APPENDIX A CONNECTION ASSESSMENT

Fortis Hughenden 213S Upgrade

Project Number: 1642

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: February 11, 2016

Function	Name	Company	Signature	Date
Senior Engineer	Bipul Karki, Ph. D., P. Eng.	Alberta Electric System Operator		Feb 11, 2016
Manager, Projects & System Access Studies	Mohamed Kamh, Ph.D., P. Eng.	Alberta Electric System Operator		Feb. 11, 2016

Public

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 Hughenden Upgrade

AESO Project Number: P1642

Revision: 3

Revision Date: February 5, 2016

	Name	Date	Signature
Prepared	Fatima Belmoufid, EIT. (AltaLink)	Feb 08, 2016	
Reviewed	Carl Wang, P. Eng. (AltaLink)	Feb. 08, 2016	
Joby Varghese For Approved	Ryan Cui, P. Eng. (AltaLink)	Feb 08, 2016	Joby Varghese

PROFESSIONAL ENGINEER
YUNFEI WANG
ALBERTA
Feb 08, 2016

AltaLink APEGGA Permit Number P-7862

(Page intentionally blank)

Executive Summary

Project Overview

FortisAlberta Inc. (FortisAlberta), the market participant, has applied to the Alberta Electric System Operator (AESO) requesting a 2.8MW load increase at the existing Hughenden 213S substation. The Hughenden 213S substation is located in Provost area (AESO Planning area 37) at 04-03-41-07-W4M.

AESO project 1642, hereafter the Project, seeks to address FortisAlberta's need. The requested in-service date (ISD) for the Project is December 1, 2016.

Existing System

The Provost area is located in the Central East region of Alberta and consists primarily of 138 kV and 240 kV transmission systems. The primary source of supply in the area is the coal-fired plant at Battle River. The area is connected to the neighbouring planning areas of Battle River (AESO Planning area 36), Lloydminster (AESO Planning area 13), Hanna (AESO Planning area 42) and Wainwright (AESO Planning area 32).

Connection Alternatives Considered for the Project

Two (2) connection alternatives were proposed for the Project:

- Alternative 1: Addition of one (1) new 138/25kV 25/33/42MVA LTC Transformer with the existing T-tap connection to 138 kV transmission line 703L;
- Alternative 2: Addition of one (1) new 138/25kV 25/33/42MVA LTC Transformer with in-and-out connection to 138 kV transmission line 703L.

FortisAberta confirmed that of these two alternatives, only Alternative 2 meets their reliability criteria[1]. Thus, this report presents the results of the detailed studies for Alternative 2.

Study Summary

This Engineering Study Report (ESR) presents the system performance studies undertaken to assess the impact of the Project on the performance of the Alberta Interconnected Electric System (AIES).

The Wainwright area, Battle River area, Lloydminster area, and Provost area were collectively considered as the Study Area. 2016 winter peak (2016 WP) and 2017 summer peak (2017 SP) scenarios were considered in the studies. Power flow and voltage stability analysis were performed for Category A and B contingencies. Short-circuit analysis was performed to calculate the short circuit levels for the major substations in the Study Area.

Study results show that there are one existing thermal loading above transmission line emergency rating and one voltage collapse under loss of Metiskow 648S Transformer T1. AESO has previously identified these violations through other projects and specified the solutions with the regional long term plan. Alternative 2 does not adversely impact the AIES and

[1] As per Section 4.2.1 of Fortis's Distribution Deficiency Report dated October 7, 2015

does not significantly alter the short circuit levels in the area. Voltage stability analysis confirms that voltage stability margins continue to satisfy the voltage stability criteria.

The power flow study results indicate the following:

A- Pre-connection scenarios:

1- 2016 WP

- Category A (N-0)
  - No voltage violations or transmission thermal violations were observed.
- Category B (Single Element Outage (N-1))
  - The contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse. This violation is known to the AESO and is managed using real time operational practices.
  - A thermal violation was observed on the 138 kV transmission line 7L130 (Kitscoty 705S to Vermilion 710S) following the N-1 contingency of the 138 kV transmission line 749L (Metiskow 648S to Edgerton 899S). 749L contingency leaves 7L130 to radially feed the area load which causes thermal violation on this line.. This violation is known to the AESO and is managed using real time operational practices.

2- 2017 SP

- Category A(N-0)
  - No voltage violations or transmission thermal violations were observed.
- Category B (Single Element Outage (N-1))
  - The contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse. This violation is known to the AESO and is managed using real time operational practices.

B- Post-connection scenarios:

3- 2016 WP

- Category A(N-0)
  - No voltage violations or transmission thermal violations were observed.
- Category B (Single Element Outage (N-1))
  - Similar to the pre-connection scenario, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow

648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse in 2016WP Post-connection as well.

- Thermal overloading was observed on the 138 kV transmission line 7L130 (Kitscoty 705S to Vermilion 750S) under the N-1 contingency of the 138 kV transmission line 749L (Metiskow 648S to Edgerton 899S). The 749L contingency leaves 7L130 to radially feed the area load which causes thermal violation on this line. This violation is known to the AESO and is managed using real time operational practices.

4- 2017 SP

- Category A(N-0)
  - No voltage violations or transmission thermal violations were observed
- Category B (Single Element Outage (N-1))
  - Similar to the pre-connection scenario, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse in 2017 SP Post-connection. This violation is known to the AESO and is managed using real time operational practices.

Conclusions and Recommendation

The connection assessment performed for upgrade of Hughenden 213S indicates that the proposed connection will not adversely impact the performance of the AIES. It is recommended to connect the Project through Alternative 2.

Contents

Attachments

Figures

Tables

1. Introduction

This Customer Connection Engineering Study Report presents the results of the study conducted to analyze the impact of the Project on the AIES.

1.1. Project

1.1.1. Project Overview

FortisAlberta has submitted System Access Service Request (SASR) to the AESO requesting a 2.8MW DTS increase at the existing Hughenden 213S substation. The Hughenden 213S substation is located in Provost area (AESO Planning area 37) at 04-03-41-07-W4M.

1.1.2. Load Component

- Existing DTS at Hughenden 213S substation: 16.1 MW.
- Power factor: 0.9 lagging
- Type of load: Residential, industrial, and commercial loads
- Requested DTS increase: 2.8MW
- FortisAlberta does not anticipate further upgrades at the Hughenden 213S substation for the next 10 years.

1.1.3. Generation Component

There is no generation component related to this project.

1.2. Study Scope

1.2.1. Study Objectives

The objectives of the study were the following:

- To assess the performance of the system following the connection of the Project to the AIES
- To identify any pre- and post- connection system constraints and recommend mitigation measures to facilitate the Project connection, if required.

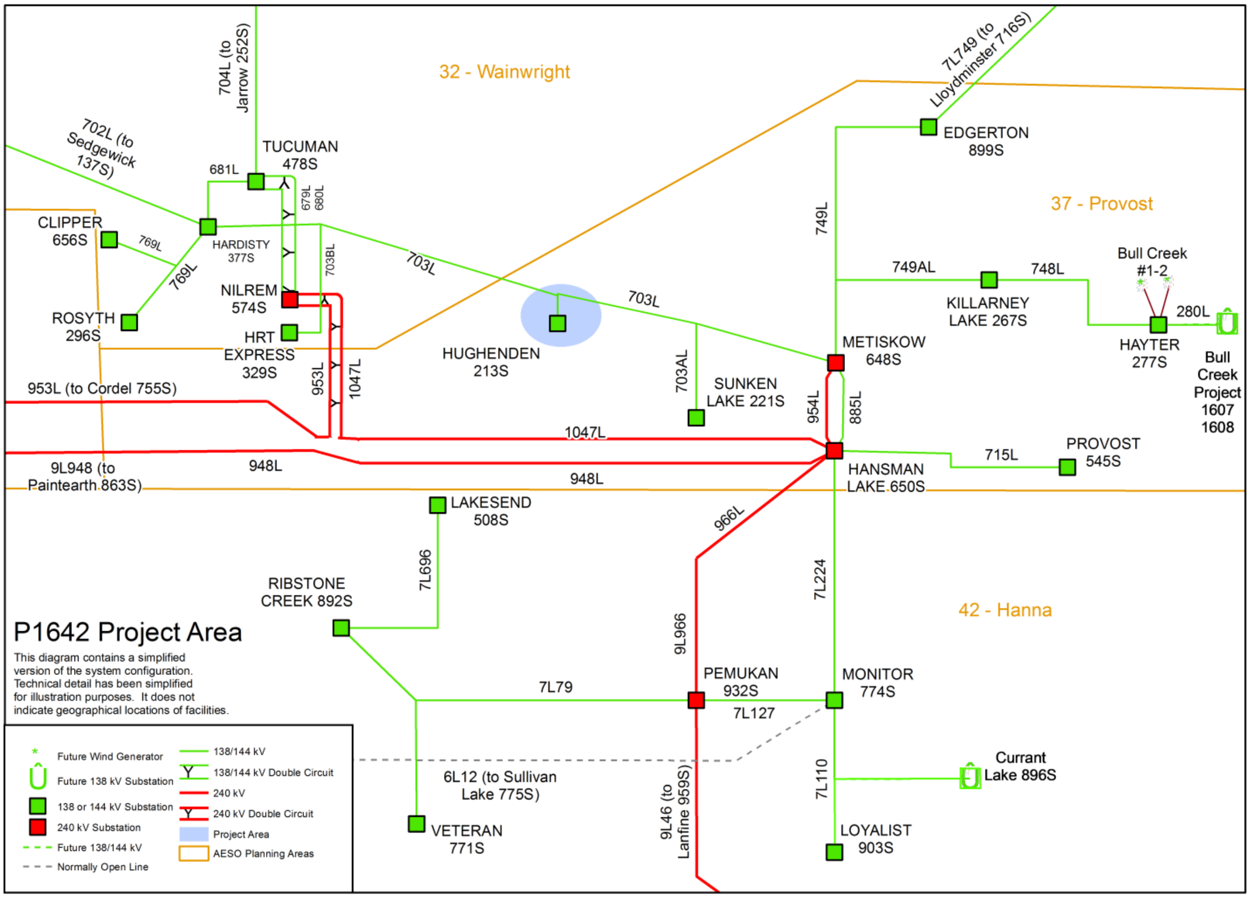
1.2.2. Study Area

1.2.2.1. Study Area Description

The Provost area is located in the Central East sub-region of Alberta and consists primarily of 138 kV and 240 kV transmission systems. The primary source of supply in the area is the coal-fired plant at Battle River. The pre-connection area transmission system in 2016 is shown in Figure 1.

In this study, the Study Area consists of Wainwright (AESO Planning Area 32), Alliance (AESO Planning Area 36), Lloydminster (AESO Planning Area 13), Hanna (AESO Planning Area 42), and Provost (AESO Planning Area 37).

Figure 1: Pre-connection Area Transmission System in 2016



1.2.2.2. Existing Constraints

The existing constraints in the Central East sub-region are managed in accordance with Section 302.1 of the ISO rules, Real Time Transmission Constraint Management (TCM Rule).

1.2.3. Studies Performed

2016/2017 winter peak (2016 WP) and 2017 summer peak (2017 SP) scenarios were used to assess the impact of the Project for near term assessment. In addition, 2025 winter peak (2025 WP) scenario was used to evaluate the long-term short circuit level impact following the proposed developments.

Power flow, voltage stability, and short-circuit studies were performed for pre- and post-connection on the selected scenarios under N-0 (Category A) and N-1 (Category B) contingencies. Table 3-1 summarizes the study scenarios used for the connection studies.

1.2.4. Report Overview

The Executive Summary provides a high-level summary of the report and its conclusions. Section 1 provides an introduction of the Connection Project. Section 2 describes the Reliability Criteria, system data, and other study assumptions used in this study. Section 3 presents the study methodology used in this study. Section 4 discusses the pre-connection system assessment. Section 5 presents the connection alternative identified. Section 6 provides a technical analysis of the post-connection system assessment for the alternative selected for further study. Section 7 provides a short-circuit analysis for the pre- and post-connection. Section 8 discusses the connection project dependencies. Section 9 presents the summary and recommendations of this study.

2. Criteria, System Data, and Study Assumptions

2.1. Criteria, Standards, and Requirements

2.1.1. AESO Transmission Reliability Criteria

The Transmission Planning (TPL) Standards, which are included in the Alberta Reliability Standards, and the AESO's *Transmission Planning Criteria – Basis and Assumptions* (Reliability Criteria)[2] 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 should follow the 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 2.1-1.

[2] Filed under a separate cover.

Table 2.1-1: Post Contingency Voltage Deviation Guidelines

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

2.1.2. AESO Information Document (ID) and Authoritative Documents (ADs)

ISO Rules Section 304.4, *Maintaining Network Voltage*, and information document ID #2010-007RS, General Operating Practice – Voltage Control, were applied to establish pre-contingency voltage profile in the study area and its vicinity.

2.1.3. Voltage Stability Criteria

Voltage Stability Analysis was performed using PV analysis method to establish Voltage Stability margin.

The applicable voltage stability criteria are stated in AESO Transmission Planning Criteria – Basis and Assumptions and they were applied for Category A and Category B contingencies.

2.2. Load and Generation Assumptions

2.2.1. Load Assumptions

Table 2-2 presents the AESO's 2014 Long-term Outlook (2014 LTO) corporate forecast for the Central Region at the time of Central Region peak. The load at central region is maintained as per the table below for both pre- and post- connection.

Table 2-2: 2014LTO Region Forecast Load

2014LTO at Peak		Forecast (MW)	
Description	Season	2016	2017
Central Region	Summer	1542.6	1602.8
	Winter	1779.5	1847.1
AIL w/o Losses	Summer	10833.6	11440.4
	Winter	12154.2	12796.1

2.2.2. Generation and Inter-Tie Assumptions

The local generators in the Study Area were manually updated based on Table 2-3. The Battle River plant unit #5 was taken off-line to simulate N-G (Category A) and N-G-1 (Category B) events.

Table 2-3: Local Generators in the Study Scenarios

Substation Name	Generator Id	Pmax (MW)	2016 WP (MW)	2017SP (MW)
Battler River 757S	3	162.6	149.0	149.0
Battle River 757S	4	166.3	155.0	155.0
Battle River 757S	5*	407.0	OFF	OFF
Total	-	735.9	304	304

* Battle River 5 was chosen for N-G criteria.

The import through the BC intertie has minimal impact on this study and therefore intertie assumptions were consistent with that in the AESO base cases. The intertie to SK is considered at zero. The most stressed, no-wind scenario was assumed. All wind generators in the study area were switched off in the studies.

2.2.3. HVDC Assumptions

The Western Alberta Transmission HVDC Line (WATL) and the Eastern Alberta Transmission HVDC Line (EATL) were dispatched to minimize total system loss in all study scenarios.

2.3. System Projects

The status of the transmission system project CETD in the study scenarios is based on the projected facility in-service date shown Table 2-4. All these components, except those that are canceled, were modeled in the study cases.

Table 2-4: Summary of System Project CETD in the Study Cases

Project	Subproject	Subproject Name	In-Service Date
811	1	Bourque 970S (Partial Stage 1)	Complete
811	1	Bourque 970S (Partial Stage 2)	Complete
811	2	Cold Lake Area Bonnyville 700S and 7L146	Complete
811	3	St. Paul Area Upgrades - Watt Lake	Complete
811	4	St. Paul Upgrades St. Paul 707S, 7L139/7L70	August-2016

811	5	Vermillion 710S Substation Upgrade	Complete
811	6	Heisler Area Upgrades	Complete
811	7	EN-7 - Kitscoty 705S and lines 7L14/7L130	Complete
811	9	7L701 Line Clearance Mitigation	Complete
811	10	7L157 Bourque 970S to Mahihkan 837S	Complete
811	11	7L574 Bourque 970S to Wolf Lake 822S	Complete
811	12	Bourque 970S to Leming Lake 715S	Complete
811	13	7L160 Bourque 970S to Mahihkan 837S	Complete
811	14	EN-14 - St. Paul Area Upgrades - 7LA92	Complete
811	16	EN-16 7L24 Termination at Bonnyville 700S	Complete
811	20	EN-20 7L587 Marguerite Lake 826S to Wolf Lake 822S	Complete
811	22	7L14 Line Clearance Mitigation	Canceled
811	23	7L53/7L117 Line Clearance Mitigation	Canceled
811	24	EN-24 - St. Paul Area Upgrades - Whitby Lake 819S	Complete
811	25	EN-25 - Bonnyville 700S Transformer addition	Oct-2016
811	26	EN-26 Kitscoty 6L06 Decommission	Complete

The developments identified in the 2015 AESO Long Term Transmission Plan (2015 LTP) were not modeled in the studies.

2.4. Customer Connection Projects

Table 2-5 lists the customer connection projects that passed AESO Gate 2 and were modeled in all the study scenarios.

Table 2-5: Summary of relevant facility assumptions for connection studies

Proj No	Project Name	Planning Area	Gen MW	Load MW	Type	Planned ISD
851	TransCanada Keystone KXL Pump station #2-Eyre	37-Provost	0.0	25.0	Load	July, 2016
863	TransCanada Keystone KXL Pump station #3-Current	42-Hanna	0.0	25.0	Load	July, 2016
864	TransCanada Keystone KXL Pump	42-Hanna	0.0	25.0	Load	July, 2016

	station #4-Armitage					
1495	Fortis Hayter 277S 42MVA Transformer and 25KV Breaker Add.	37-Provost	0.0	0.0	Equipment Change	Sep, 2015
1516	Enbridge Sunken Lake 221S Transformer Change	37-Provost	0.0	14	Load	Jan, 2017

2.5. Facility Ratings and Shunt Elements

Table 2-6 to Table 2-8 provide the ratings of the existing and future key transmission facilities in the Study Area.

