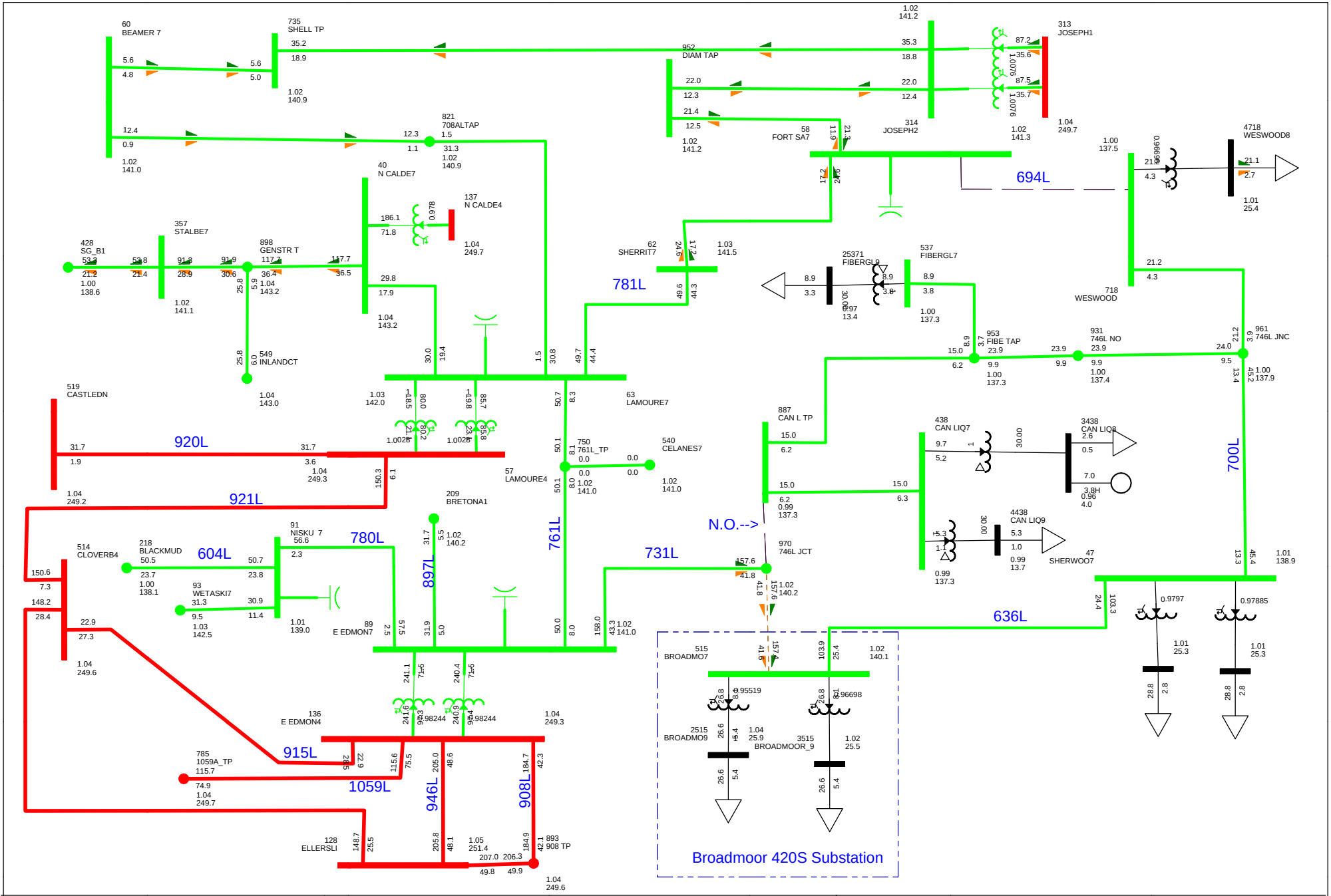
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM B-2 N-1: 694L FORT SASKATCHEWAN 54S WESTWOOD 422S WED, APR 29 2015 11:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



