# APPENDIX A CONNECTION ASSESSMENT

# Enbridge New Hardisty Substation
# Project number: 1558

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/connect

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Teshmont

# Engineering Study Report

# Connection to Enbridge Pipelines Inc. Proposed Battle Sands 594S Substation

**AESO P 1558**

**Revision Date: October 15, 2015**

Revision: 4

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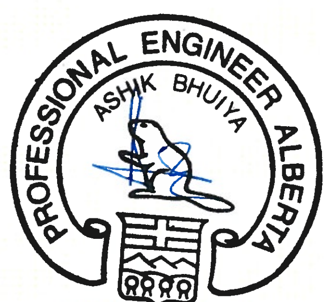

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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

# Executive Summary

This study report describes the engineering connection analysis that was performed on the transmission alternative considered to connect Enbridge's proposed Battle Sands 594S substation to the Alberta Interconnected Electricity System (AIES) in the Hardisty area.

## Project Overview

Enbridge Pipelines Inc. has submitted a System Access Service Request to the Alberta Electric System Operator (AESO) requesting the reliable connection of Enbridge's proposed 138/6.9 kV point-of-delivery substation to serve new 6.9 kV load in the Hardisty area (the Project). The proposed Enbridge substation, to be designated the Battle Sands 594S substation, will be located on Enbridge's Hardisty terminal and will have a peak load of 26 MW. A Demand Transmission Service (DTS) capacity of 26 MW was not requested. Instead, the proposed Battle Sands 594S substation DTS will be totalized with Enbridge's existing 60.3 MW DTS contract at the nearby Rosyth 296S and Clipper 656S substations. The requested project in-service date is July 1, 2017.

## Existing System

The requested connection to the proposed Battle Sands 594S substation is located in Wainwright area (AESO Planning Area 32) in which the Hardisty 377S, Rosyth 296S, and Clipper 656S substations are located. The Rosyth 296S and Clipper 656S substations only serve Enbridge load. The Rosyth 296S substation is fed radially from the Hardisty 377S substation via the 138 kV transmission line 769L. The Clipper 656S substation is connected to the 138 kV transmission line 769L through a T-tap on the 138 kV transmission line 769AL.

The Wainwright area is located in the Central East Sub-Region and consists primarily of 138 kV and 144 kV transmission lines. A 240/138 kV switching substation, the Nilrem 574S substation, located in the Wainwright area, functions as the primary source of supply in the area. The Wainwright area is connected through the transmission system to the Battle River / Alliance (AESO Planning Area 36), Lloydminster (AESO Planning Area 13), and Provost (AESO Planning Area 37) areas.

The Central East Sub-Region is impacted by the Central East Region Transmission Development[1] and Hanna Region Transmission Development Plan Stage 1[2] projects.

[1] *The Central East Region Transmission Development NID*, as originally approved by AUC Decision 2011-048 and Approval No. U2011-57

[2] *The Hanna Region Transmission System Development NID*, as originally approved by AUC Decision 2010-188 and Approval No. U2010-135

## Study Summary

In order to identify existing system constraints, pre-connection power flow, voltage stability, and short-circuit analyses were performed.

Short-circuit and motor starting analyses were performed after connection of the Project to identify post-connection system constraints and to evaluate whether the performance requirement of the Alberta Reliability Standards would be met under the studied scenarios.

The Project connection will not impact Enbridge's DTS, so post-connection power flow and voltage stability analyses are expected to yield the same results as the pre-connection results. Therefore, the post-connection power flow and voltage stability analyses were not undertaken.

The Study Area analyzed included Wainwright, and the nearby Battle River/ Alliance, Lloydminster, Provost, and Hanna areas. The study included all Category A, Category B, and selected Category C5 contingencies within the Study Area and the tie lines from the Study Area to the surrounding areas. All branches in the Study Area and the tie lines to the surrounding areas were monitored for thermal violations. All busses (69 kV and above) within the Study Area were monitored for voltage violations.

## Connection Alternative Selected for Study

Of the four potential transmission connection configurations identified, only one alternative, Alternative 1 was selected for further study. The other three alternatives were ruled out either because of space constraints or because they would require more facilities and hence would result in higher capital costs than Alternative 1.

Alternative 1 involves connecting the proposed Battle Sands 594S substation to the existing 138 kV transmission line 769L between the Rosyth 296S substation and the Clipper 656S substation T-tap (the 138 kV transmission line 769AL), by means of a T-tap configuration.