Table 2-6: Summary of Key Transmission Line Ratings

Nominal Voltage (kV)	Transmission Line	From Substation	To Substation/TAP point	Summer Rate (MVA)	Winter Rate (MVA)	Emergency Summer Rate(MVA)	Emergency Winter Rate (MVA)
138	703BL	HRT Express 329S	Express TAP	123	150	135	165
138	703L	Hardisty 377S	Express TAP	83	83	83	83
138	885L	Metiskow 648S	Hansman Lake 650S	287	287	287	287
138	749L	Metiskow 648S	Killarney TAP	121	148	133	164
138	703L	Metiskow 648S	703AL TAP	122	143	134	162
138	703L	Hughenden 213S	Express TAP	121	145	133	160
138	703L	Hughenden 213S	703AL TAP	122	147	134	162
138	715L	Provost 545S	Hansman Lake 650S	98	132	108	145
240	954L	Metiskow 648S	Hansman Lake 650S	333	333	499	499
138	703AL	Sunken Lake 221S	703AL TAP	85	90	94	99
138	748L	Killarney Lake 267S	Hayter 277S	119	146	131	161
138	749AL	Killarney Lake 267S	Edgerton 899S	121	148	133	163
138	7L224	Hansman Lake 650S	Monitor 774S	109.25	138.99	123.63	142.79
240	9L948/948L	Hansman Lake 650S	PaintEarth 863S	332	332	432	432
240	1047L	Hansman Lake 650S	Nilrem 574S	499	499	680.0	748

240	9L966	Hansman Lake 650S	Pemukan 932S	332	332	432	432
138	749L	Killarnery TAP	Metiskow 648S	121	149	133	164
138	749L/7L749	Edgerton 899S	Briker TAP	88	127	97	140
138	7L749	Briker TAP	Lloydminster 716S	109.25	138.99	123.6	142.79
138	7L42	Lloydminster 716S	Hill 751S	94.88	94.88	94.88	94.88
138	7L14	Hill 751S	Kitscoty 705S	71.88	86.25	71.88	86.25
138	7L130	Kitscoty 705S	Vermilion 710S	71.88	86.25	71.88	86.25

Table 2-7: Summary of Key Transformer Ratings

Substation Name and Number	Nominal Ratio	Id	Rate (MVA)
Metiskow 648S	240/138	T3	200
Metiskow 648S	138/25	T1	25
Hughenden 213S	138/25	T1	25
Provost 545S	138/25	T1	42
Sunken Lake 221S	138/4.16	T2	25
Sunken Lake 221S	138/4.16	T1	25
Killarney Lake 267S	138/25	T1	42
Hayter 277S	138/25	T1	47
Edgerton 899S	138/25	3T	25
Hansman Lake 650S	240/138	T1	200
Hansman Lake 650S	240/34.5	T2	200

Table 2-8: Summary of Shunt Elements in the Study Area

Substation Name and Number	Nominal Bus Voltage (kV)	Capacitors			Reactors		
		Number of Switched Shunt Blocks	Total at Nominal Voltage (MVAr)	Status in Study	Number of Switched Shunt Blocks	Total at Nominal Voltage (MVAr)	Status in Study
Sunken Lake 221S	138	18.1	18.1	Off/On/TBD	-	-	-
Hill 751S	138	1x18.12 + 1x22.96	41.08	TBD	-	-	-
Killarney Lake	138	1x9.1+2x10.9	30.9	TBD	-	-	-

267S							
Lloydminster 716S	138	1x18.12	18.12	TBD	-	-	-
Metiskow 648S	138	1x27	27	TBD	-	-	-
Nilrem 574S	138	2x24.8	49.6	TBD	-	-	-
Tucuman 478S	138	1x27.17	27.17	TBD	-	-	-
Vermilion 710S	138	1x22.96	22.96	TBD	-	-	-
Lanfine 959S	34.5	1x200	200	SVC	1x-100	-100	-
Monitor 774S	144	2	50 (20 & 30)	On/off/TBD	-	-	-
Stettler 769S	144	1	15	On/off/TBD	-	-	-
Lanfine 959S	144	2	60(2x30)	On/off/TBD	-	-	-
Sullivan Lake 775S	72	1	10	On/off/TBD	-	-	-
Three Hills 770S	25	1	4.95	On/off/TBD	-	-	-
	144	1	20	On/off/TBD	-	-	-
Michichi Creek 802S	144	1	10	On/off/TBD	-	-	-
Youngstown 772S	25	1	2.4	On/off/TBD	-	-	-
	72	1	5	On/off/TBD	-	-	-
Hanna 763S	25	1	4.95	On/off/TBD	-	-	-
Pemukan 932S	138	2	55(2 x 27.55)	On/off/TBD	-	-	-
Hansman Lake 650S	34.5	1	200	SCV	1	-100	-

2.6. Voltage Profile Assumptions

The AESO ID #2010-007RS was used to establish normal system (i.e., pre-contingency) voltage profiles in the study area and its vicinity prior to commencing analysis. The voltage profile for the key nodes in the study area under normal operation condition is listed in Table 2-9.

For steady state analysis, the operating range of the SVC at Hansman Lake 650S was maintained in the range of -20 MVAr to +20 MVAr. The voltage set-point is 253 kV. The operating range of the SVC at Lanfine 959S was maintained in the range of -20 MVar to +20 MVAr. The voltage set-point is 258 kV.

Table 2-9: Summary of Voltage at Key Nodes in the Study Area

Substation	Nominal Voltage (kV)	Minimum Operating Limit (kV)	Desired Range (kV)	Maximum Operating Limit (kV)	2016 WP (kV)	2017 SP (kV)
Battle River 757S	144	144	146-150	155	149.6	149.7
Cordel 755S	240	253	254-257	260	254.8	254.2
Nevis 766S	240	246	248-255	265	253.3	249.8
	144	145	149-152	155	149.2	150.2
Oyen 767S	144	140	143-146	155	143.7	144.1
Killarney Lake 267S	138	138	138-144	145	142.4	143.2
Metiskow 648S	240	250	250-260	260	254.4	254.4
Hardisty 377S	138	140	140-144	145	142.9	142.2
Lloydminster 716S	144	137	142-149	151	146.6	144.7

3. Study Methodology

3.1. Study Objectives

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

- To assess the impact of the Project connection to the AIES.
- To identify Pre- and Post-connection system constraints and recommend mitigation measures to facilitate the connection, if required.

3.2. Study Scenarios

Table 3-1 summarizes the study scenarios used for the connection studies.

Table 3-1: Study Scenarios

Scenario #	Scenario	Power Flow	Voltage Stability	Short Circuit*	Generation level
01	2017SP Pre Project	X	-	-	Low generation, Critical generation off
02	2016WP Pre Project	X	-	x	Low generation, Critical generation off*
03	2017SP Post Project	X	-	-	Low generation, Critical generation off
04	2016WP Post Project	X	X	X	Low generation, Critical generation off*
05	2025WP post project	-	-	X	All generation in service

Note: * All generators in the Study Area will be switched on for short-circuit analysis.

3.3. Connection Studies Carried Out

Load flow, voltage stability, and short circuit studies were performed for different study scenarios according to Table 3-1.

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

- Power flow (Category A and Category B, from the Reliability Criteria)
- Short-Circuit analysis

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

- Power flow (Category A and Category B from the Reliability Criteria)
- Voltage stability (Category A and Category B from the Reliability Criteria)
- Short-Circuit analysis

3.4. Power Flow Analysis

Pre- and post-connection power flow studies were performed to assess system performance for Category A and Category B conditions. The system in the Study Area and its vicinity was monitored to identify any thermal violation, voltage range violation, and voltage deviation as per Reliability Criteria stated in Section 2.1.1.

The transmission elements that were monitored to record any violations of the Reliability Criteria include all the components at 69 kV and above in the Study Area and its vicinity.

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

3.4.1. Contingencies Studied

The study includes all Category B contingencies (69 kV and above) within the Study Area and the tie lines from the Study Area to surrounding areas. A list of selected special Category B contingencies was provided in Table 3-2. These transformer contingencies will lead to a bus outage due to the bus configuration.

Table 3-2: List of Special Category B Contingencies

Contingencies	Elements Loss	From Substation	To Substation
163S T5	869L	Amoco Empress 163S	Sandy Point 204S
	760L	Empress 394S	Oyen 767S
	871L	Amoco Empress 163S	Sand Hills 341S
	669L	Amoco Empress 163s	Cypress 562S

Contingencies	Elements Loss	From Substation	To Substation
	163S Transformer T5	-	-
394S T1	760L	Empress 394S	Amoco Empress 163S
	668L	Empress 394S	Cypress 562S
	394S Transformer T1	-	-
767S T1	767S Transformer T1	-	-
	7L132	Oyen 767S	Lanfine 959S
	7L760	Oyen 767S	760L TAP
	6L09	Oyen 767S	6L21 TAP
648S T1	648S Transformer T1	-	-
	703L	Metiskow 648S	703AL TAP
	749L	Metiskow 648S	749AL TAP
	885L	Metiskow 648S	Hansman Lake 650S
863S T2	863S Transformer T2	-	-
	9L27	Cordel 755S	Paintearth Creek 863S
	9L948/948L	Paintearth Creek	Hansman Lake 650S
766S T1	766S Transformer T1	-	-
	9L20	Nevis 766S	Cordel 755S
	9L912/912L	Nevis 766S	Red Deer 63S
899S T3	899S Transformer T3	-	-
	749L	Edgerton 899S	7LB749 TAP
	749L	Edgerton 899S	749AL TAP
751S T1	751S Transformer T1	-	-
	7L42	Hill 751S	Lloydminster 716S
	7L14	Hill 751S	Kitscoty 705S
	6L06	Hill 751S	Kitscoty 705S
	751S Cap bank	-	
	751S Transformer T2	-	
709S T1	709S Transformer T1	-	-
	7L65	Vegreville 709S	Vermilion 710S
	7L177	Vegreville 709S	North Holden 395S
	7L92	Vegreville 709S	7LA92 TAP
526S T1	526S Transformer T1	-	-
	7L129	Buffalo Creek 526S	7LA129 TAP
	7L50	Buffalo Creek 526S	704L TAP
	562S Cap bank		
252S T2	252S Transformer T2	-	-
	704L	Jarrow 252S	704AL TAP
	704L	Jarrow 252S	7L50 TAP

Contingencies	Elements Loss	From Substation	To Substation
	408L	Jarrow 252S	Wainwright 51S
	61L	Jarrow 252S	Cochin 968S
478S T1	478S Transformer T1	-	-
	704L	Tucuman 478S	704AL TAP
	681L	Tucuman 478S	Hardisty 377S
	679L	Tucuman 478S	Nilrem 574S
	680L	Tucuman 478S	Nilrem 574S
	478S Cap bank	-	-
377ST1	377S Transformer T1	-	-
	377S Cap Bank	-	-
	681L	Hardisty 377S	Tucuman 478S
	702L	Hardisty 377S	702L TAP
	769L	Hardisty 377S	Rosyth 296S
	703L	Hardisty 377S	703BL TAP
574ST2	574S Transformer T2	-	-
	574S Transformer T3	-	-
51ST3	51S Transformer T3	-	-
	704L	Wainwright 51S	704L TAP

3.5. Voltage Stability (PV) Analysis

The objective of the voltage stability analysis was to determine the ability of a power system to maintain sufficient reactive power margins at all the buses in the system under normal (Category A) and abnormal (Category B) steady-state operating conditions. In the study, PV (Power-Voltage) analysis was performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology, as described in detail in the AESO Transmission Reliability Criteria.

PV curves were generated for Category A condition and a selected set of critical Category B contingencies in the Study Area. The maximum operating load limits are:

- 5% below the load at the collapse point on the PV curve for Category A
- 5% below the pre-contingency load corresponding to the collapse point on the PV curve for Category B contingencies

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

3.5.1. Contingencies Studied

The study includes, Category A and Category B contingencies. Also all Category B contingencies (69 kV and above) within the Study Area and the tie lines from the Study Area to the surrounding areas are included. Only a selected set of critical contingencies were chosen for the PV result plots.

3.6. Short-Circuit Analysis

Short-circuit analysis was performed for three-phase and single-phase to ground current levels. All generators in and around the Study Area were switched on to evaluate the maximum fault current under three-phase-to-ground faults and single-line-to-ground faults. The scope of the analysis included 3-phase bolted faults and single-line to ground faults.

Short circuit analysis was performed to evaluate the three-phase and single-phase to ground current levels at selected buses in the Study Area in the pre- and post-connection systems.

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 system configuration without the Project. The steady-state performance of the pre-connection system was assessed under the 2017 SP and 2016 WP study scenarios. The power flow analyses were based on the Reliability Criteria described in Section 2.

4.1.1. Scenario #1 – 2017 SP (Pre-connection)

The contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse. This violation is an existing issue known to the AESO and is managed using real time operational practices.

No thermal or other voltage violations were observed under N-1 contingencies.

The results of the power flow analysis are summarized in Table 4-1 and shown in the power flow diagrams in Attachment A.

Table 4-1: Summary of System Performance – 2017 SP Pre-connection

Contingency	Voltage Performance		
	Substation / Bus	Voltage Violation	Deviation (%)
N-0: Normal Operation Condition	-	None	Acceptable
N-1: Metiskow 648S 138/25kV Transformer T1[3]	Voltage Collapse		

4.1.2. Scenario #2 – 2016 WP (Pre-connection)

As in the 2017 SP, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse. This violation is an existing issue known to the AESO and is managed using real time operational practices.

A thermal loading violation was observed on the 138 kV transmission line 7L130 (Kitscoty 705S to Vermilion 710S) under N-1 contingency of the 138 kV transmission line 749L (Metiskow 648S to Edgerton 899S). The 749L contingency leaves 7L130 to radially feed the area load which causes thermal violation on this line. This violation is known to the AESO and is managed using real time operational practices.

No other voltage violations were observed under N-1 contingencies.

[3] While the loss of the 138/25 kV transformer at Metiskow 648S substation is considered a Category B (N-G-1) event, this event would in fact result in the simultaneous loss of the 138 kV bus and the 138 kV transmission lines 749L, 703L, and 885L, due to the Metiskow 138 kV bus configuration.

The results of the power flow analysis are summarized in Table 4-2, Table 4-3 and shown in the power flow diagrams in Attachment A.

Table 4-2: Summary of System Performance – Thermal Loading, 2016 WP Pre-connection

Contingency	Thermal Loading				
	Element	Rating (MVA)	Emergency rating (MVA)	Flow (MVA)	%I
N-0: Normal Operation Condition	none	-			-
N-1: 749L (Metiskow 648S to Edgerton 899S)	7L130 (Kitscoty 705S to Vermilion 710S)	86.2	86.2	92.5	102.5

Table 4-3: Summary of Voltage Violation and Deviation– 2016 WP Pre-connection

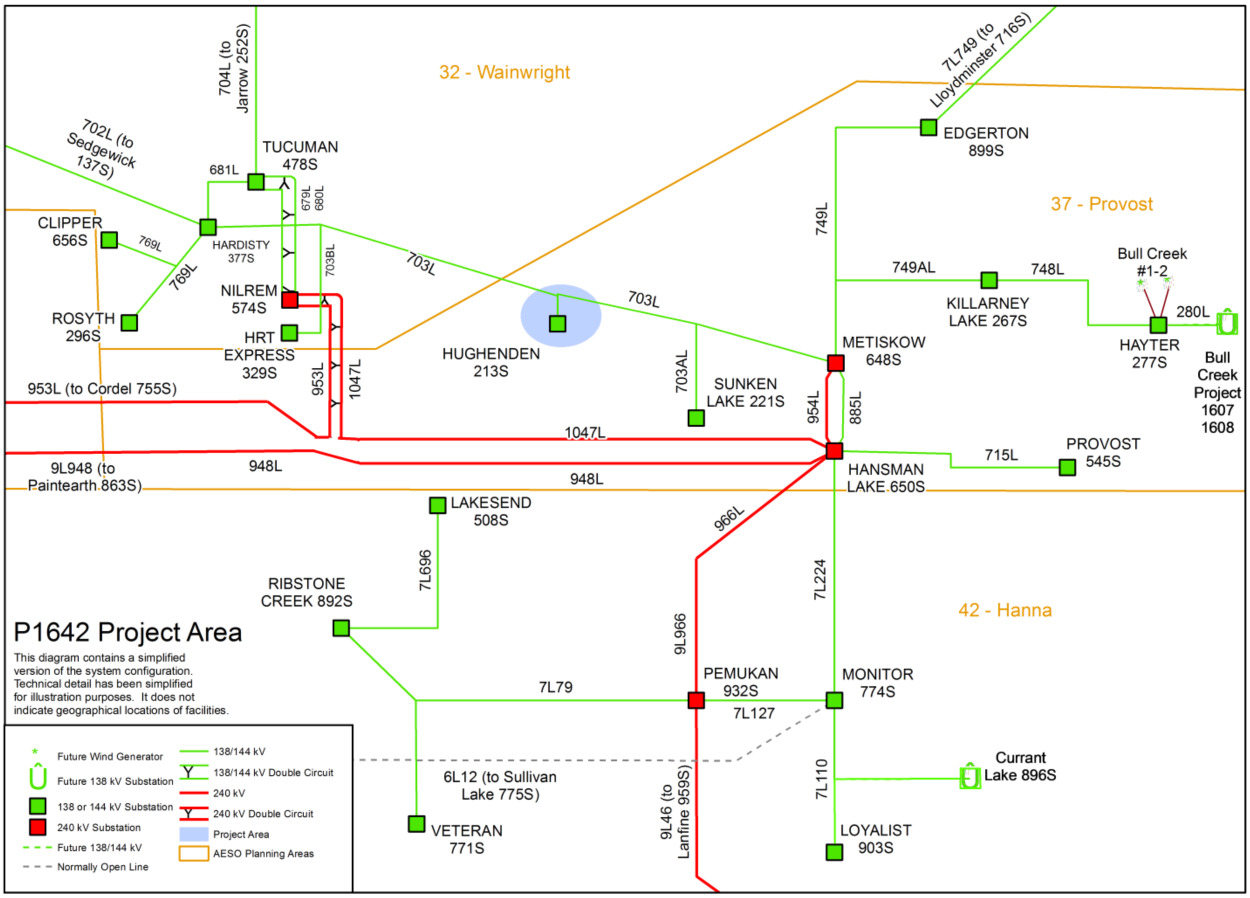
Contingency	Voltage Performance		
	Substation / Bus	Voltage Violations	Deviation (%)
N-0: Normal Operation Condition	-	None	Acceptable
N-1: Metiskow 648S 138/25kV Transformer T1	Voltage Collapse		

5. Connection Alternatives

5.1. Overview

Currently, Hughenden 213S has one 138/24.5 kV 15/20/25 MVA Transformer and a 24.9 kV, 25 MVA Voltage Regulator. The substation is connected to the 138 kV transmission line 703L via T-tap configuration. Figure 2 shows the existing system configuration.

Figure 2: Provost Area (Existing)



As per FortisAlberta's Need for Development[4] document dated, load shifting was examined to address the need on 2.8 MW DTS increase. Load shifting would require extensive distribution facilities and would not resolve the reliability concerns for the distribution system supplied by the Hughenden 213S substation. Therefore, two transmission alternatives were examined to address the load increase at Hughenden 213S substation.

[4] Filed under a separate cover.

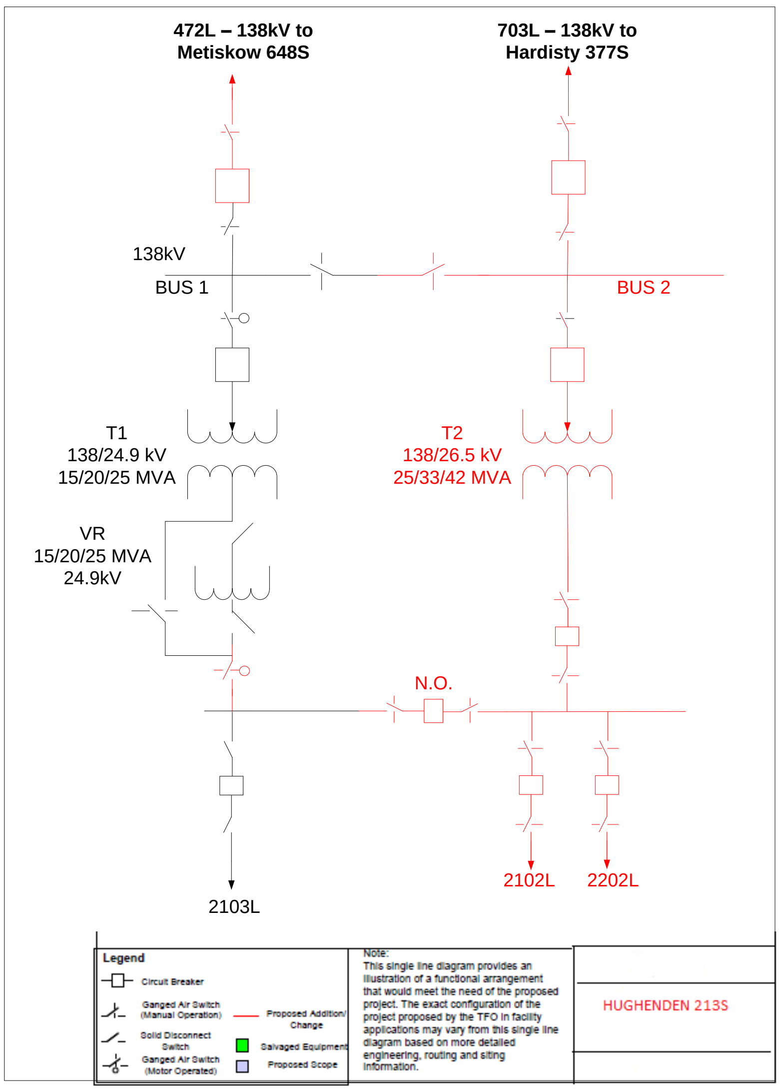
Alternative 1: Addition of one (1) new 138/25kV 25/33/42MVA LTC transformer at Hughenden 213S with existing T-tap connection to 138 kV transmission line 703L

This alternative consisted of the addition of a 138/25 kV 25/33/42 MVA LTC Transformer to Hughenden 213S and maintain the T-tap connection to the 138 kV transmission line 703L.