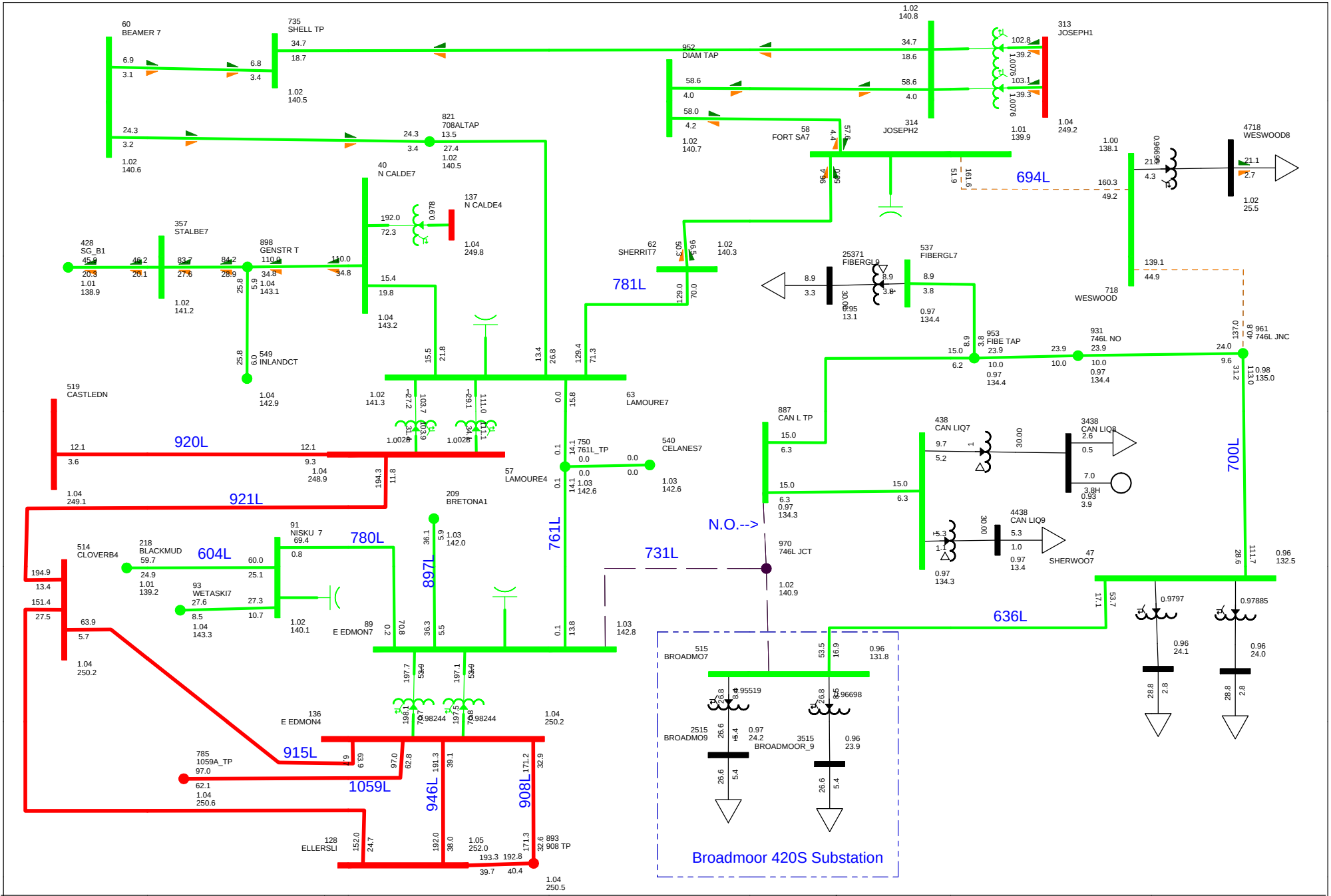
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM B-3 N-1: 731L BROADMOOR 420S TO EAST EDMONTON 38S WED, APR 29 2015 11:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S POST-CONNECTION - DIAGRAM B-4 N-0: NORMAL OPERATION WED, APR 29 2015 11:42	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S POST-CONNECTION - DIAGRAM B-5 N-1: 694L FORT SASKATCHEWAN 54S WESTWOOD 422S WED, APR 29 2015 11:42	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



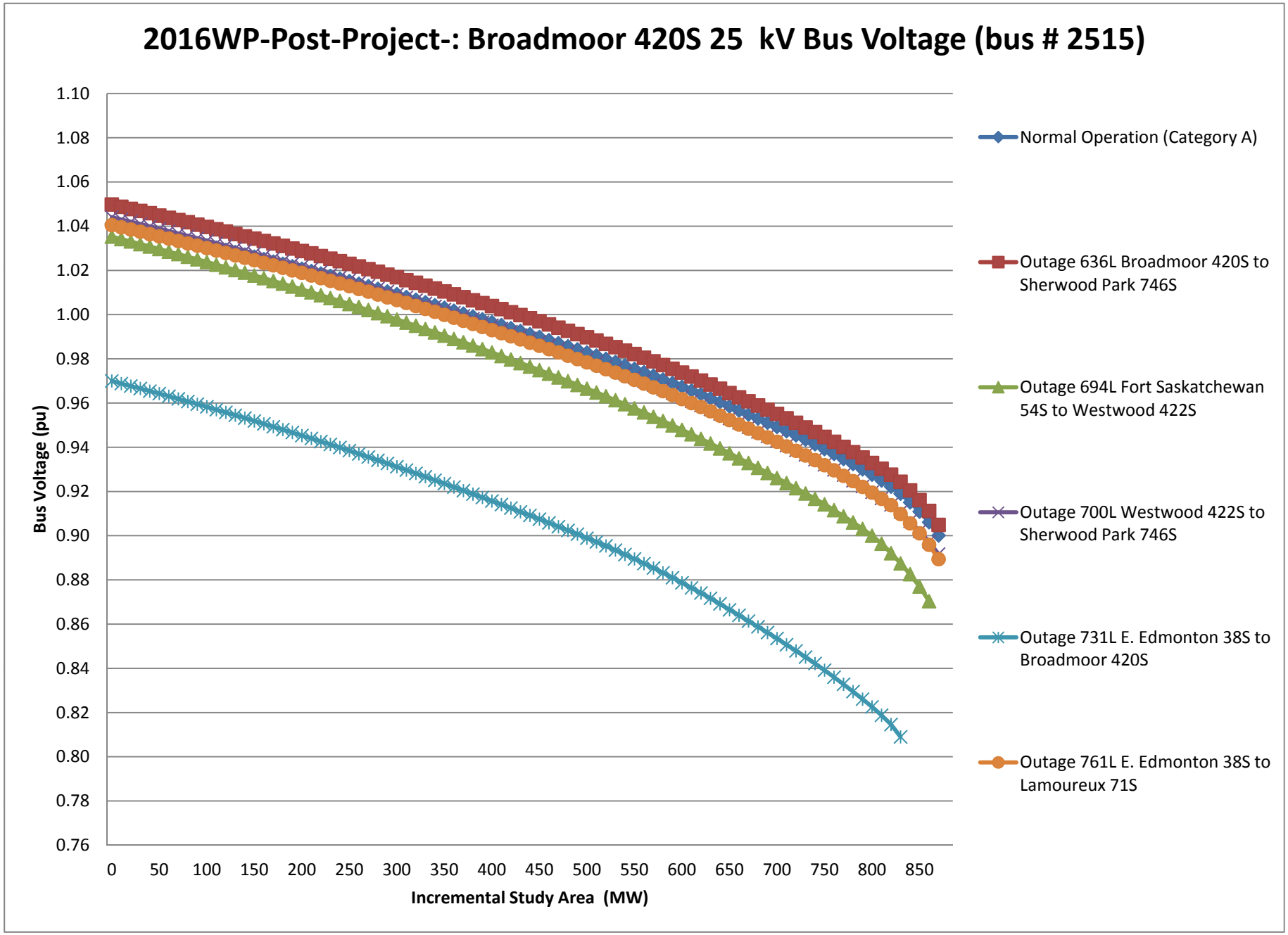
Broadmoor 420S Substation 2016 WP	BROADMOOR 420S POST-CONNECTION - DIAGRAM B-6 N-1: 731L BROADMOOR 420S TO EAST EDMONTON 38S WED, APR 29 2015 11:42	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