## Study Results

The pre-connection power flow and the voltage stability analyses were performed for the 2017 summer peak (SP) and 2017 winter peak (WP) pre-connection scenarios. Motor starting analysis was performed for the 2017WP post-connection scenario. In addition, short-circuit analysis was performed for 2017WP pre-connection and post-connection scenarios, as well as 2024WP post-connection scenario. The Study results indicate:

Pre-connection results:

1. No Category A, Category B, or selected Category C voltage violations were identified.
2. Category B thermal loadings violations were observed for the 2017SP and 2017WP pre-connection scenarios, under several Category B contingencies.

These thermal loading violations are existing and known to the AESO. They are currently being mitigated in real time by the AESO and Transmission Facilities Owner (TFO) operating practices.

Post-connection results:

1. Short-circuit analysis showed that the Project connection will not negatively impact short-circuit current levels in the Study Area.
2. Motor starting analysis showed that the impact of “across-the-line” starting of one motor, in VFD bypass mode, is acceptable during both system normal and contingency conditions.

## Recommendation

The engineering study indicates that Alternative 1 will not adversely impact the AIES in the Study Area. Based on these results, Teshmont recommends Alternative 1 to connect the proposed Enbridge Battle Sands 594S substation to the AIES.

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# 1. Introduction

This study report describes the engineering connection analysis that was performed on the transmission alternative considered to connect Enbridge's proposed Battle Sands 594S substation to the Alberta Interconnected Electricity System (AIES) in the Hardisty area.

## 1.1. Project

### 1.1.1. Project Overview

Enbridge Pipelines Inc. (the customer) submitted a System Access Service Request (SASR) to the Alberta Electric System Operator (AESO) requesting the connection of the proposed Enbridge 138/6.9 kV point-of-delivery (POD) substation, comprised of two 138/6.9 kV, 25/33.3 MVA transformers, located on Enbridge's Hardisty terminal.

In this report, the requested connection to the Enbridge's proposed Battle Sands 594S substation will be referred to as "the Project". The requested in-service date (ISD) for the Project is July 1, 2017.

### 1.1.2. Load Component

The proposed facility includes 26 MW of new motor load. No additional Demand Transmission Service (DTS) has been requested as part of the Project. The AESO agreed to support Enbridge's request for totalization of the proposed Battle Sands 594S substation DTS with Enbridge's existing DTS at Rosyth 296S and Clipper 656S substations.

#### 1.1.2.1. Proposed Battle Sands 594S Substation Project Load Details

- **Existing Hardisty DTS**: 60.3 MW totalized from Rosyth 296S and Clipper 656S substation loads.
- **Request for the Hardisty DTS**: 60.3 MW totalized from the proposed Battle Sands 594S, Rosyth 296S, and Clipper 656S substation loads.
- **Peak Substation Load**: 26 MW @ 0.95 power factor, to be included in the 60.3 MW DTS
- **Load Type**: Industrial motor / pump station
- **Number of Motors**: 4 @ 7000 HP each
- **Future Allowance for Load Growth**: Enbridge does not currently have future expansion plans to increase the load above 26 MW at the proposed Battle Sands 594S substation.

#### 1.1.3. Generation Component

This project has no generation component.

### 1.2. Study Scope

#### 1.2.1. Study Objectives

The objectives of the study are the following:

- To assess the impact of connecting the Project on the AIES.
- To identify any system constraints that would prevent the granting of approval for the Project.
- To recommend the optimal connection point within the Study Area.

#### 1.2.2. Study Area

The Project is located in the Wainwright area (AESO Planning Area 32). The Study Area includes the Wainwright area and the following AESO Planning Areas: Battle River / Alliance (AESO Planning Area 36), Lloydminster (AESO Planning Area 13), Provost (AESO Planning Area 37), and Hanna (AESO Planning Area 42).

**Table 1-1: Study Area Transmission System Summary**

| Area Number | Planning Area Name | Voltage Range |
|---|---|---|
| 32 | Wainwright | 69 kV to 240 kV |
| 36 | Battle River / Alliance | 69 kV to 240 kV |
| 13 | Lloydminster | 69 kV to 240 kV |
| 37 | Provost | 138 kV to 240 kV |
| 42 | Hanna | 69 kV to 240 kV |

##### 1.2.2.1. Study Area Description

The Project will be located approximately 4 km southeast of the Town of Hardisty in the Wainwright area. The Wainwright area is located in the AESO's Central East Sub-Region and consists primarily of 138 kV and 144 kV transmission systems. A 240/138 kV switching substation, the Nilrem 574S substation, functions as the primary source of supply in the Wainwright area. The area is connected to the AESO Planning Areas of Battle River/Alliance, Lloydminster, and Provost.