Alternative 2: Addition of one (1) new 138/25kV 25/33/42MVA LTC transformer at Hughenden 213S with In-and-Out connection to 138 kV transmission line 703L

Alternative 2 consisted of the addition of a 138/25 kV 25/33/42 MVA LTC Transformer to Hughenden 213S and transform the T-tap connection to the 138 kV transmission line 703L to an in-and-out configuration. Figure 3 shows the configuration of this alternative.

Figure 3: Alternative 2 – 138/25 kV 25/33/42 MVA LTC Transformer addition with In-and-out connection to 138 kV transmissions line 703L



5.2. Connection Alternatives Evaluated

5.2.1. Connection Alternatives Selected for Further Studies

Alternative 2 was studied as it meets FortisAlberta's reliability criteria[5].

5.2.2. Connection Alternatives Not Selected for Further Studies

Alternative 1 doesn't meet FortisAlberta's reliability criteria. Therefore, it was eliminated from further studies.

[5] [5] As per Section 4.2.1 of Fortis's Distribution Deficiency Report dated October 7, 2015

6. Technical Analysis of the Connection Alternatives

Power flow and voltage stability analysis were performed for Alternative 2. The results of power flow and voltage stability analyses showed the following:

- Similar thermal criteria violations were observed in pre-connection scenarios and post-connection scenarios as shown in Table 6-1 to Table 6-3. These criteria violations will be managed using real time operational practices
- Similar to the pre-connection, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse;
- Voltage stability margins in the Study Area would continue to meet the Reliability Criteria following the Project connection.

6.1. Alternative 2 – Addition of one (1) new 138/25kV 25/33/42MVA LTC transformer with In-and-out connection to 138 kV transmission line 703L

The power flow and voltage stability analyses results indicate that Alternative 2 would not adversely impact the performance of AIES. The detailed results are presented in the following subsections.

6.1.1. Power Flow Analysis

The power flow analyses were based on the Criteria, System Data, and Study Assumptions as described in Section 2.

6.1.1.1. Scenario #3 – 2017 SP (Post-connection)

As with the pre-connection, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse in 2017 SP Post-connection.

No thermal or voltage violations were observed under Category B contingencies. The results are summarized in Table 6-1 and shown in the power flow diagrams in Attachment B.

Table 6-1: Summary of System Performance – 2017 SP Post-connection

Contingency	Voltage Performance		
	Substation / Bus	Voltage Violation	Deviation (%)
N-0: Normal Operation Condition	-	None	Acceptable
N-1: Metiskow 648S 138/25kV Transformer T1	Voltage Collapse		

6.1.1.2. Scenario #4 – 2016 WP (Post-connection)

A comparative result of the power flow analysis for 2016 WP Post-connection and 2016WP Pre-connection are summarized in Table 6-2, Table 6-3 and shown in the power flow diagrams in Attachment B.

Similar to the pre-connection, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse in 2016 WP Post-connection as well.

Similar to the pre-connection, thermal overloading was observed on 138 kV transmission line 7L130 (Kitscoty 705S to Vermilion 750S) under N-1 contingency of 138 kV transmission line 749L (Metiskow 648S to Edgerton 899S). 749L contingency leaves 7L130 to radially feed the area load which causes thermal violation on this line.This violation is managed using real time operational practices.

The results of the power flow analysis are summarized in Table 6-2 and shown in the power flow diagrams in Attachment B.

Table 6-2: Summary of System Performance – Thermal Loading 2016 WP Post-connection

Contingency	Overloaded Branch	Line Rating (MVA)		2016 WP Pre-Connection	2016 WP Post-Connection	%I Loading Difference
		Normal	Emergency	Loading (%I / MVA)	Loading (%I / MVA)	Post-Pre
N-1: 749L (Metiskow 648S to Edgerton 899S)	7L130 (Kitscoty 705S to Vermilion 710S)	86.25	86.25	102.5% / 92.5	102.4% / 92.6	-0.1

Table 6-3: Summary of Voltage Violation and Deviation 2016 WP Post-connection

Contingency	Voltage Performance		
	Substation / Bus	Voltage Violations	Deviation (%)
N-0: Normal Operation Condition	-	Acceptable	Acceptable
N-1: Metiskow 648S 138/25kV Transformer T1	Voltage Collapse		

6.1.2. Voltage Stability Analysis (Alternative 2)

Voltage stability analysis was performed using Scenario #4 (2016 WP) to investigate the system active power margin after the proposed development under Category A and Category B contingency conditions.

The sink sub-system includes the loads in the Study Area. The source system was formed by the generation in the Wabamun area (AESO Planning area 40) and Fort McMurray area (AESO Planning area 25). The total load of 624.7 MW at the Study Area was considered as the starting point of the PV analysis.

6.1.2.1. Scenario #4 – 2016 WP (Post-connection)

The voltage stability margins under Category A and the four most severe Category B contingencies are listed in Table 6-4. The voltages at Hughenden 213S, Metiskow 648S, Hardisty 377S, Sunken Lake 221S, and Rosyth 296S substations were monitored during the studies. The PV plots are presented in Attachment C.

Table 6-4: Summary of Voltage Stability Analysis

System Condition	Incremental Area Load Increase before Collapse Point (MW)	Available Voltage Stability Margin (%)	Meets Voltage Stability Criteria?
N-0: Normal Operation Condition	320.0	51.2	Yes
N-1: 7L130 (Vermillion 710S to Kitscoty 705S)	80	12.8	Yes
N-1: 749L (Edgerton 899S to Metiskow 648S)	110	17.6	Yes
N-1: 7L14 (Vermilion 710S to Hill 751S)	120	19.2	Yes
N-1: 899S T3 (Edgerton 899S Transformer fault)	160	25.6	Yes

6.2. Conclusions

Power flow and voltage stability analyses were performed on the connection Alternative 2 to evaluate the impacts of the Project connection on the AIES. There is one thermal loading violation and one voltage collapse observed for both pre-connection and post-connection of the Project. The identified constraints are addressed using real time operational practice.

The study results confirm that the proposed connection alternatives 2 will not adversely impact the performance of AIES.

7. Short-Circuit Analysis

Short circuit studies were performed to determine the changes of fault levels at the Hughenden 213S, and surrounding substations, including Metiskow 648S, Hardisty 377S, Sunken Lake 221S, Rosyth 296S and HRT Express 329S substations, prior to and post connection of the Project.

Short circuit studies shows that the Project will not adversely change the fault levels within the AIES.

7.1. Pre-Connection

Short circuit studies were performed using the 2016 WP scenario to determine the fault levels at Hughenden 213S and its surrounding substations prior to the Project. The single phase and three phase fault current results are presented in Table 7-1.

Table 7-1: Summary of Short-Circuit Current Levels – Pre-Connection (2016 WP)

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (pu)	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (pu)
Hughenden 213S	138	142.2	4.87	0.033521+ j0.082332	3.89	0.039766+ j0.151048
Hughenden 213S T1 Low side 25kV	25	25.8	4.10	0.100400+ j0.573785	3.89	0.060655+ j0.674804
Metiskow 648S	138	142.6	7.26	0.017979+ j0.056960	8.05	0.004016+ j0.042194
	240	254.4	5.32	0.013792+ j0.046066	6.49	0.002545+ j0.021800
Hardisty 377S	138	143.2	6.92	0.021872+ j0.059069	7.98	0.005944+ j0.037545
Sunken Lake221S	138	142.5	7.15	0.018312+ j0.057809	7.79	0.005129+ j0.045632
Rosyth 296S	138	143.1	6.64	0.022990+ j0.061404	7.37	0.008324+ j0.045555
HRT Express 329S	138	143.2	6.62	0.023130+ j0.061576	7.23	0.009092+ j0.048540

7.2. Post-Connection

Short circuit studies were performed using the 2016 WP scenario and 2025 WP scenario to determine the fault levels at the Hughenden 213S substation and its surrounding substations after the Project.

7.2.1. Alternative 2: Addition of one (1) new 138/25kV 25/33/42MVA LTC transformer with In-and-out connection to the 138 kV transmission line 703L

The single phase and three phase fault current results following Alternative 2 developments are presented in Table 7-2 and Table 7-3.

Table 7-2: Summary of Short-Circuit Current Levels – Post-Connection (2016 WP)

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (pu)	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (pu)
Hughenden 213S	138	142.7	4.87	0.033757+ j0.082396	3.90	0.039798+ j0.151155
Hughenden 213S T1 low side 25kV	25	25.9	4.14	0.079565+ j0.574157	3.95	0.059478+ j0.661449
Hughenden 213S T2 Low side 25kV	25	26.0	4.99	0.068196+ j0.477628	4.60	0.065040+ j0.600933
Metiskow 648S	138	142.7	7.27	0.018012+ j0.056945	8.06	0.004016+ j0.042210
	240	254.4	5.33	0.013796+ j0.045973	6.49	0.002546+ j0.021809
Hardisty 377S	138	144.5	6.90	0.022341+ j0.059671	7.96	0.006047+ j0.037862
Sunken Lake221S	138	142.7	7.16	0.018347+ j0.057795	7.79	0.005129+ j0.045648
Rosyth 296S	138	144.4	6.62	0.023458+ j0.062007	7.36	0.008428+ j0.045872
HRT Express 329S	138	144.4	6.60	0.023589+ j0.062159	7.22	0.009193+ j0.048848

Table 7-3: Summary of Short-Circuit Current Levels – Post-Connection (2025 WP)

Substation Name and Number	Base Voltage (kV)	Pre-Fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (pu)	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (pu)
Hughenden 213S	138	142.2	5.33	0.029986+ j0.075151	4.17	0.114098+ j0.351503
Hughenden 213S T1 low side 25kV	25	25.2	4.27	0.071625+ j0.539176	4.07	0.055527+ j0.621358
Hughenden 213S T2 Low side 25kV	25	25.3	5.15	0.061094+ j0.449079	4.75	0.061057+ j0.566058
Metiskow 648S	138	143.1	8.46	0.014738+ j0.049114	9.24	0.007874+ j0.042058
Hardisty 377S	138	143.1	7.98	0.017834+ j0.051374	10.31	0.086572+ j0.186359
Sunken Lake221S	138	143.1	8.31	0.015066+ j0.049980	8.90	0.102723+ j0.352128
Rosyth 296S	138	143.0	7.61	0.018943+ j0.053712	9.31	0.005906+ j0.037397
HRT Express 329S	138	143.0	7.58	0.019117+ j0.053931	9.04	0.002545+ j0.021776

8. Project Interdependencies

There are no identified dependencies for the Project.

9. Summary and Recommendations

FortisAlberta Inc. (FortisAlberta), the market participant, has applied to the Alberta Electric System Operator (AESO) requesting a 2.8MW load increase at the existing Hughenden 213S substation. The Hughenden 213S substation is located in Provost area (AESO Planning area 37) at 04-03-41-07-W4M.

The requested in-service date (ISD) for the Project is December 1, 2016.

Two (2) connection alternatives were proposed for the Project:

- Alternative 1: Addition of one (1) new 138/25kV 25/33/42MVA LTC Transformer with the existing T-tap connection to 138 kV transmission line 703L;
- Alternative 2: Addition of one (1) new 138/25kV 25/33/42MVA LTC Transformer with in-and-out connection to 138 kV transmission line 703L.

FortisAberta confirmed that of these two alternatives, only Alternative 2 meets their reliability criteria. Thus, this report presents the results of the detailed studies for Alternative 2.

Study results show that there are one existing thermal loading above transmission line emergency rating and one voltage collapse under loss of Metiskow 648S Transformer T1. AESO has previously identified these violations through other projects and specified the solutions with the regional long term plan. Alternative 2 does not adversely impact the AIES and does not significantly alter the short circuit levels in the area. Voltage stability analysis confirms that voltage stability margins continue to satisfy the voltage stability criteria.

The power flow study results indicate the following:

A- Pre-connection scenarios:

1- 2016 WP

- Category A (N-0)
  - No voltage violations or transmission thermal violations were observed.
- Category B (Single Element Outage (N-1))
  - The contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse. This violation is known to the AESO and is managed using real time operational practices.
  - A thermal violation was observed on the 138 kV transmission line 7L130 (Kitscoty 705S to Vermilion 710S) following the N-1 contingency of the 138 kV transmission line 749L (Metiskow 648S to Edgerton 899S). 749L contingency leaves 7L130 to radially feed the area load which causes thermal violation on this line.. This violation is known to the AESO and is managed using real time operational practices.

2- 2017 SP

- Category A(N-0)
  - No voltage violations or transmission thermal violations were observed.
- Category B (Single Element Outage (N-1))
  - The contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse. This violation is known to the AESO and is managed using real time operational practices.

B- Post-connection scenarios:

3- 2016 WP

- Category A(N-0)
  - No voltage violations or transmission thermal violations were observed.
- Category B (Single Element Outage (N-1))
  - Similar to the pre-connection scenario, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse in 2016WP Post-connection as well.
  - Thermal overloading was observed on the 138 kV transmission line 7L130 (Kitscoty 705S to Vermilion 750S) under the N-1 contingency of the 138 kV transmission line 749L (Metiskow 648S to Edgerton 899S). The 749L contingency leaves 7L130 to radially feed the area load which causes thermal violation on this line. This violation is known to the AESO and is managed using real time operational practices.

4- 2017 SP

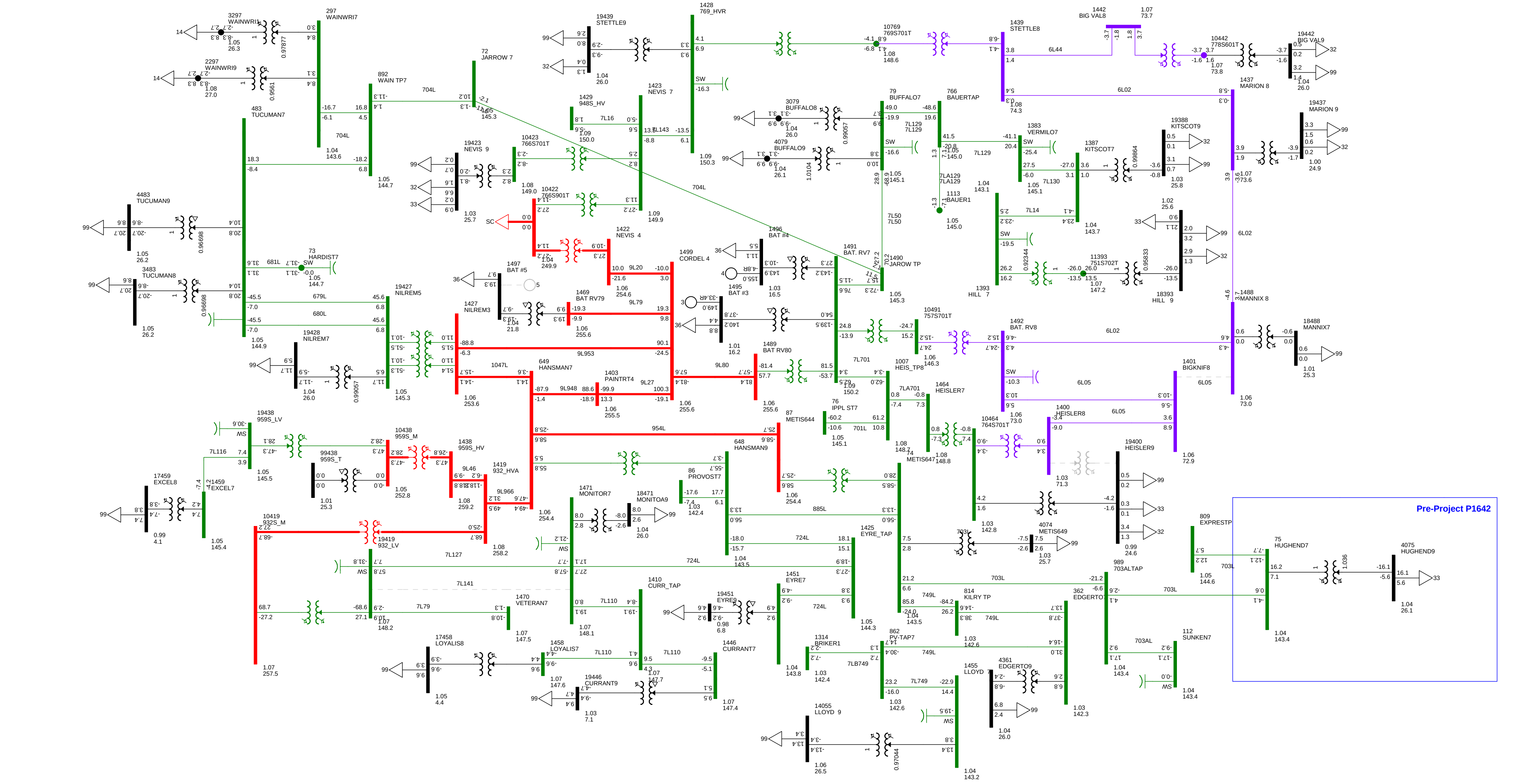
- Category A(N-0)
  - No voltage violations or transmission thermal violations were observed
- Category B (Single Element Outage (N-1))
  - Similar to the pre-connection scenario, the contingency of the Metiskow 648S 138/25kV transformer T1, which trips the Metiskow 648S 138kV bus and all three 138kV lines connected to the bus, will cause voltage collapse in 2017 SP Post-connection. This violation is known to the AESO and is managed using real time operational practices.

Recommendations

The connection assessment performed for upgrade of Hughenden 213S indicates that the proposed connection will not adversely impact the performance of the AIES. It is recommended to connect the Project through Alternative 2.