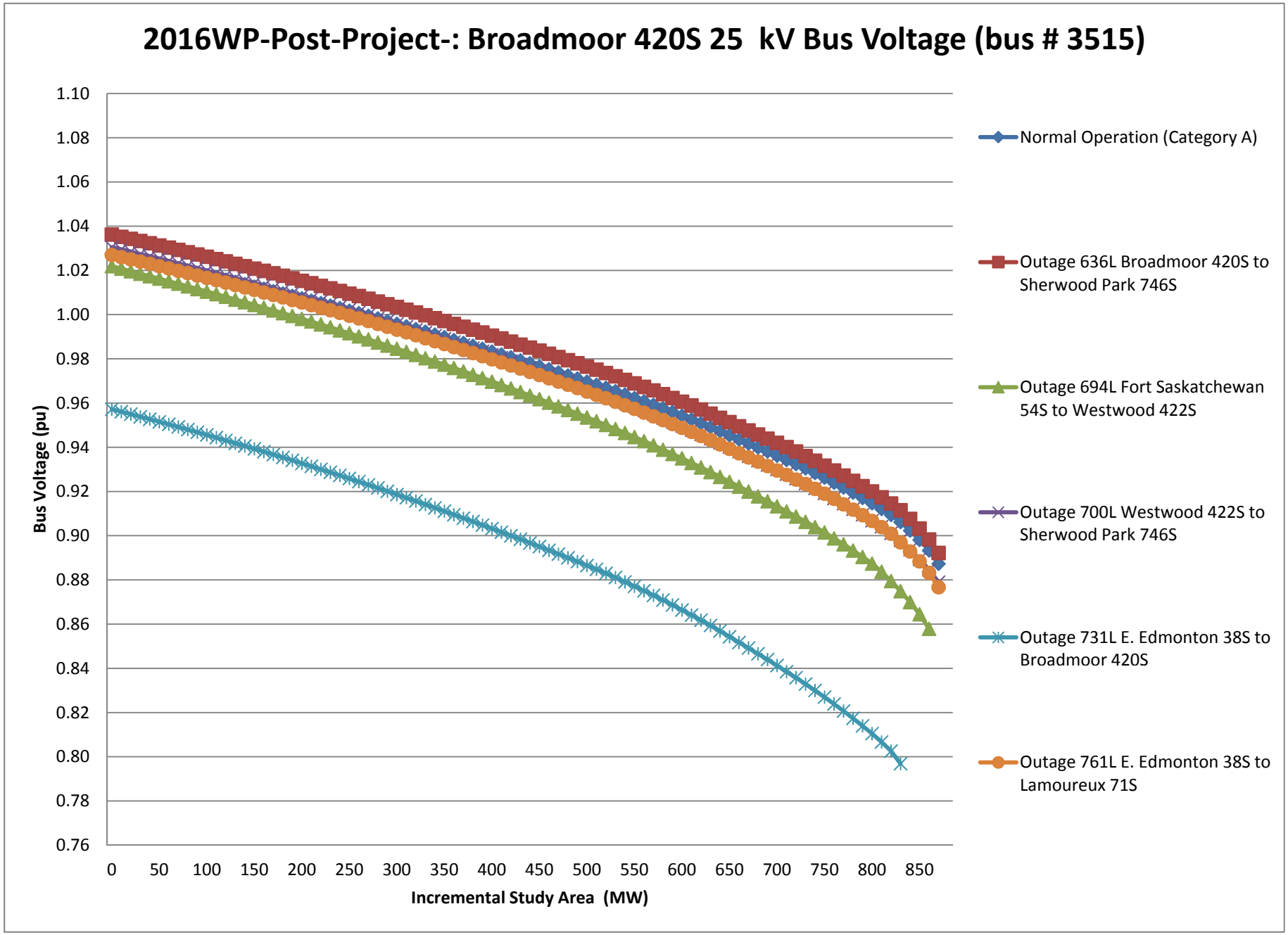
ATTACHMENT C

Post-Connection: Voltage Stability Analysis

Table 1: P-V Analysis-2016WP Post-Connection

Operation Conditions	2016WP Forecasted load (MW)	105% Margin (MW)	Meets Voltage Criteria?
N-0: Normal Operation	1963.7	2061.9	YES
N-1: 636L Broadmoor 420S to Sherwood Park 746S	1963.7	2061.9	YES
N-1: 694L Fort Saskatchewan 54S to Westwood 422S	1963.7	2061.9	YES
N-1: 700L Westwood 422S to Sherwood Park 746S	1963.7	2061.9	YES
N-1: 731L East Edmonton 38S to Broadmoor 420S	1963.7	2061.9	YES
N-1: 761L East Edmonton 38S to Lamoureux 71S	1963.7	2061.9	YES


2016WP-Post-Project-: Broadmoor 420S 25 kV Bus Voltage (bus # 2515)
Bus Voltage (pu)
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
0.76
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
Incremental Study Area (MW)
Normal Operation (Category A)
Outage 636L Broadmoor 420S to Sherwood Park 746S
Outage 694L Fort Saskatchewan 54S to Westwood 422S
Outage 700L Westwood 422S to Sherwood Park 746S
Outage 731L E. Edmonton 38S to Broadmoor 420S
Outage 761L E. Edmonton 38S to Lamoureux 71S