The Study Area is impacted by the Central East Region Transmission Development (CETD)[3] and the Hanna Region Transmission Development Plan Stage 1 (HRTD)[4] projects.

The CETD consists of several 138/144 kV enhancements in the Wainwright and Lloydminster areas intended to serve increasing load and generation, as well as 240 kV and 144 kV enhancements in the Cold Lake area to serve oil sands expansions. Many of these developments are under construction and are expected to enter service by 2017. However, due to changes in forecast assumptions and system conditions, especially those related to the proposed wind generation connections in the eastern part of the region, the AESO has reassessed the need for approved facilities in the CETD as part of its regional plan assessments. The Central East Sub-Regional Plan is a part of the published AESO 2013 Long-term Transmission Plan (2013 LTP).[5]

Currently, the Hanna region transmission system is being upgraded in accordance with the HRTD to ensure that there is adequate capacity and reliability of supply for the growing load in the area. As part of the HRTD, new 240 kV and 138 kV transmission lines will be built and some existing 138/144 kV and 69/72 kV transmission lines will be decommissioned. All of the facilities included in the HRTD Stage 1 are already in service. The AESO is re-assessing the HRTD Stage 2 and will file necessary components in the future. An area map of the transmission system near the Project (excluding the HRTD Stage 2) is shown in Figure 1-1.

The closest existing substations to the Project are Rosyth 296S and Clipper 656S substations, both approximately 1 km to the north of the proposed Battle Sands 594S substation location. The Rosyth 296S substation is fed radially from the Hardisty 377S substation via the 138 kV transmission line 769L. The Clipper 656S substation is connected to the 138 kV transmission line 769L through a T-tap on the 138 kV transmission line 769AL.

#### 1.2.2.2. Existing Constraints

The existing constraints in the Study Area are currently managed by the following planned and installed Remedial Action Scheme (RAS):

1. Battle River 7L50 and 7L701 TPS
2. RAS #134: 174L-395S North Holden overload mitigation scheme
3. RAS #138: 7L50 -526S Buffalo Creek overload mitigation scheme
4. RAS #139: 901T-766S Nevis overload mitigation scheme
5. EATL RAS for 912L and 9L20 contingencies

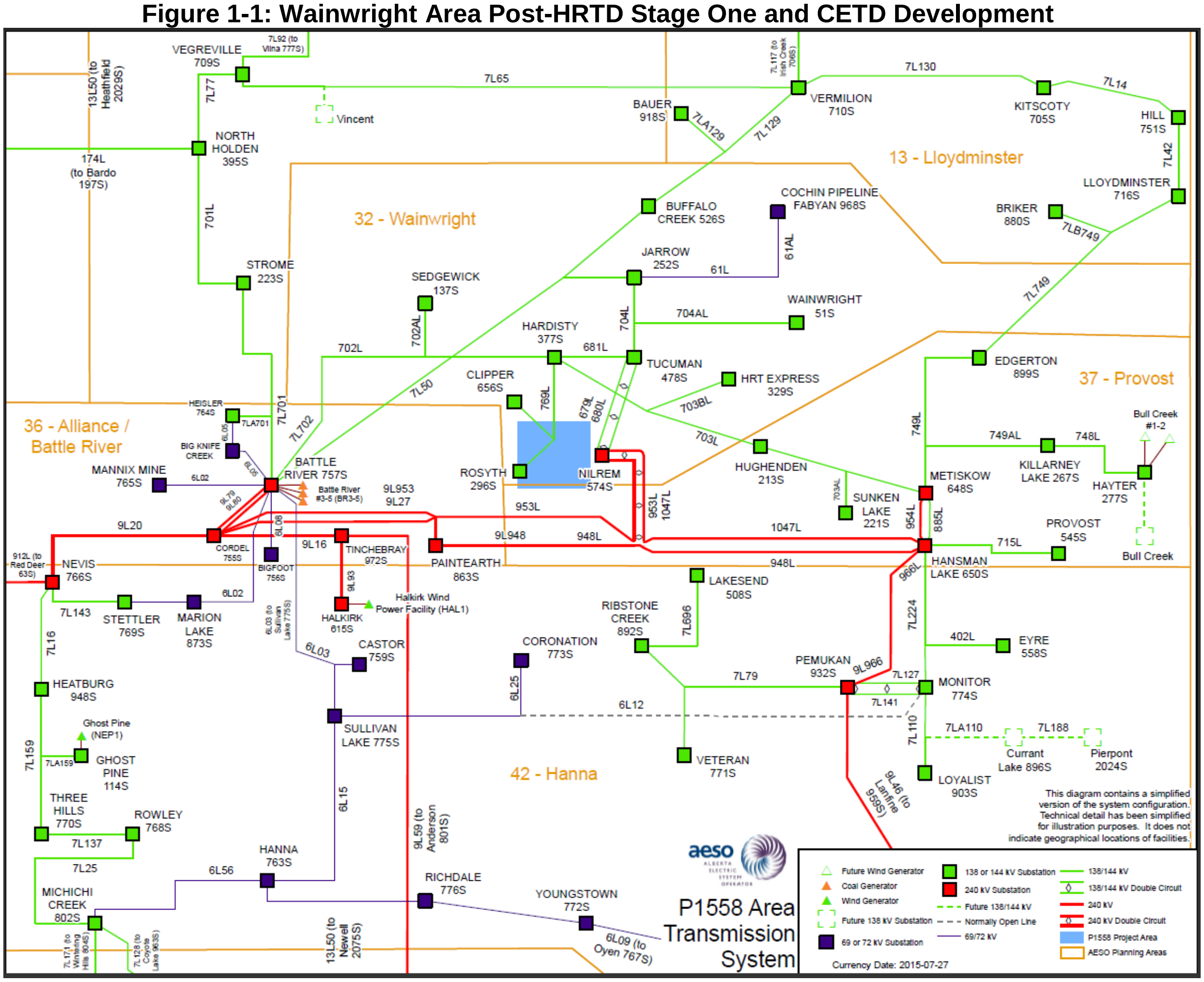
[3] *The Central East Region Transmission Development NID*, as originally approved by AUC Decision 2011-048 and Approval No. U2011-57
[4] *The Hanna Region Transmission System Development NID*, as originally approved by AUC Decision 2010-188 and Approval No. U2010-135
[5] Available on the AESO website at: http://www.aeso.ca/downloads/AESO_2013_Long-termTransmissionPlan_Web.pdf