Attachment A

Pre-Connection Power Flow Analysis Results (Scenarios 1 and 2)



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

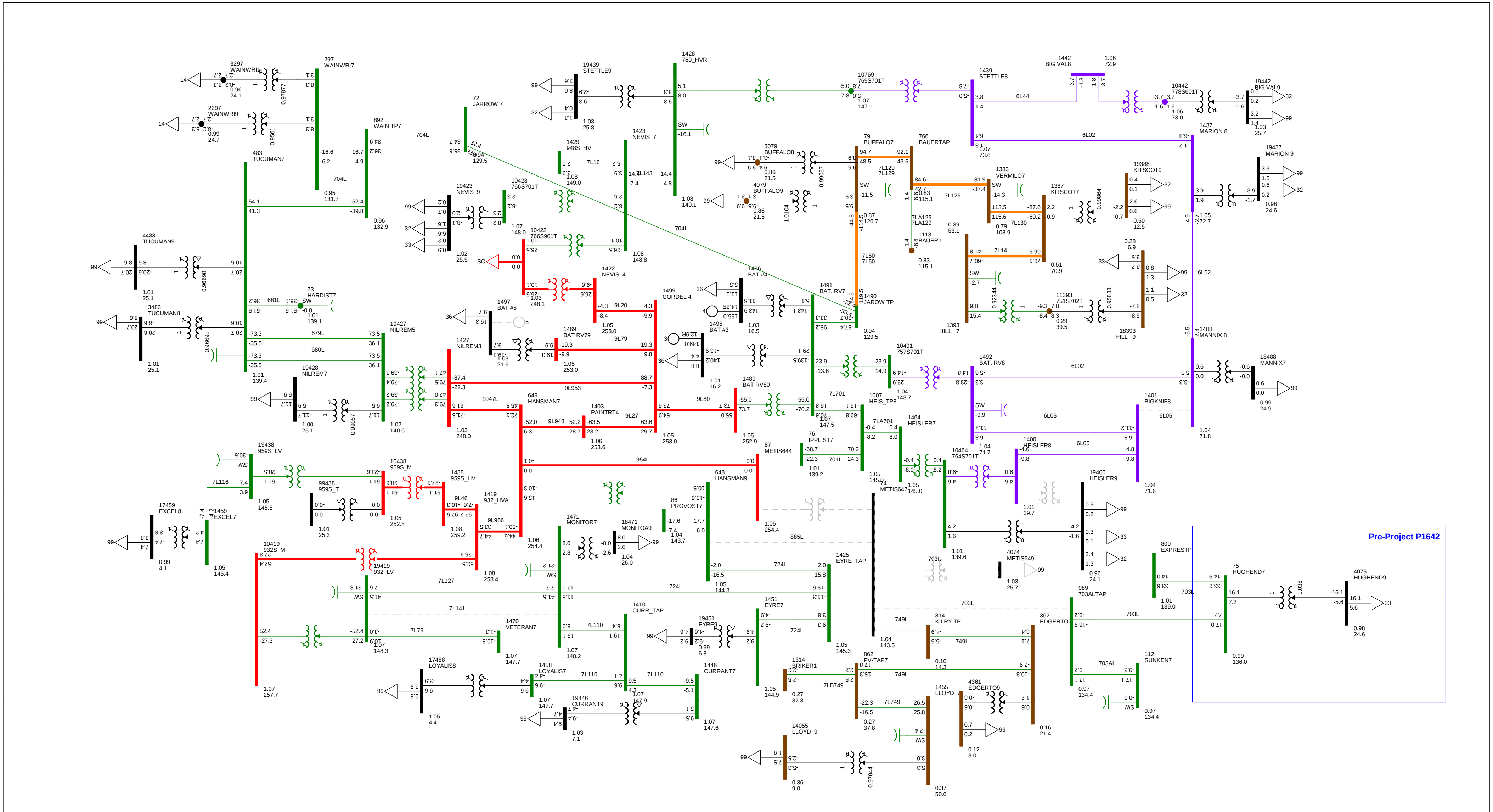
BC and MATL (Import): 53.8 MW

FIGURE A1-1-N-0: NORMAL OPERATION

2017 SUMMER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

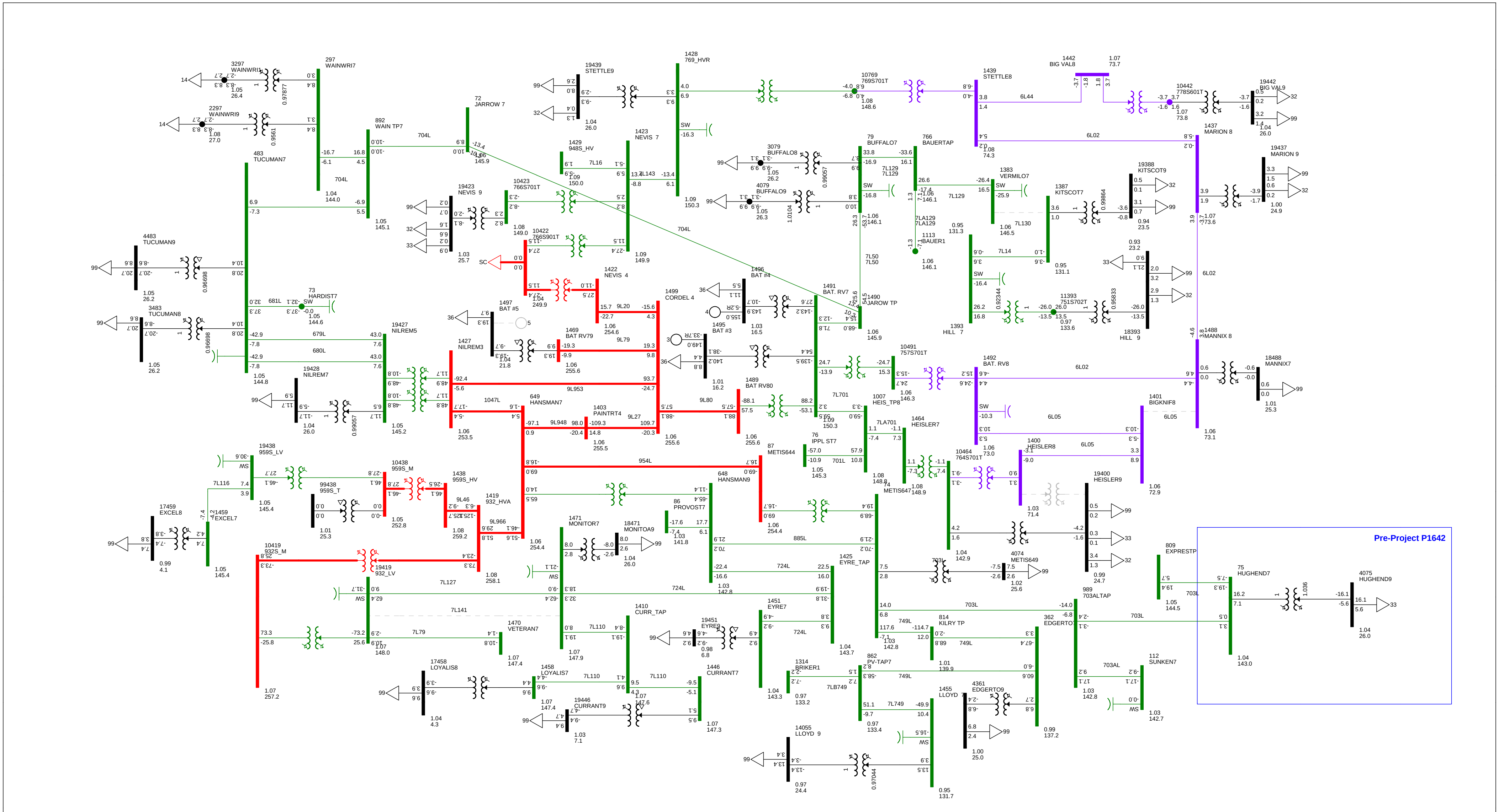
SK Tie (Import): -0.1 MW   BC and MATL (Import): 77.5 MW

FIGURE A1-2 N-1: METISKOW 648S 138/25 KV TRANSFORMER T1(BLOW UP)

2017 SUMMER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

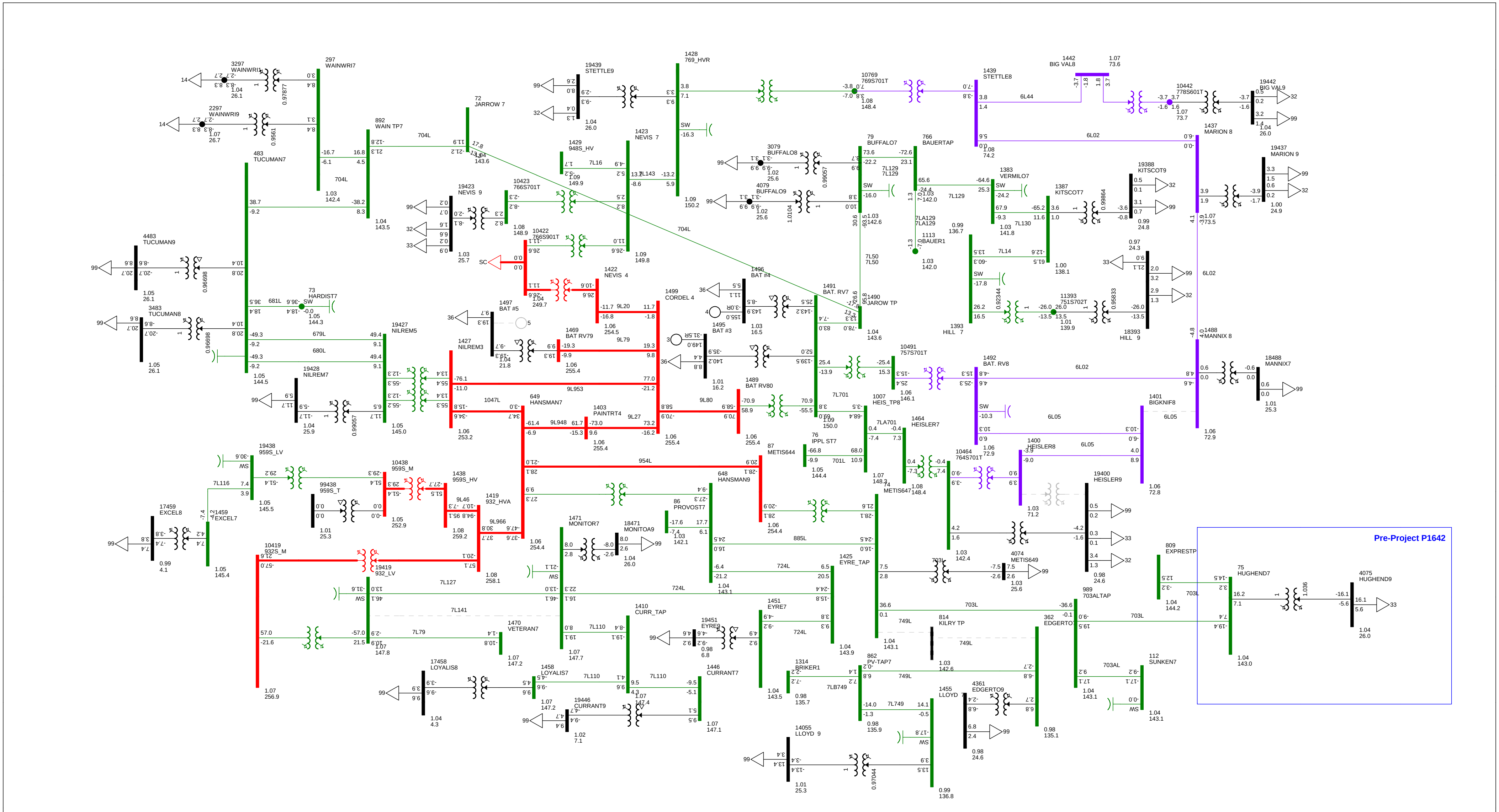
BC and MATL (Import): 56.0 MW

FIGURE A1-3 N-1: 7L130 (VERIMILION 710S TO KITSCOTY 705S)

2017 SUMMER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

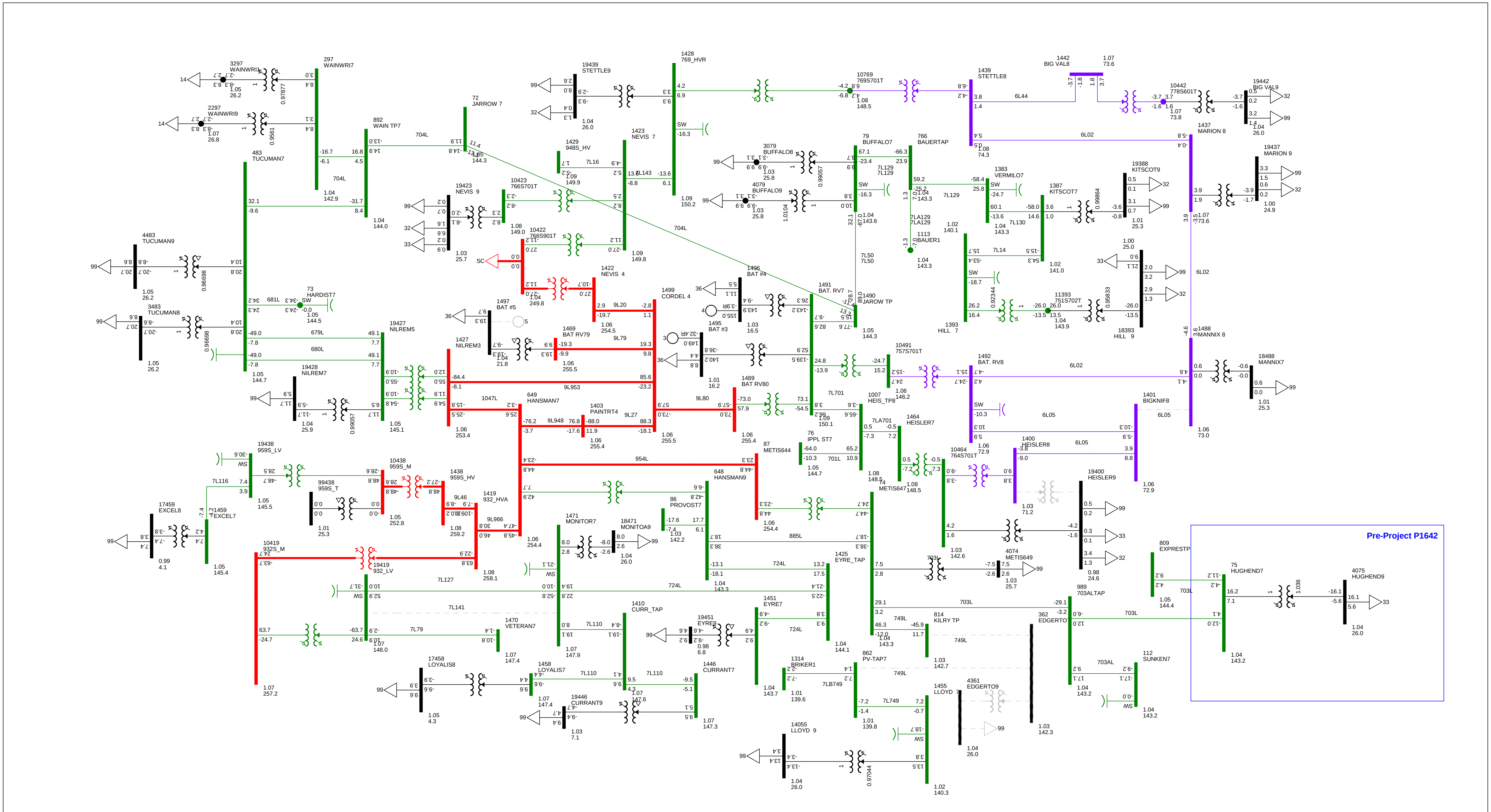
SK Tie (Import): -0.1 MW   BC and MATL (Import): 12.9 MW

FIGURE A1-4 N-1: 749L (EDGERTON 899S TO METISKOW 648S)

2017 SUMMER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

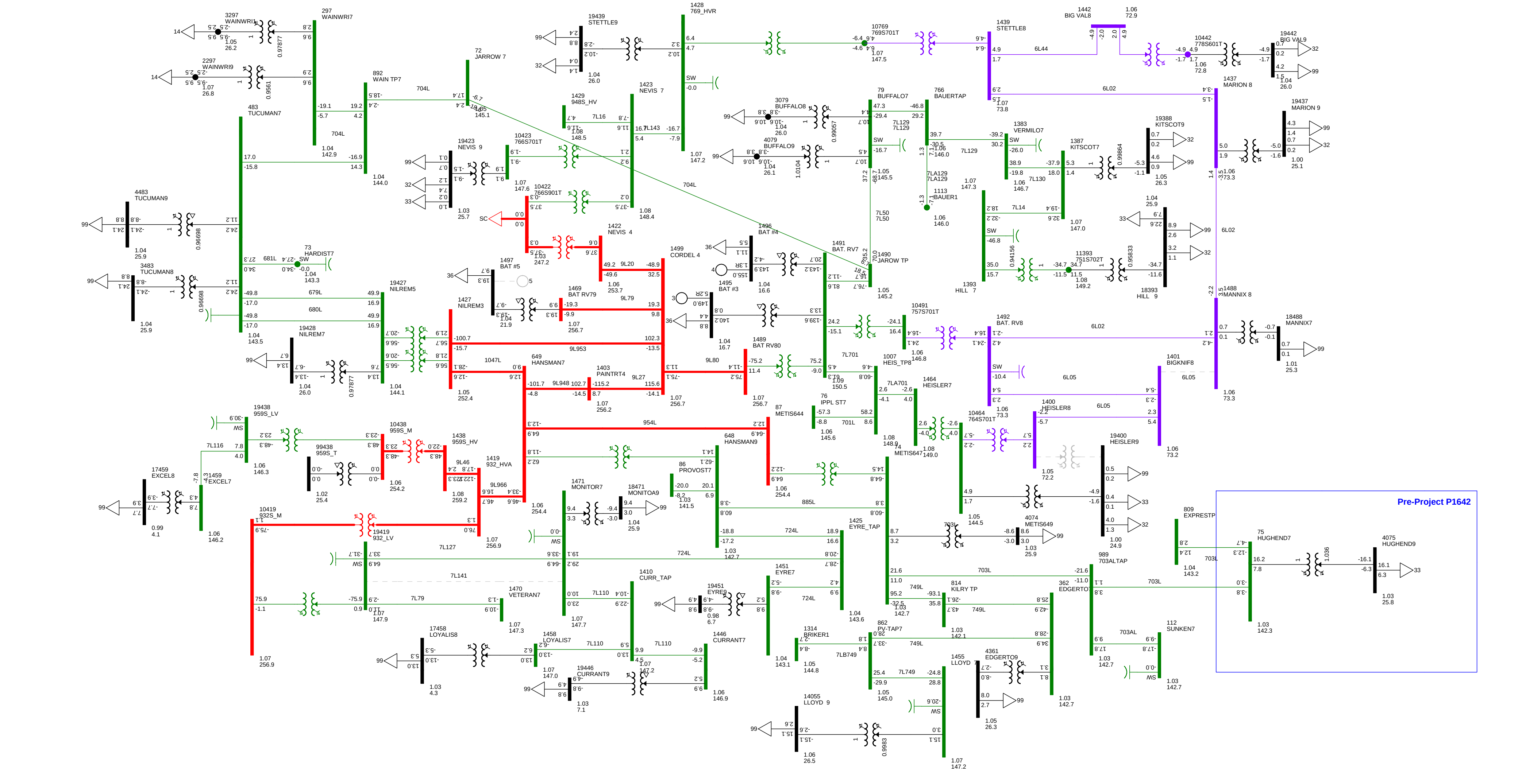
SK Tie (Import): -0.1 MW   BC and MATL (Import): 50.8 MW