2016WP-Post-Project-: Broadmoor 420S 25 kV Bus Voltage (bus # 3515)
Bus Voltage (pu)
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
0.76
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
Incremental Study Area (MW)
Normal Operation (Category A)
Outage 636L Broadmoor 420S to Sherwood Park 746S
Outage 694L Fort Saskatchewan 54S to Westwood 422S
Outage 700L Westwood 422S to Sherwood Park 746S
Outage 731L E. Edmonton 38S to Broadmoor 420S
Outage 761L E. Edmonton 38S to Lamoureux 71S

ATTACHMENT D

Post - Connection: Power Flow Analysis

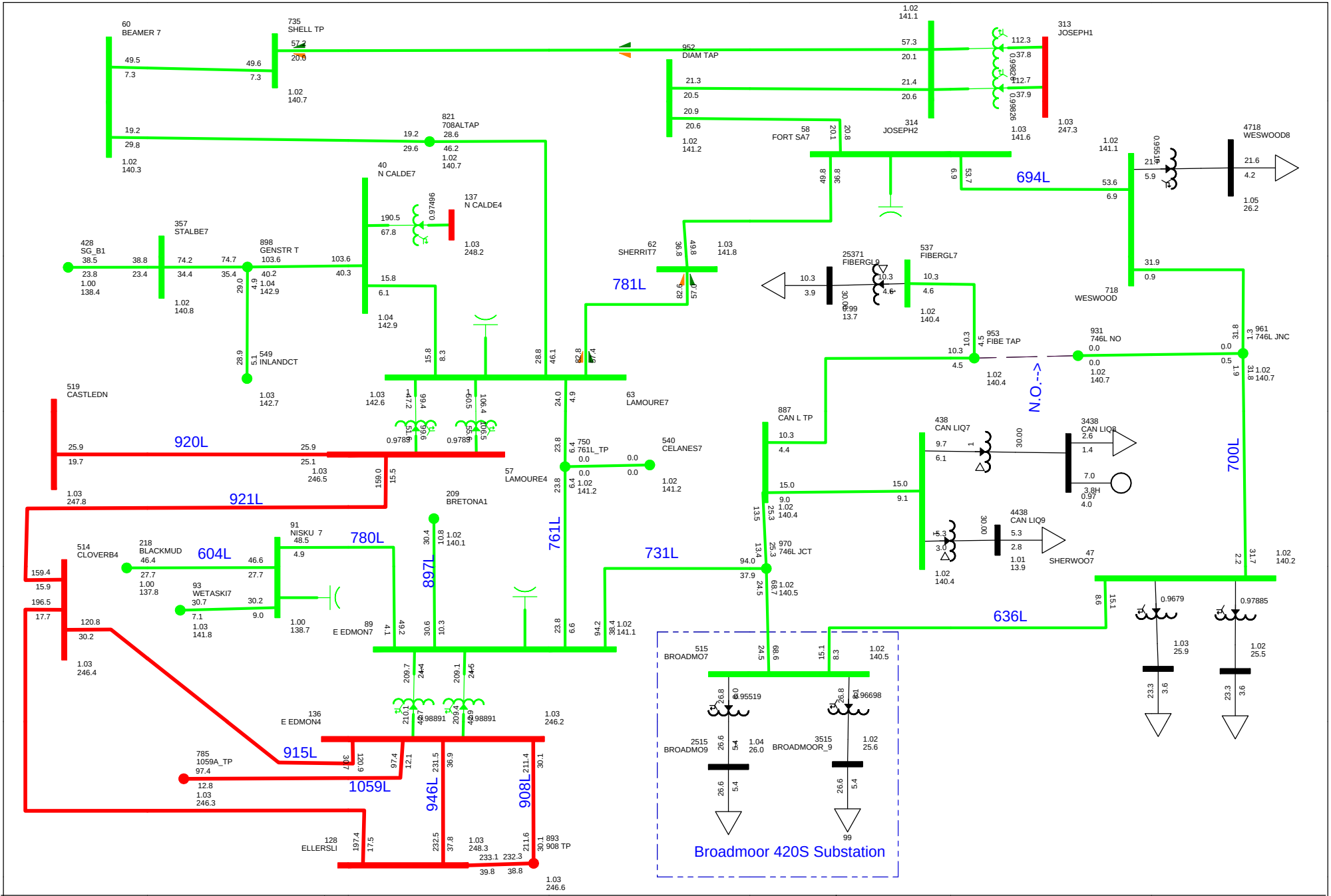
With N.O point change (2016)

Table 1: 2016SP Post-connection Study Results

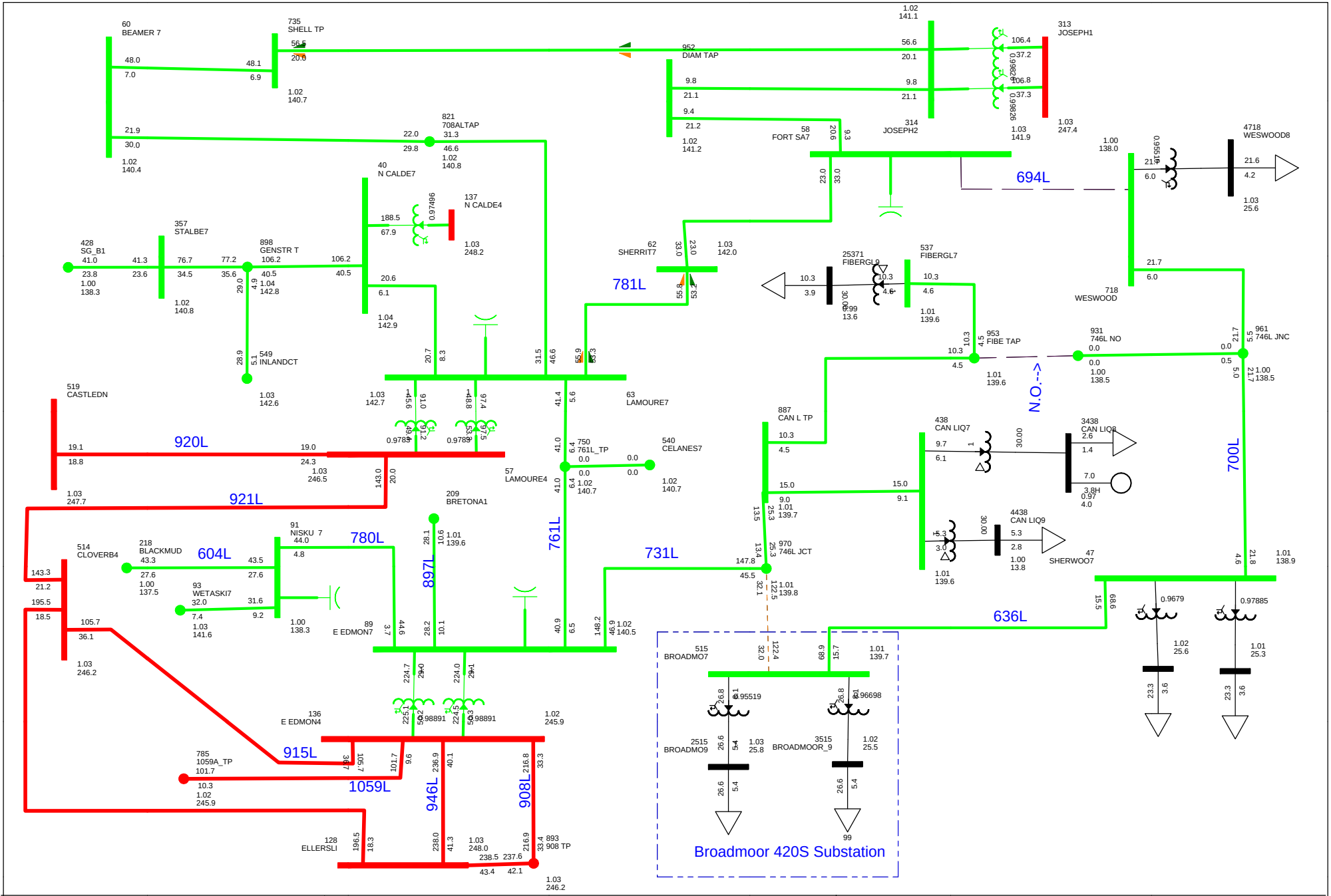
Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment D
N-0: Normal Operation	None	--	-	None	D-1
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to 746L Junction	105%	119/127	None	D-2
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	108%	119/130	None	D-3
	781L Lamoureux 71S to Sherritt 172S	--	--		
	700L Westwood 422S to 746L Junction	--	--		
N-1: 781L Lamoureux 71S to Sherritt 172S	707L Fort Saskatchewan 54S to Dow Chemical 166S	--	--	None	D-4

Table 2: 2016WP Pre-connection Study Results

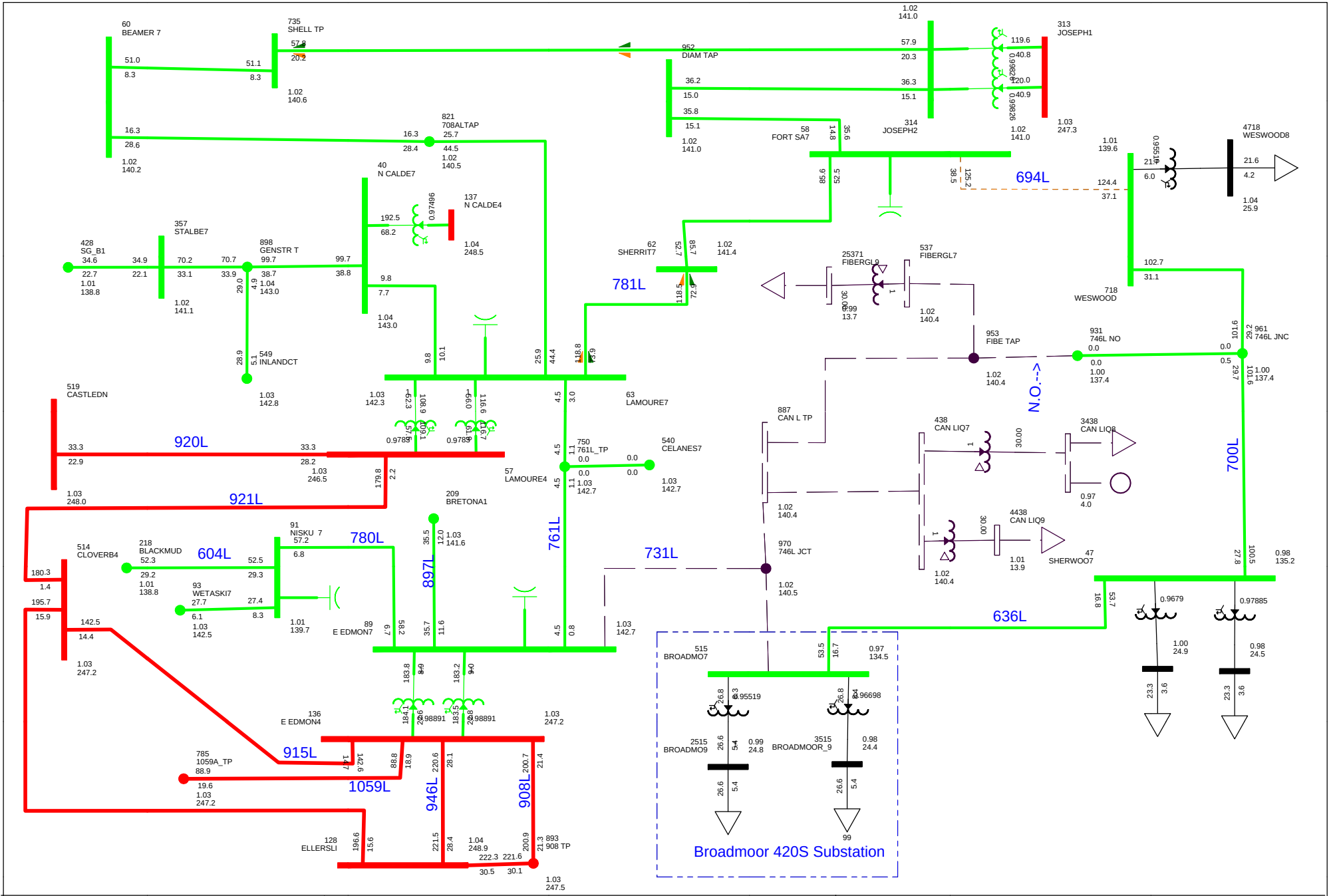
Contingency	Thermal Overloads	% of Loading	Loading Rating/Flow (MVA)	Voltage Violation	Figure in Attachment D
N-0: Normal Operation	None	--	--	None	D-5
N-1: 694L Fort Saskatchewan 54S Westwood 422S	731L Broadmoor 420S to the Junction	--	--	None	D-6
N-1: 731L Broadmoor 420S to East Edmonton 38S	694L Fort Saskatchewan 54S Westwood 422S	--	--	None	D-7
	700L Westwood 422S to 746L Junction	--	--		