FIGURE A1-5 N-1: EDGERTON 899S TRANSFORMER T3

2017 SUMMER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

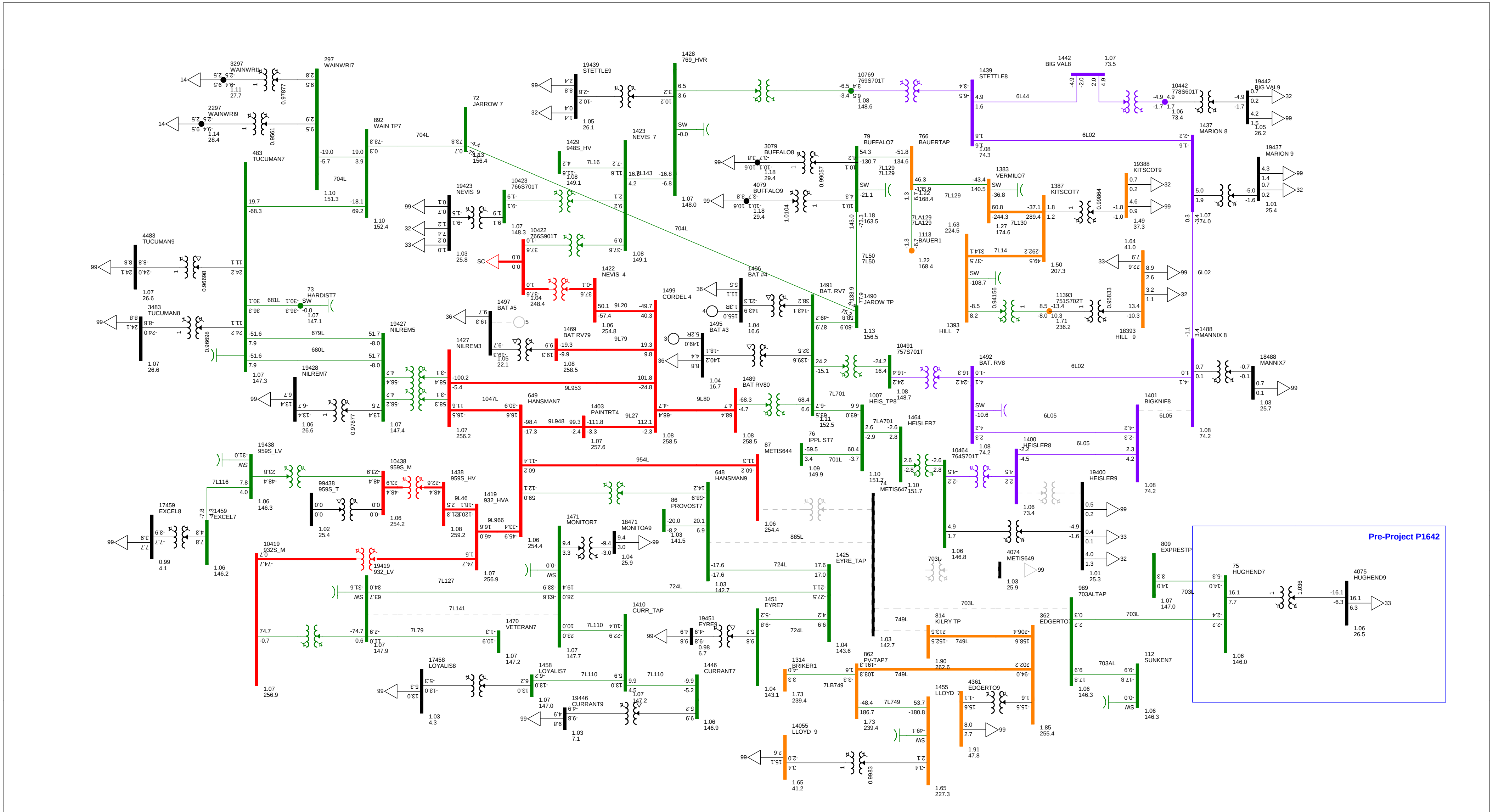
SK Tie (Import): -0.1 MW

BC and MATL (Import): 107.2 MW

FIGURE A2-1-N-0: NORMAL OPERATION

2016 WINTER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

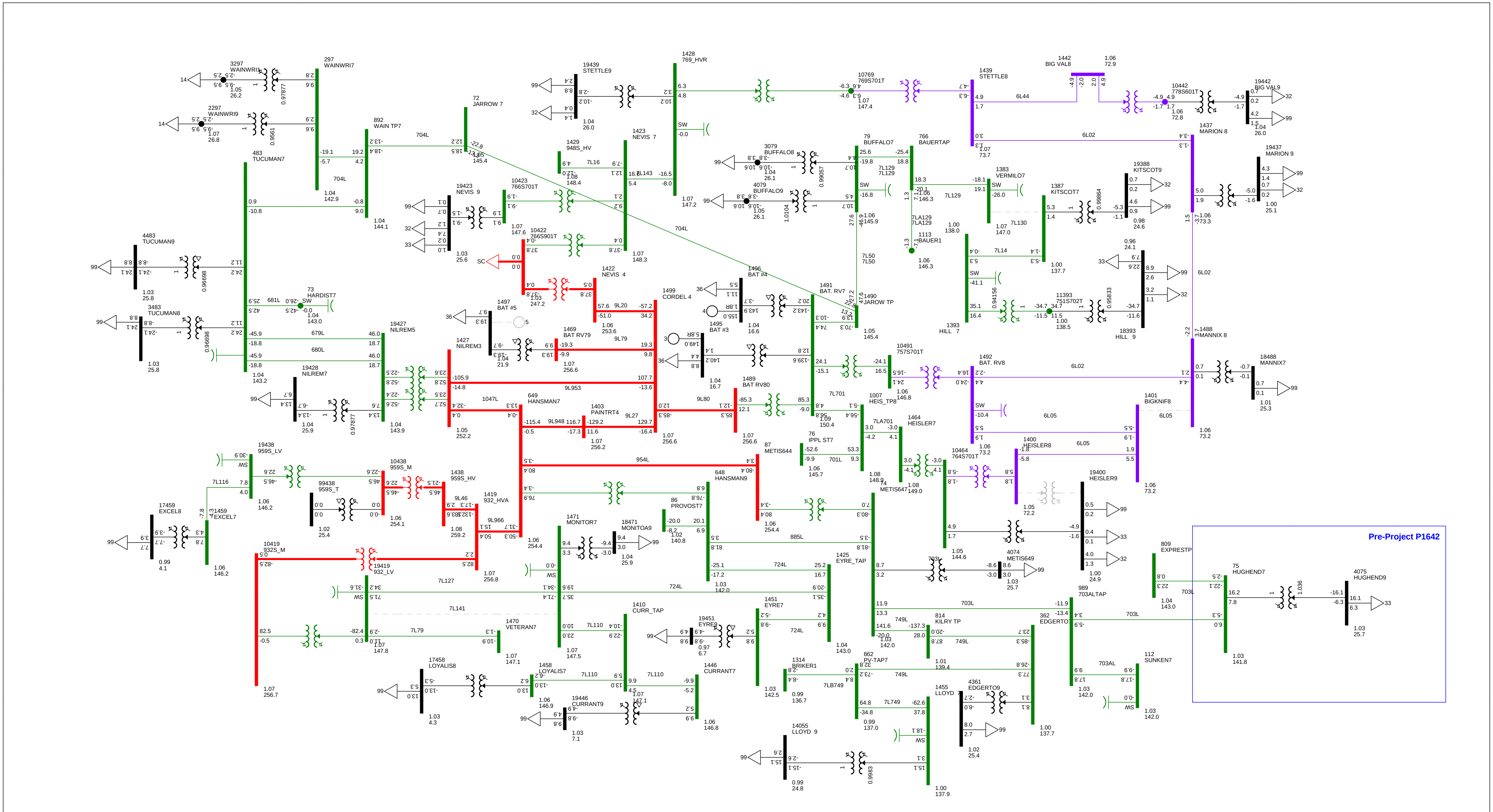
BC and MATL (Import): 107.7 MW

FIGURE A2-2 N-1: METISKOW 648S 138/25 KV TRANSFORMER T1(BLOW UP)

2016 WINTER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

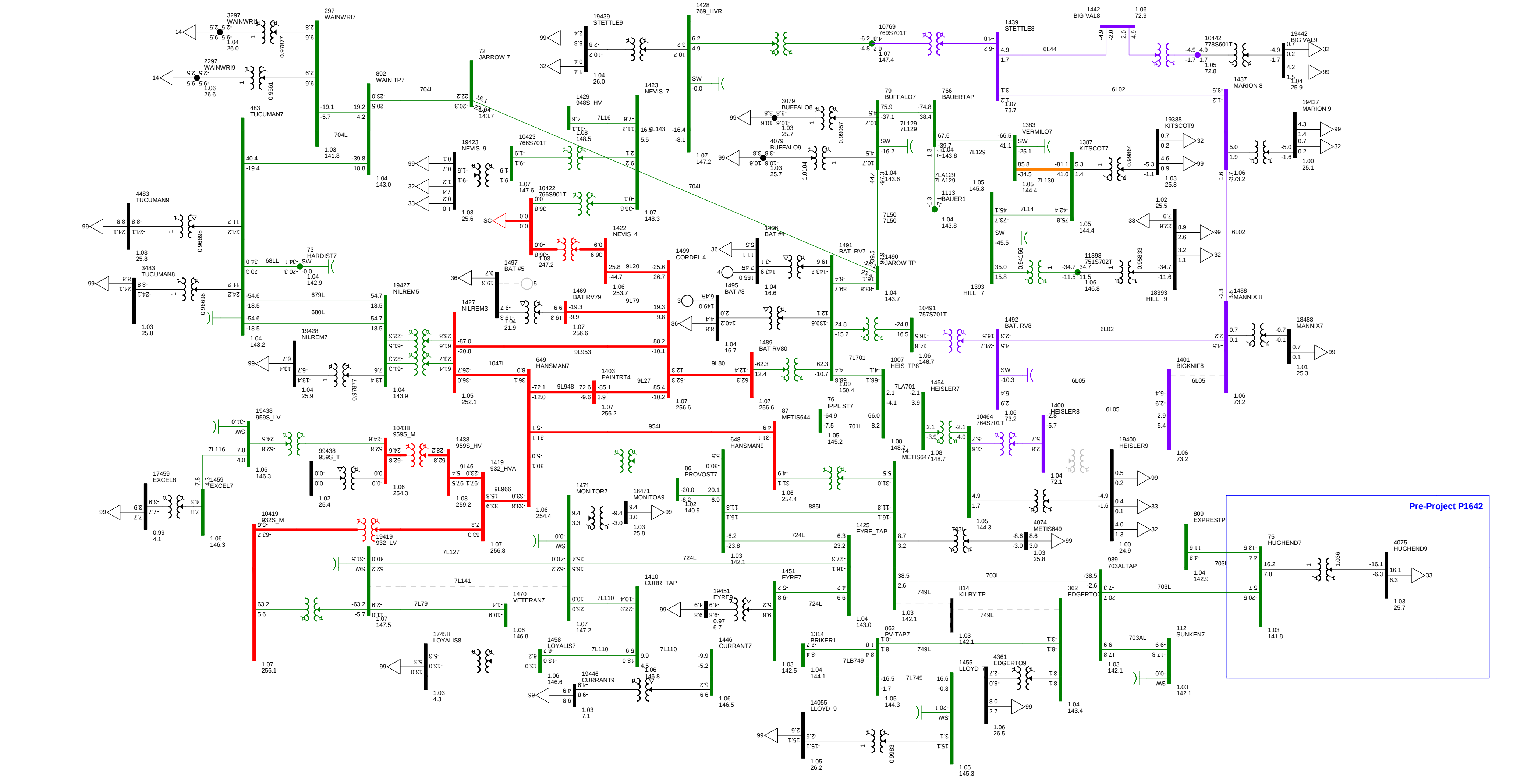
SK Tie (Import): -0.1 MW   BC and MATL (Import): 111.5 MW

FIGURE A2-3 N-1: 7L130 (VERIMILION 710S TO KITSCOTY 705S)

2016 WINTER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

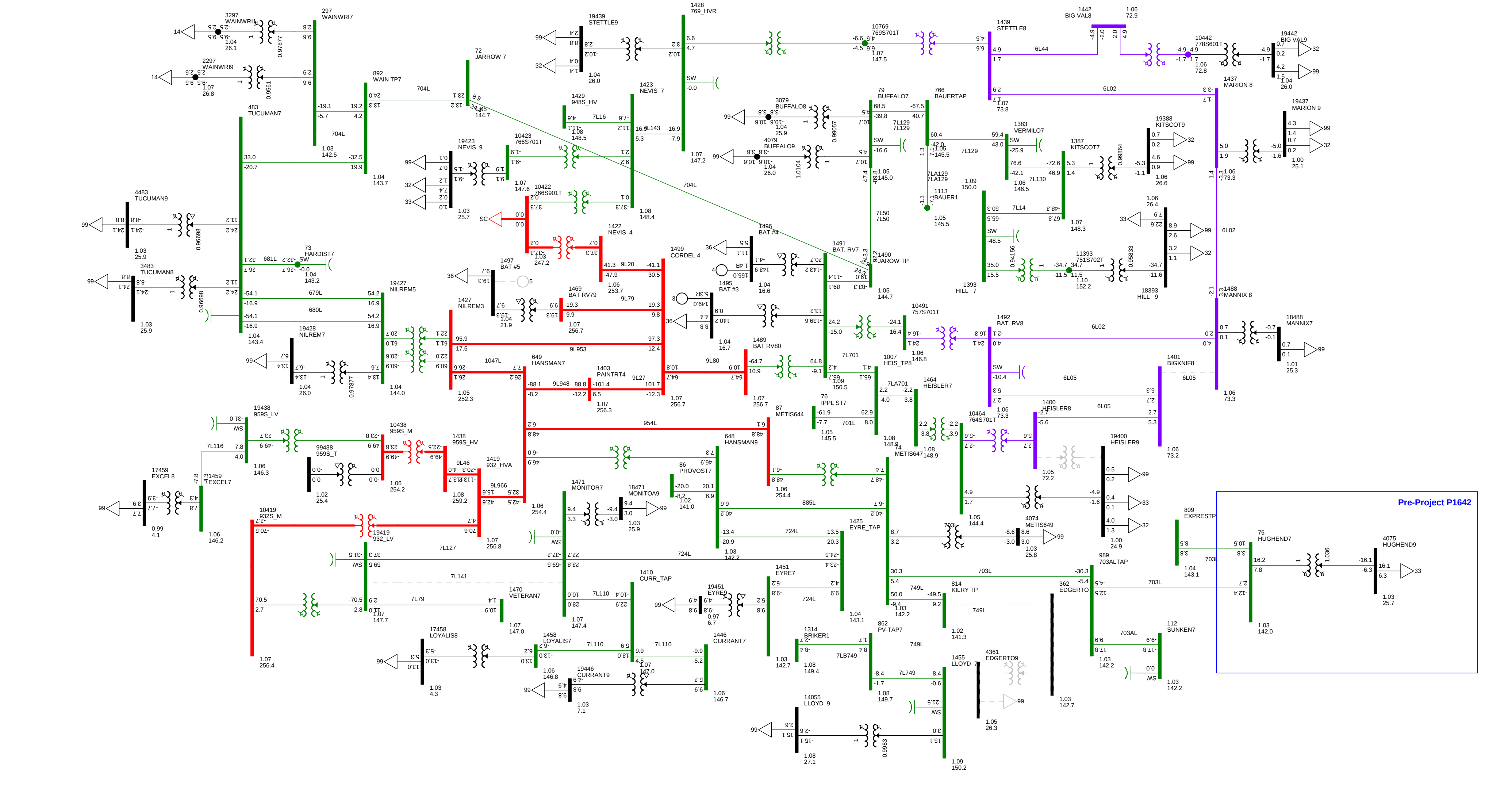
SK Tie (Import): -0.1 MW   BC and MATL (Import): 64.3 MW

FIGURE A2-4 N-1: 749L (EDGERTON 899S TO METISKOW 648S)

2016 WINTER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

BC and MATL (Import): 105.3 MW

FIGURE A2-5 N-1: EDGERTON 899S TRANSFORMER T3

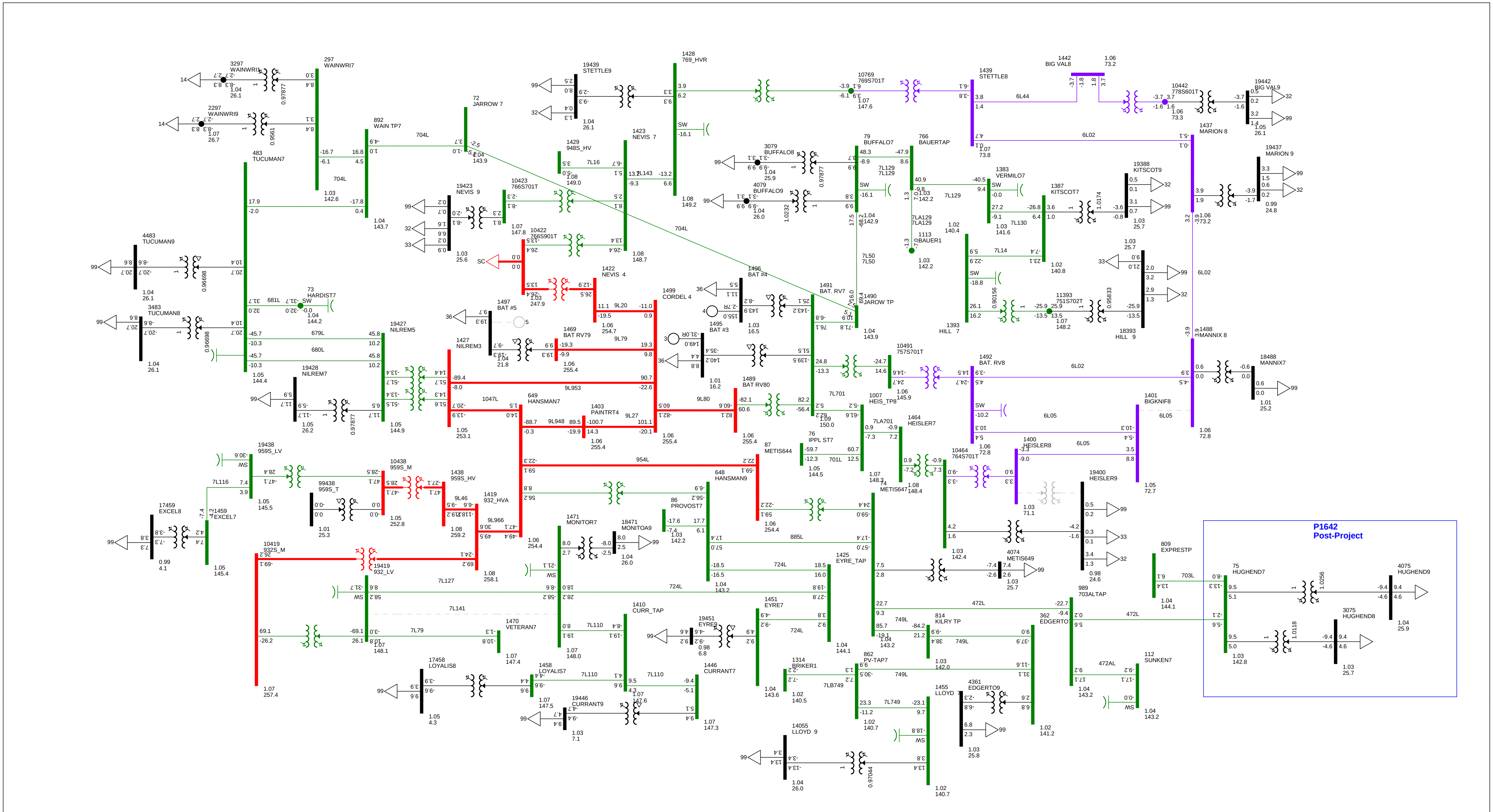
2016 WINTER PEAK (PRE-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

Attachment B

Post-Connection Power Flow Analysis Results (Scenarios 3 and 4) – Alternative 2



Fortis Hughenden Upgrade - P1642

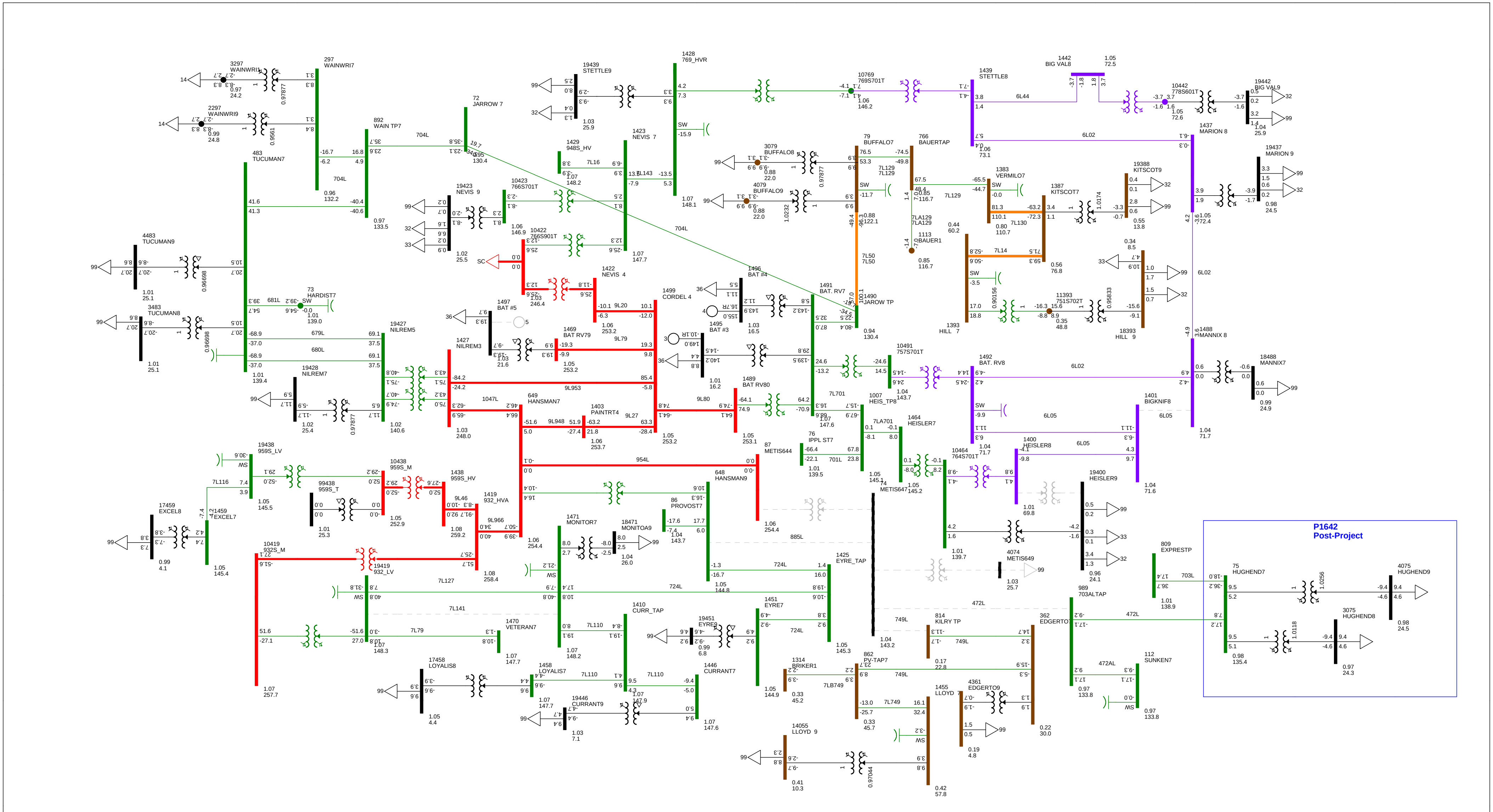
SK Tie (Import): -0.1 MW   BC and MATL (Import): 52.4 MW

FIGURE B1-1-N-0: NORMAL OPERATION

2017 SUMMER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

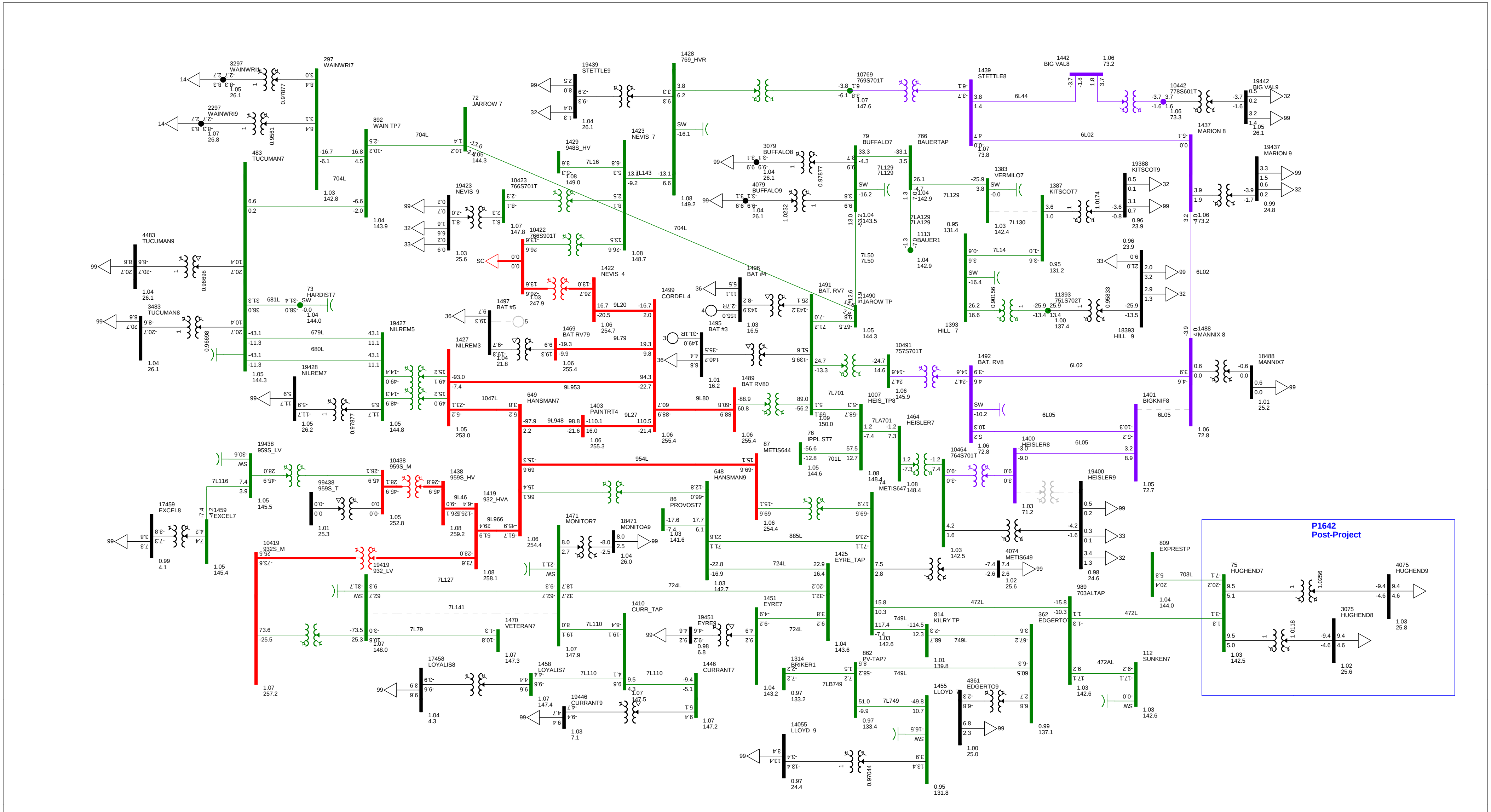
BC and MATL (Import): 35.6 MW

FIGURE B1-2 N-1: METISKOW 648S 138/25 KV TRANSFORMER T1

2017 SUMMER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

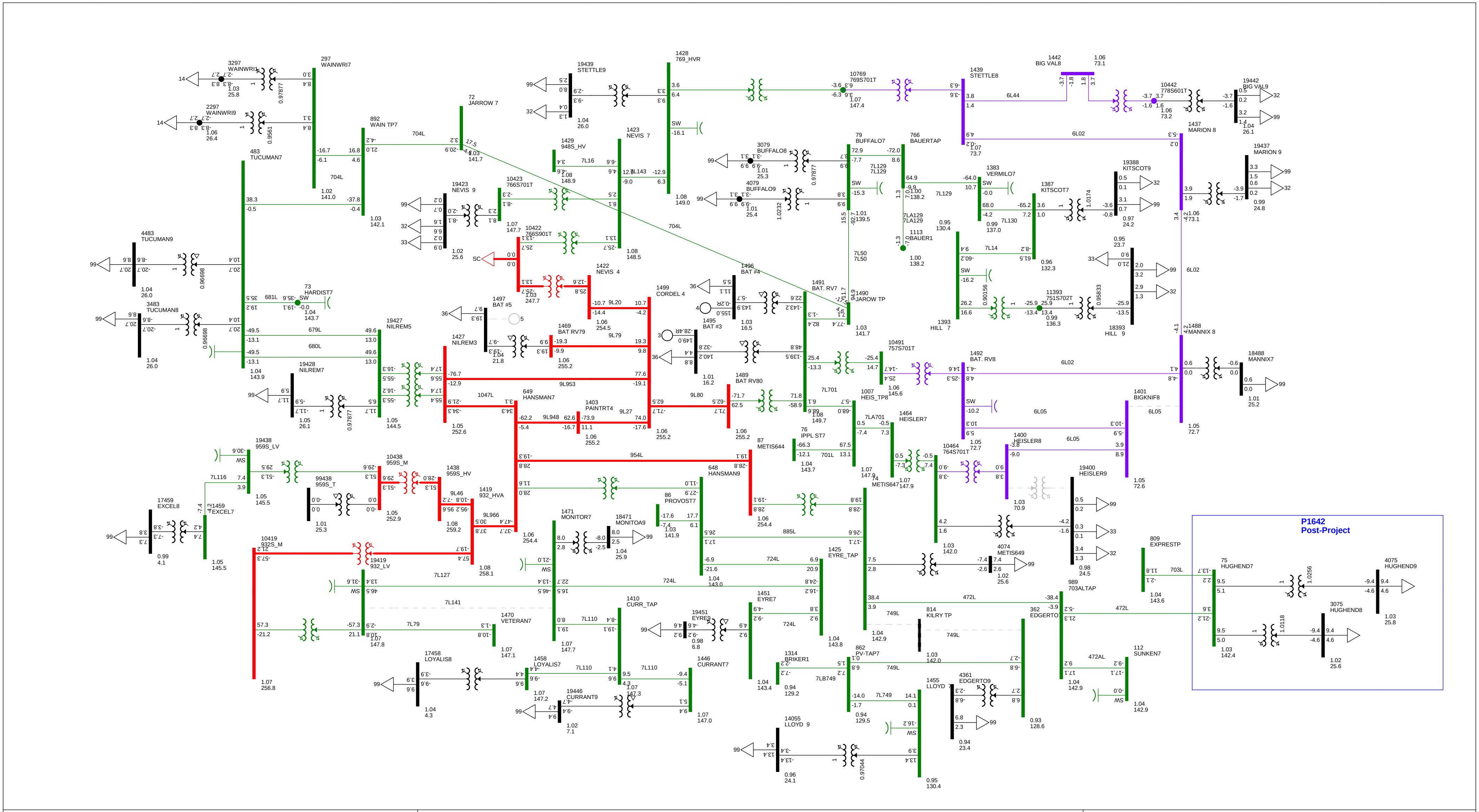
BC and MATL (Import): 54.7 MW

FIGURE B1-3 N-1: 7L130 (VERIMILION 710S TO KITSCOTY 705S)

2017 SUMMER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

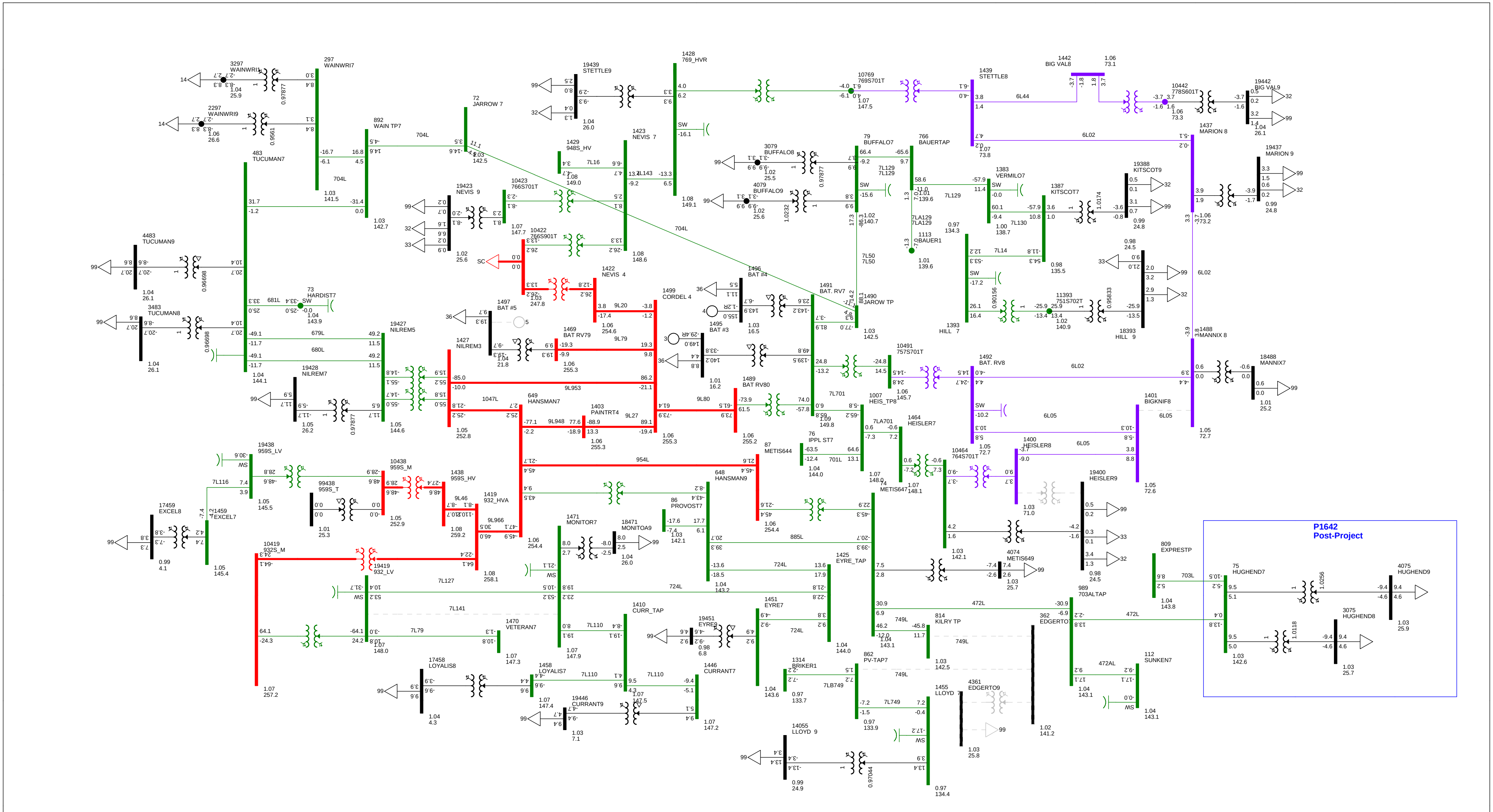
SK Tie (Import): -0.1 MW   BC and MATL (Import): 12.2 MW

FIGURE B1-4 N-1: 749L (EDGERTON 899S TO METISKOW 648S)

2017 SUMMER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

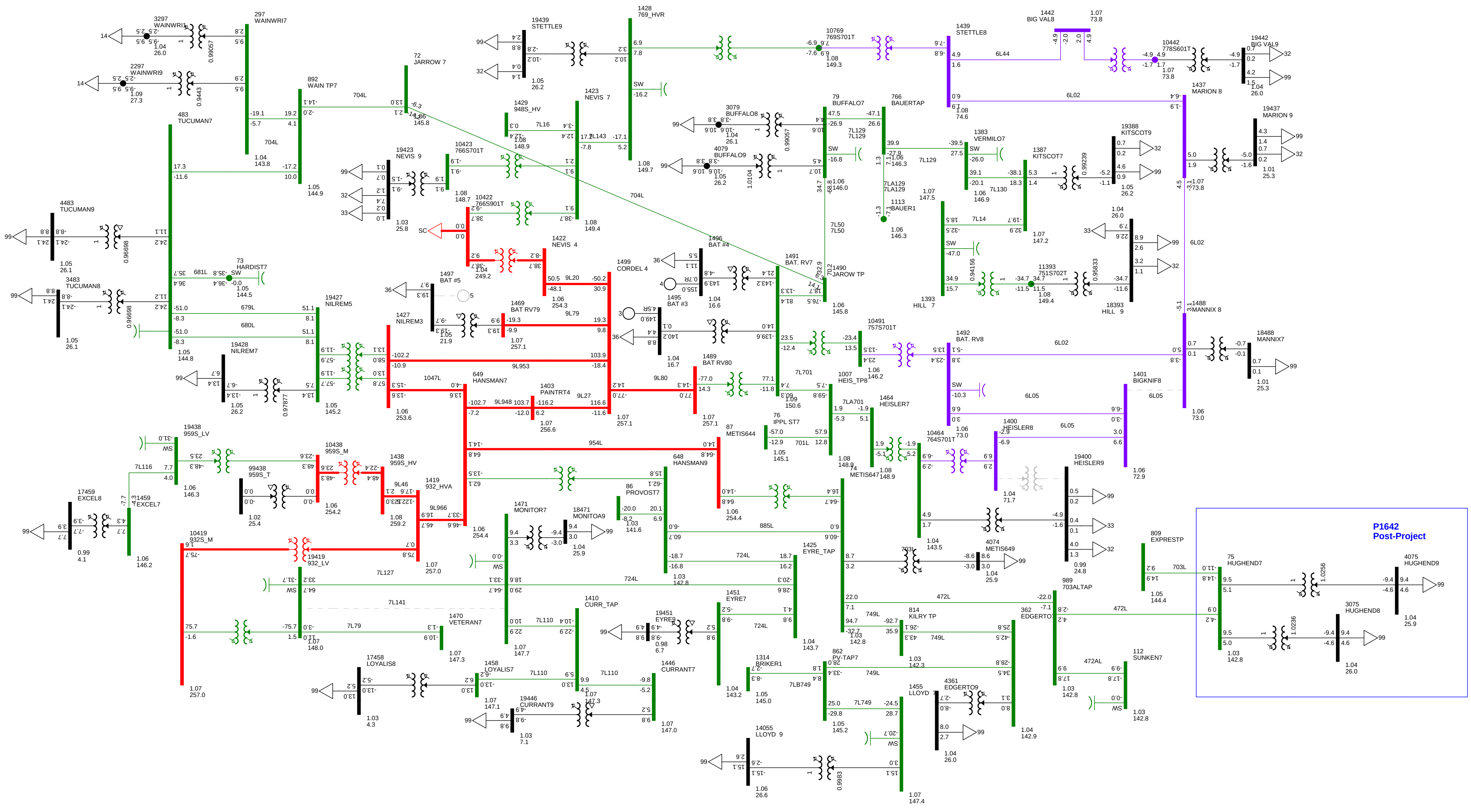
SK Tie (Import): -0.1 MW   BC and MATL (Import): 49.6 MW