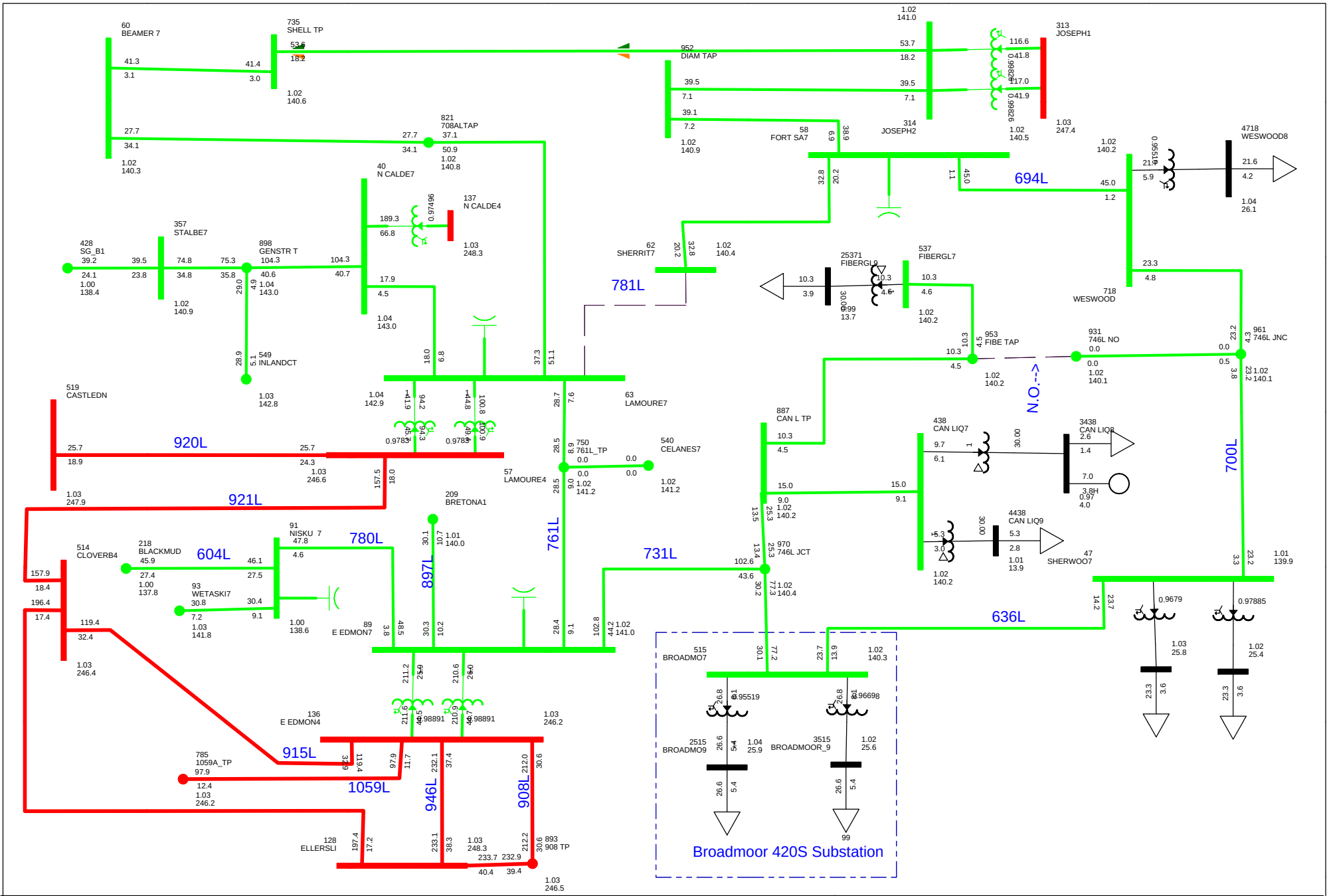
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-1 N-0: NORMAL OPERATION WED, OCT 07 2015 10:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