FIGURE B1-5 N-1: EDGERTON 899S TRANSFORMER T3

2017 SUMMER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate A
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

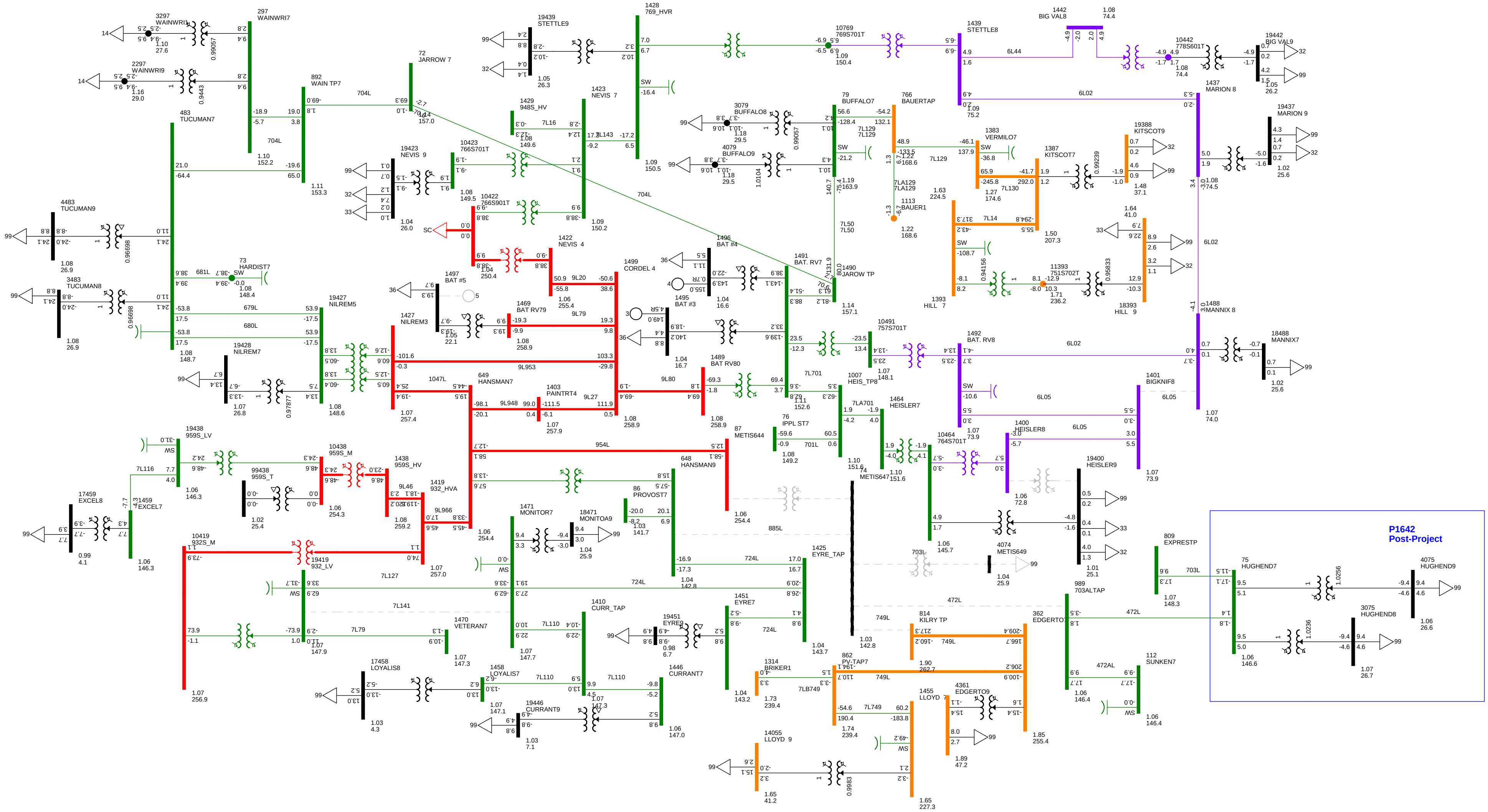
BC and MATL (Import): 89.6 MW

FIGURE B2-1-N-0: NORMAL OPERATION

2016 WINTER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

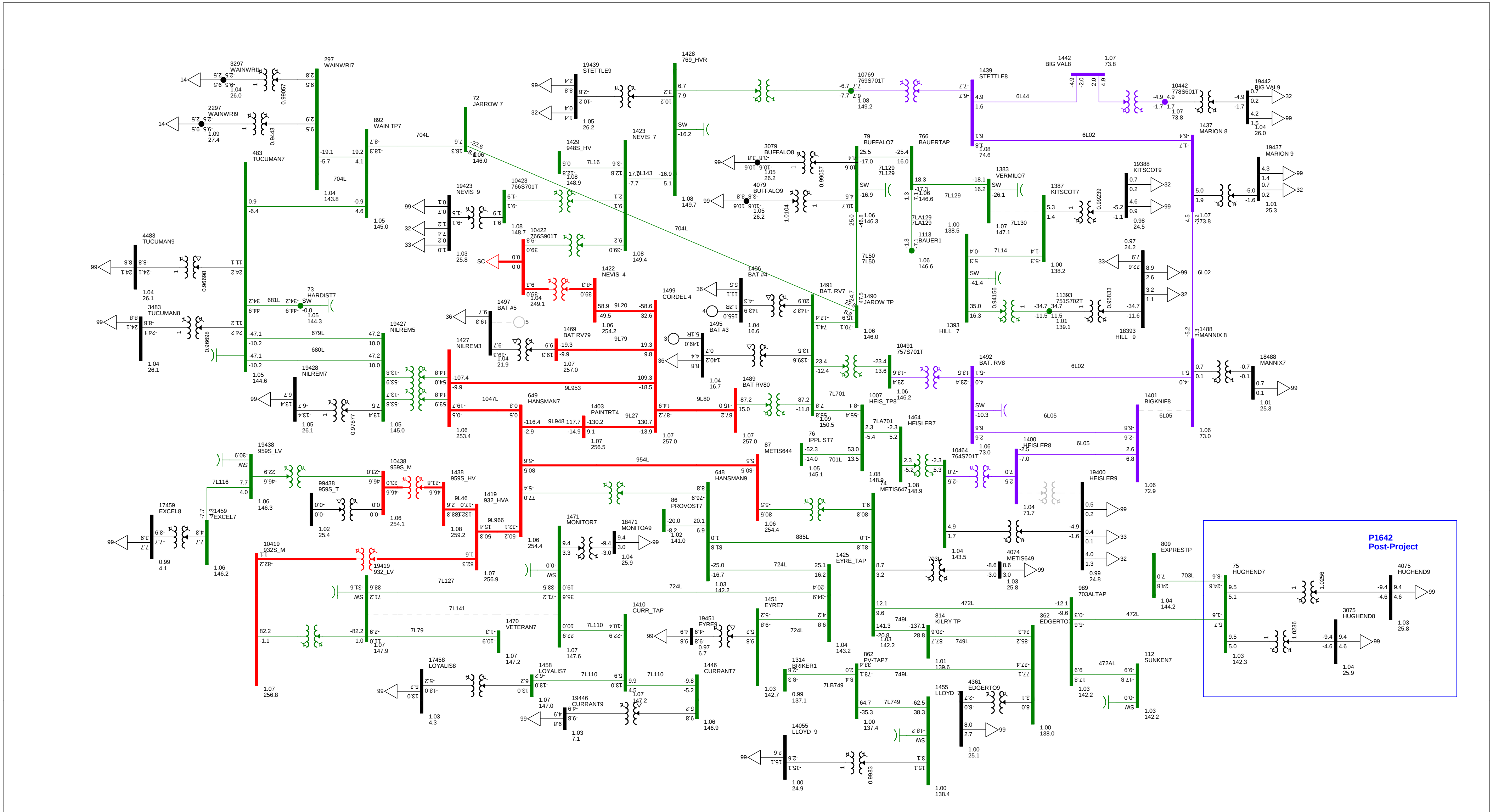
SK Tie (Import): -0.1 MW   BC and MATL (Import): 90.1 MW

FIGURE B2-2 N-1: METISKOW 648S 138/25 KV TRANSFORMER T1(BLOW UP)

2016 WINTER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

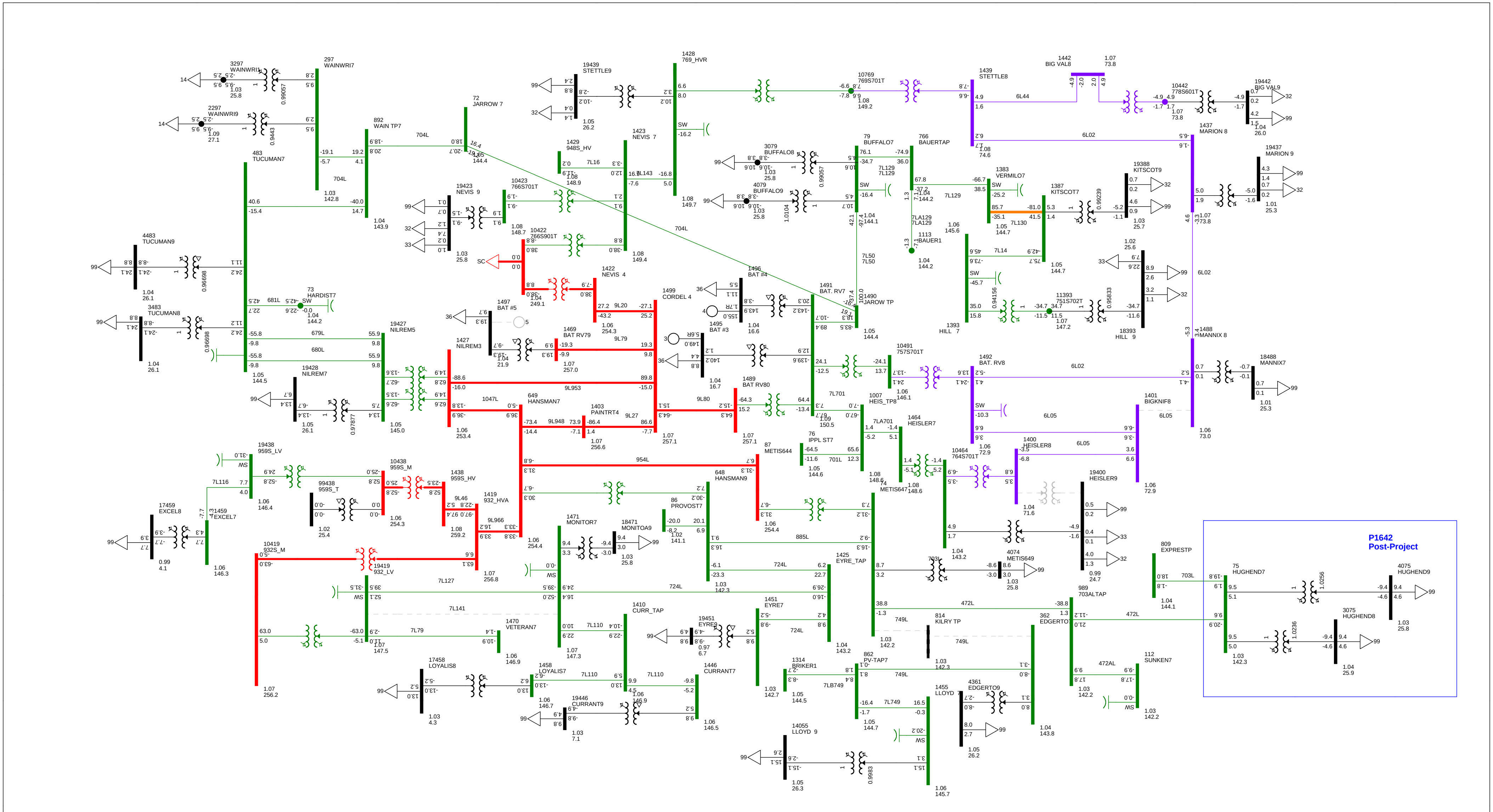
BC and MATL (Import): 93.9 MW

FIGURE B2-3 N-1: 7L130 (VERIMILION 710S TO KITSCOTY 705S)

2016 WINTER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

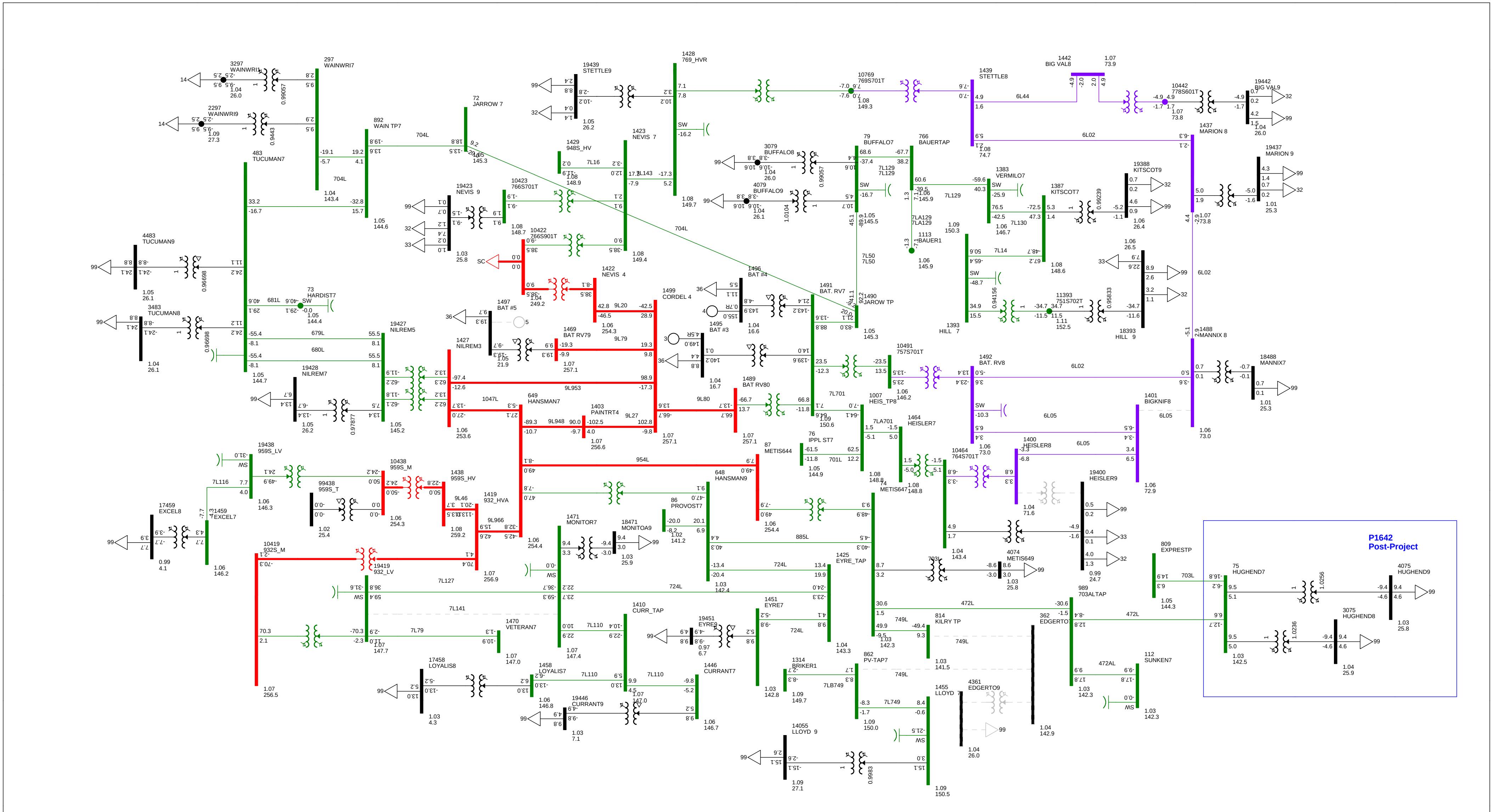
BC and MATL (Import): 46.8 MW

FIGURE B2-4 N-1: 749L (EDGERTON 899S TO METISKOW 648S)

2016 WINTER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000



Fortis Hughenden Upgrade - P1642

SK Tie (Import): -0.1 MW

BC and MATL (Import): 87.6 MW

FIGURE B2-5 N-1: EDGERTON 899S TRANSFORMER T3

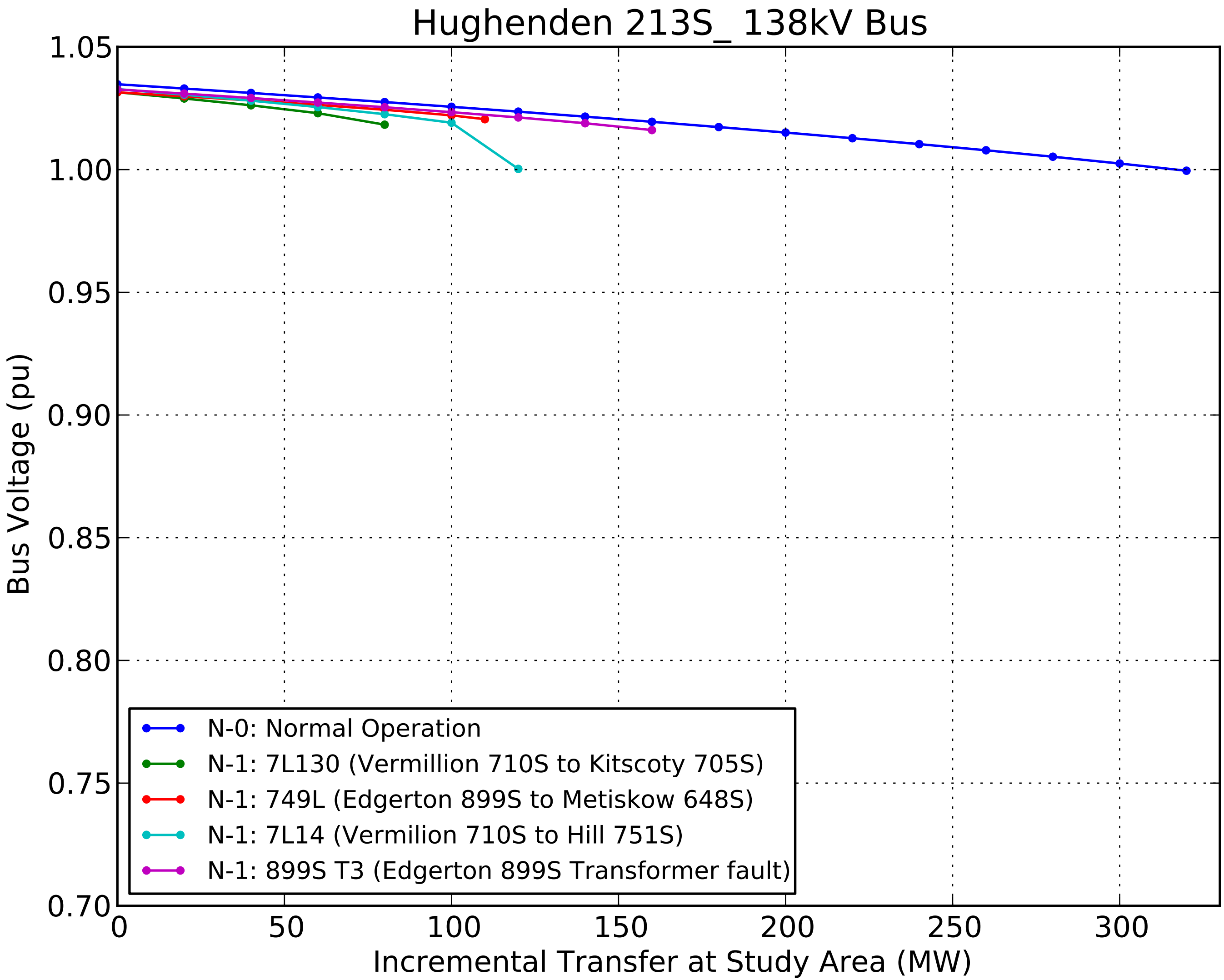
2016 WINTER PEAK (POST-CONNECTION)

PRINTED ON TUESDAY 10. NOVEMBER 2015

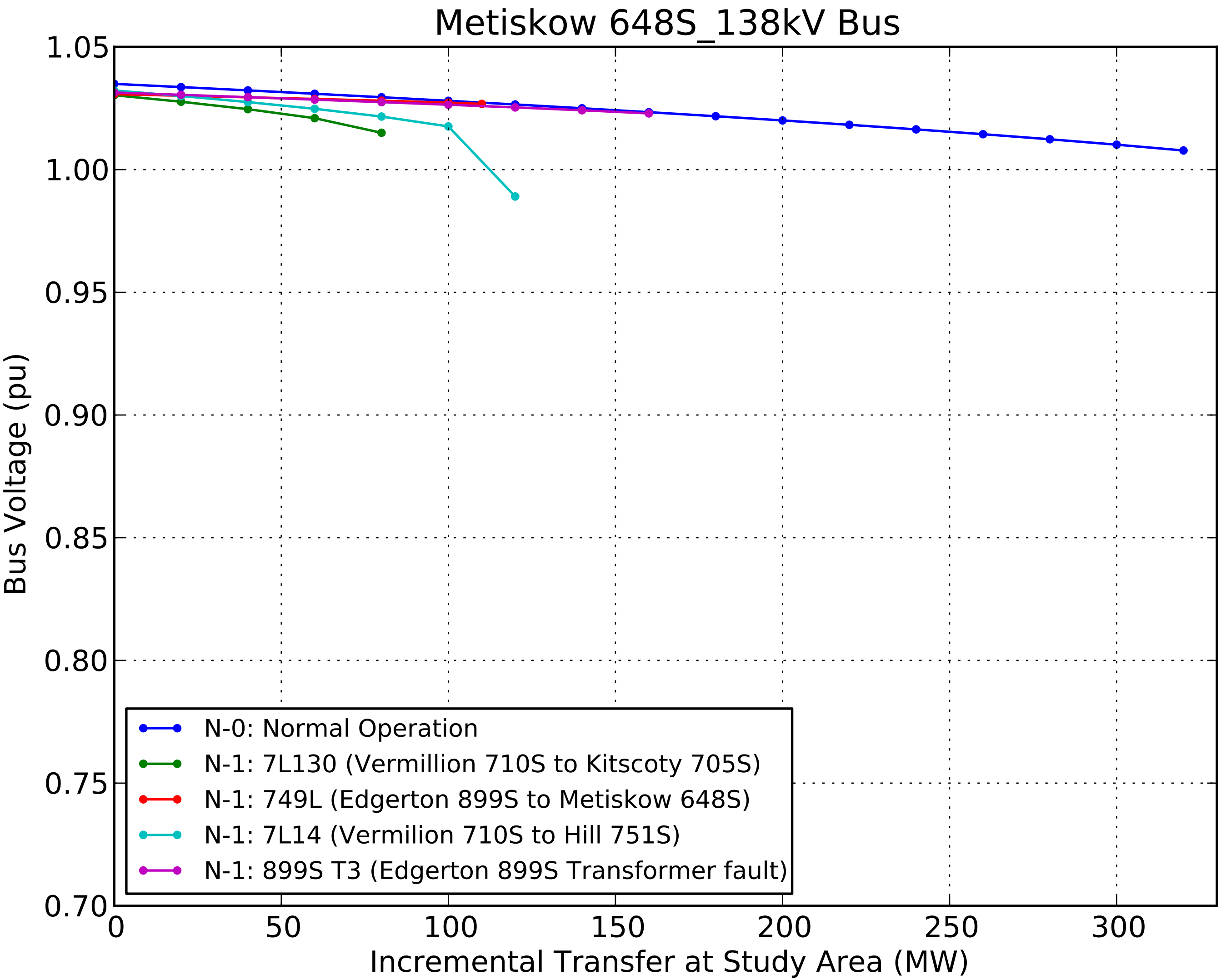
Bus - Voltage (kV/pu)
Branch - MW/Mvar
Equipment - MW/Mvar
100.0%Rate B
1.200OV 0.900UV
kV: <=25.000 <=69.000 <=138.000 <=240.000 <=500.000 >500.000

Attachment C

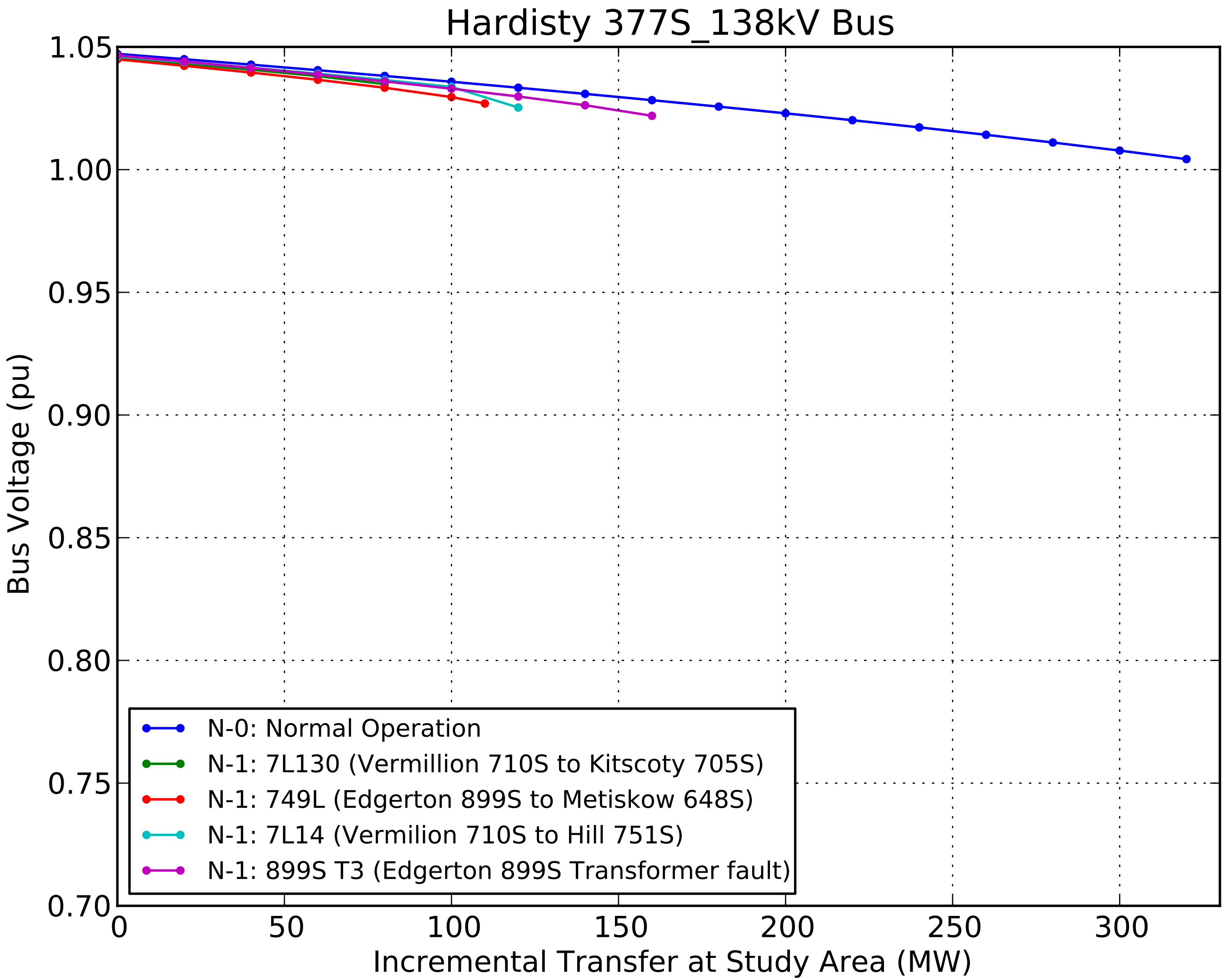
Post-Connection Voltage Stability Analysis Results (Scenarios 4) – Alternative 2



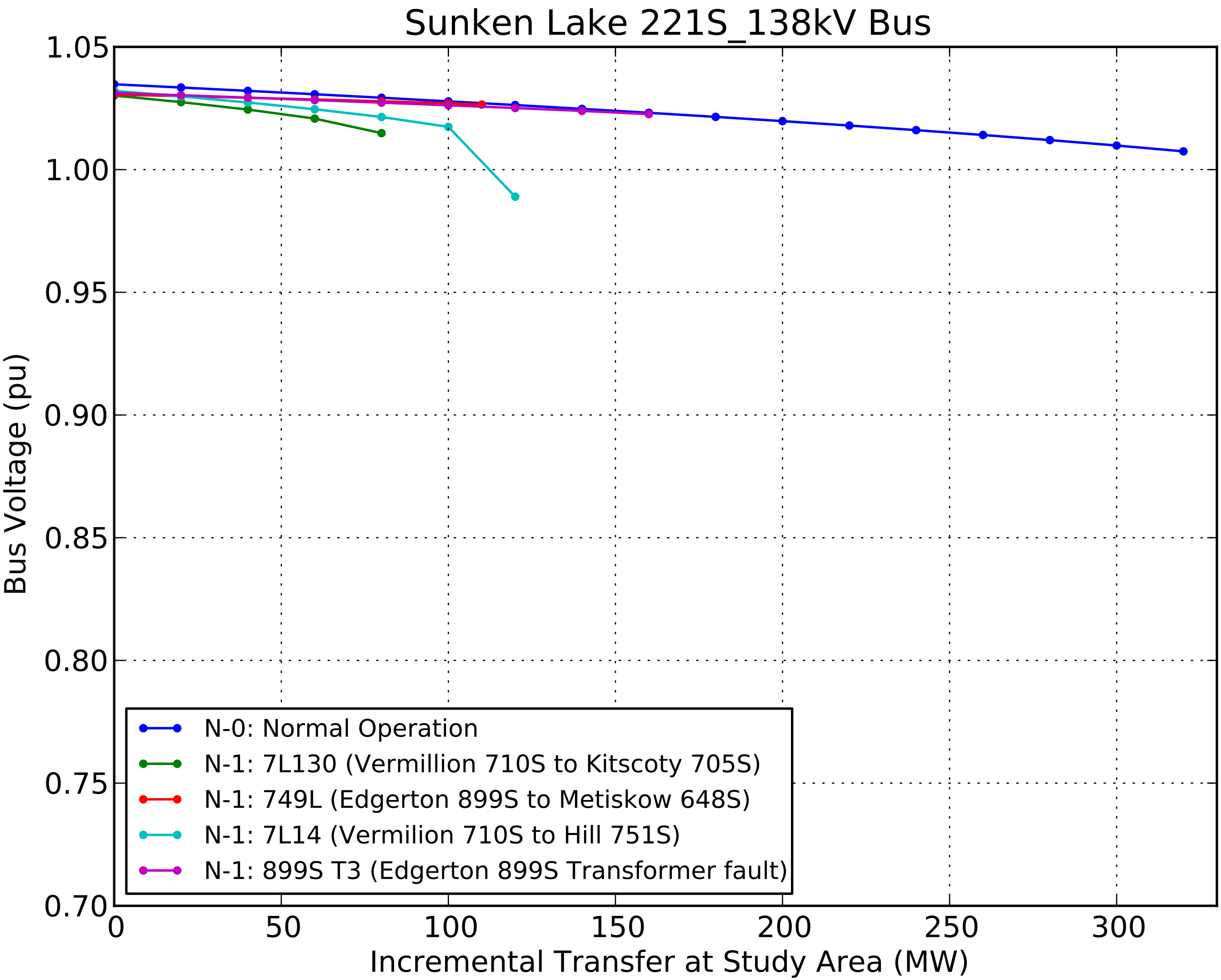
Hughenden 213S_ 138kV Bus
Bus Voltage (pu)
Incremental Transfer at Study Area (MW)
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0
50
100
150
200
250
300
N-0: Normal Operation
N-1: 7L130 (Vermillion 710S to Kitscoty 705S)
N-1: 749L (Edgerton 899S to Metiskow 648S)
N-1: 7L14 (Vermilion 710S to Hill 751S)
N-1: 899S T3 (Edgerton 899S Transformer fault)



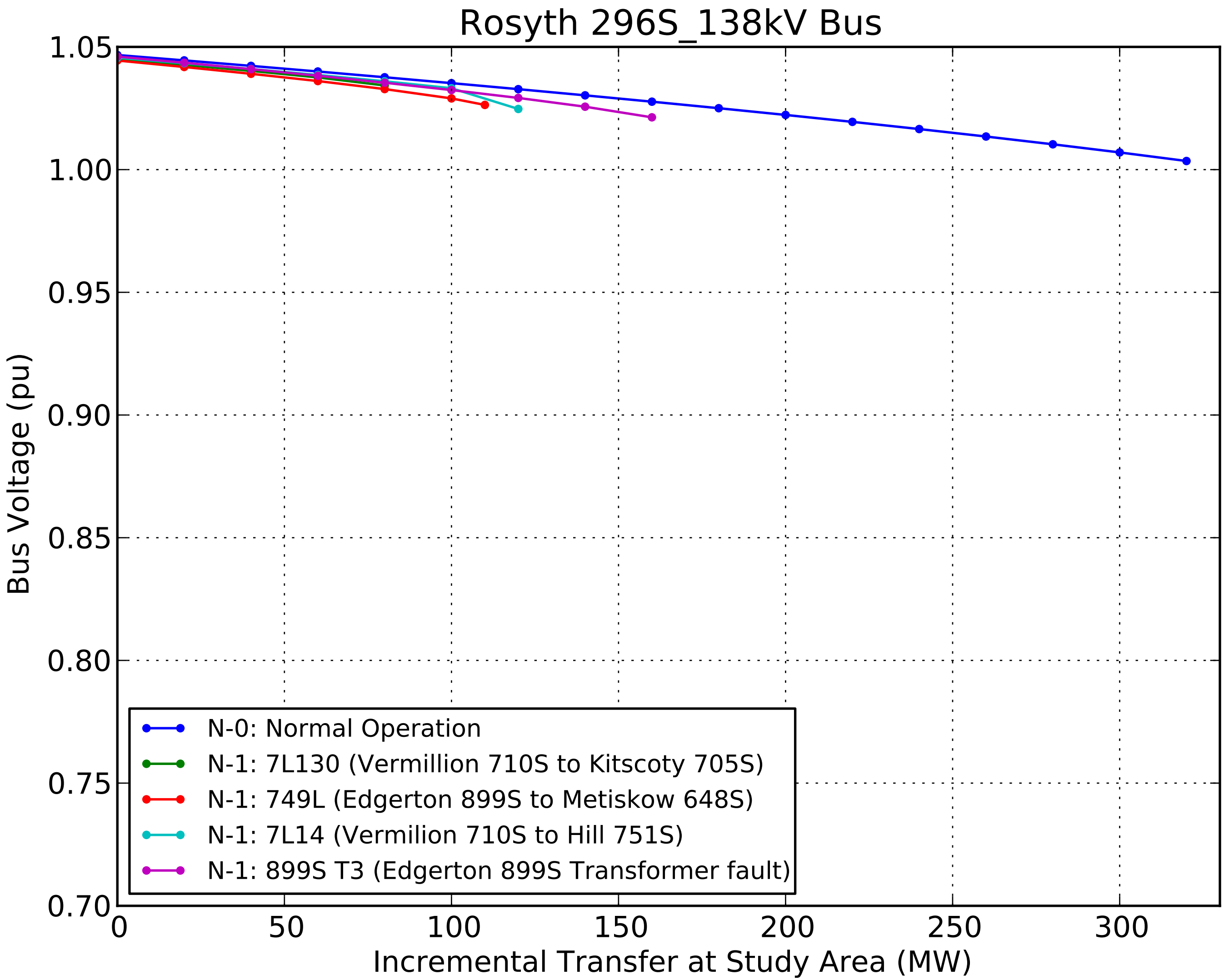
Metiskow 648S_138kV Bus
Bus Voltage (pu)
Incremental Transfer at Study Area (MW)
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0
50
100
150
200
250
300
N-0: Normal Operation
N-1: 7L130 (Vermillion 710S to Kitscoty 705S)
N-1: 749L (Edgerton 899S to Metiskow 648S)
N-1: 7L14 (Vermilion 710S to Hill 751S)
N-1: 899S T3 (Edgerton 899S Transformer fault)



Hardisty 377S_138kV Bus
Bus Voltage (pu)
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0
50
100
150
200
250
300
Incremental Transfer at Study Area (MW)
N-0: Normal Operation
N-1: 7L130 (Vermillion 710S to Kitscoty 705S)
N-1: 749L (Edgerton 899S to Metiskow 648S)
N-1: 7L14 (Vermilion 710S to Hill 751S)
N-1: 899S T3 (Edgerton 899S Transformer fault)



Sunken Lake 221S_138kV Bus
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0
50
100
150
200
250
300
Bus Voltage (pu)
Incremental Transfer at Study Area (MW)
N-0: Normal Operation
N-1: 7L130 (Vermillion 710S to Kitscoty 705S)
N-1: 749L (Edgerton 899S to Metiskow 648S)
N-1: 7L14 (Vermilion 710S to Hill 751S)
N-1: 899S T3 (Edgerton 899S Transformer fault)



Rosyth 296S_138kV Bus
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
Bus Voltage (pu)
0
50
100
150
200
250
300
Incremental Transfer at Study Area (MW)
N-0: Normal Operation
N-1: 7L130 (Vermillion 710S to Kitscoty 705S)
N-1: 749L (Edgerton 899S to Metiskow 648S)
N-1: 7L14 (Vermilion 710S to Hill 751S)
N-1: 899S T3 (Edgerton 899S Transformer fault)