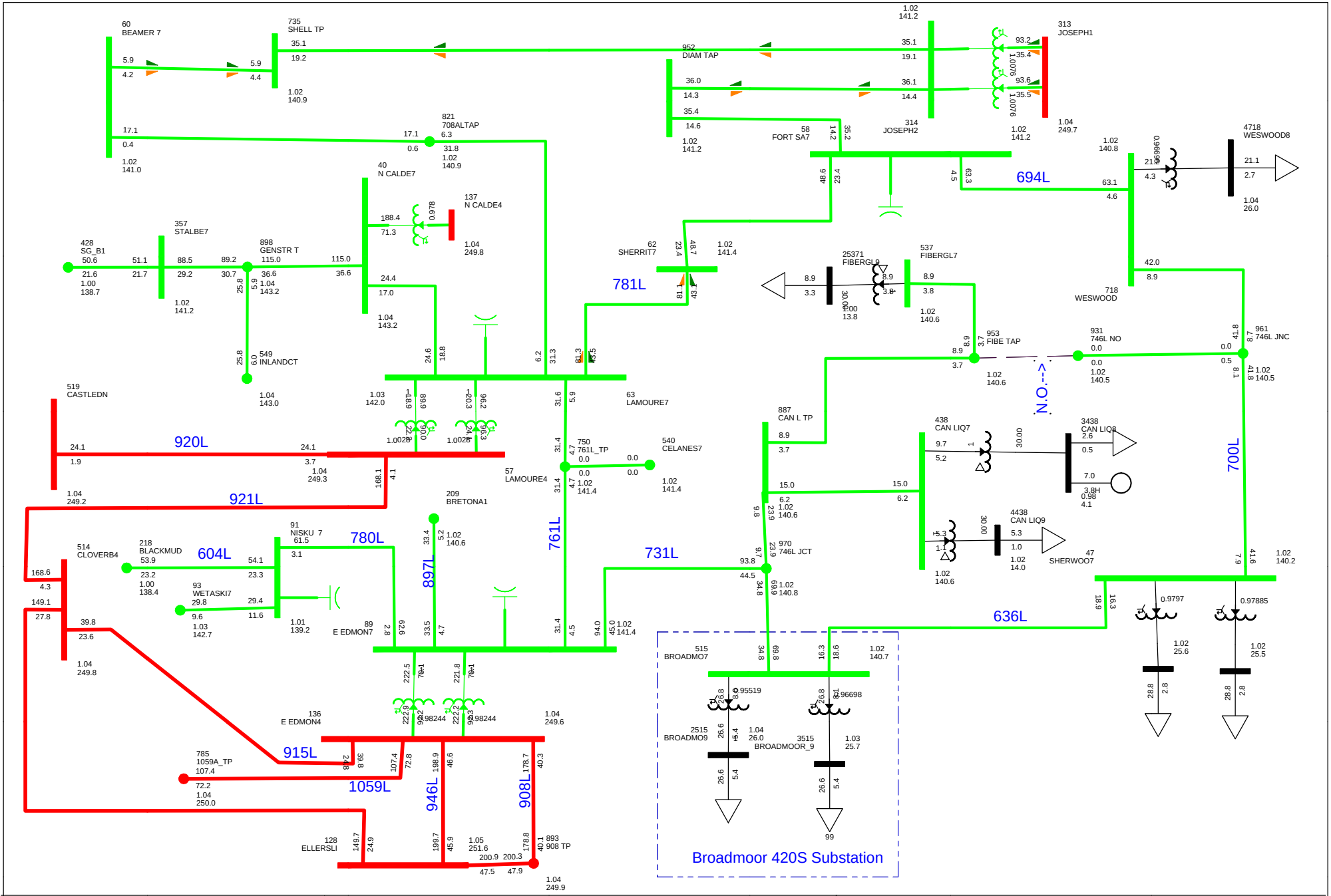
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-2 N-1: 694L FORT SASKATCHEWAN 54S WESTWOOD 422S WED, OCT 07 2015 10:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



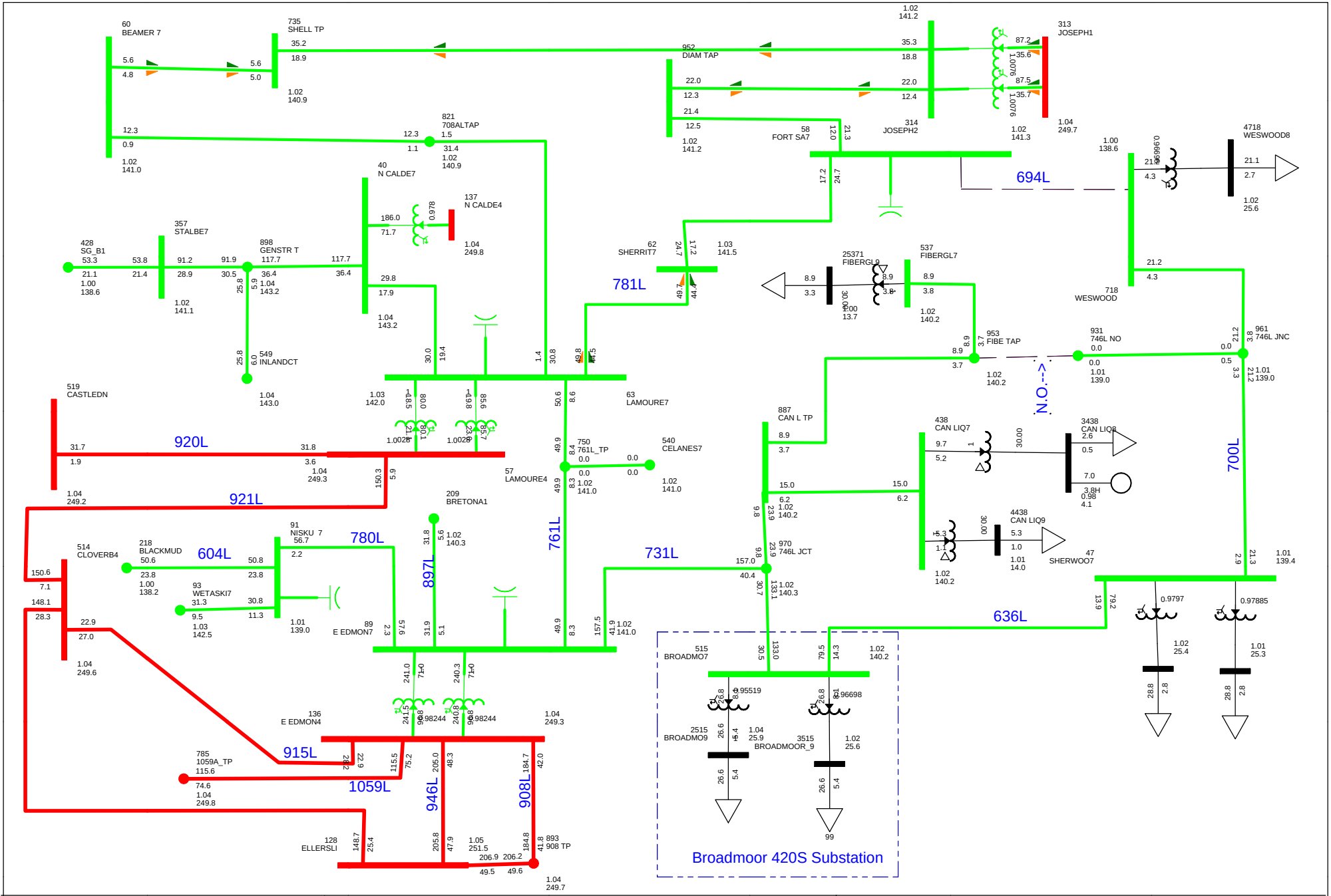
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-3 N-1: 731L BROADMOOR 420S TO EAST EDMONTON 38S WED, OCT 07 2015 10:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



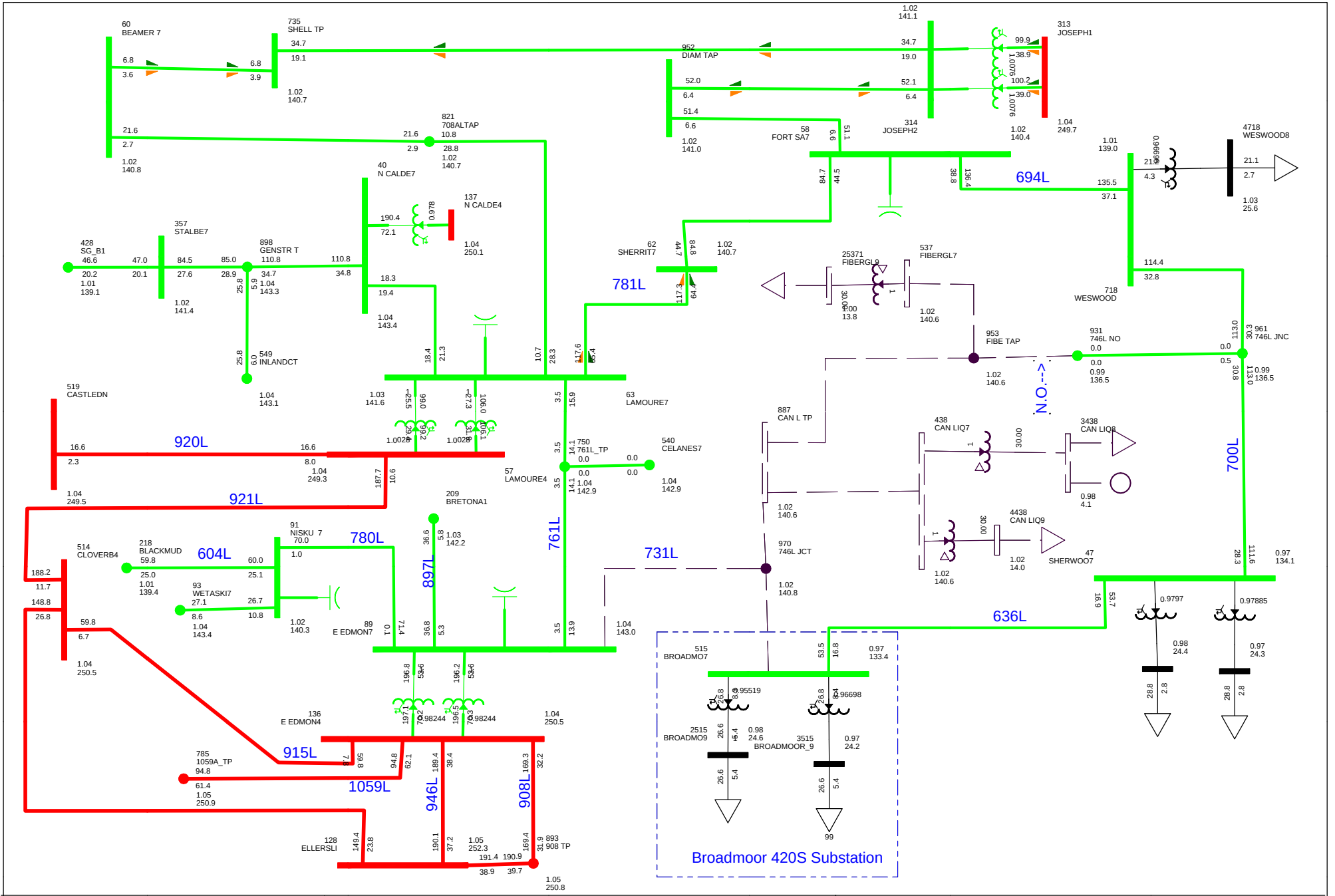
Broadmoor 420S Substation 2016 SP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-4 N-1: 781L LAMOUREUX 71S TO SHERRITT 172S WED, OCT 07 2015 10:23	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate A 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-5 N-0: NORMAL OPERATION WED, OCT 07 2015 10:26	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-6 N-1: 694L FORT SASKATCHEWAN 54S WESTWOOD 422S WED, OCT 07 2015 10:26	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Broadmoor 420S Substation 2016 WP	BROADMOOR 420S POST-CONNECTION - DIAGRAM D-7 N-1: 731L BROADMOOR 420S TO EAST EDMONTON 38S WED, OCT 07 2015 10:26	Bus - Voltage (kV/pu) Branch - MW/Mvar Equipment - MW/Mvar 100.0%Rate B 1.105OV 0.899UV kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000