#### 1.2.2.3. AESO Long-Term Plans

The system development projects which impact the Study Area are defined in the CETD. More details regarding the CETD projects and their in-service dates are presented in Table 2-5 in Section 2.3.

The AESO published its 2013 LTP, which included its Central Region Plan in 2014. The Central Region Plan includes new 240 kV transmission lines and substations to alleviate the existing congestion and to facilitate the new wind generation interest in the Central Region. The AESO will file the related Needs Identification Documents (NID) with the Alberta Utilities Commission (AUC) in 2016. These plans do not impact the Project study results.

**Figure 1-1: Wainwright Area Post-HRTD Stage One and CETD Development**




### 1.2.3. Studies Performed

The following pre-connection analyses were performed:

- Power flow analysis (Category A, Category B, and selected Category C5 for 2017 Summer Peak (SP) and 2017 Winter Peak (WP) load scenarios)
- Voltage stability analysis (Category A, Category B, and selected Category C5 for 2017WP load scenarios)
- Short-circuit analysis (with all generators in service for 2017WP)

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

- Short-circuit analysis (with all generators in service for 2017WP and 2024WP)
- Motor starting analysis (Category A, Category B, and selected Category C5 for 2017WP load scenarios)

## 1.3. Report Overview

The Executive Summary provides a high-level summary of the report and its conclusions.

Section 1 provides an introduction of the Engineering Study Report. Section 2 describes the reliability criteria, system data, and other study assumptions used in this report. Section 3 describes the study methodology. Section 4 discusses the pre-connection power flow and voltage stability analysis of the system. Section 5 presents the connection alternatives considered and studied. Section 6 discusses the power flow and voltage stability analysis of the connection alternative selected for further study. Section 7 presents the short-circuit analysis results. Section 8 shows the motor start analysis results. Section 9 discusses project interdependencies. Section 10 presents the summary and conclusions of this engineering study.

# 2. Criteria, System Data, and Study Assumptions

## 2.1. Criteria, Standards, and Requirements

### 2.1.1. Transmission Planning Standards and 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)* were applied to evaluate system performance under Category A system conditions (i.e., all elements in-service) and following Category B contingencies (i.e., single element outage), prior to and following the studied alternatives. Below is a summary of Category A and Category B system conditions as well as a summary of Category C5 system conditions.

**Category A**, often referred to as the N-0 condition, or N-G with the most critical generator out of service, 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.

**Category C5** events result in loss of two circuits of a multiple circuit tower. 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. For Category C5, the controlled interruption of electric supply to customers (load shedding), the planned removal from service of certain generators, and/or the curtailment of contracted firm (non-recallable reserved) transmission service electric power transfers may be necessary to maintain the overall reliability of the interconnected transmission systems.

The TPL standards, TPL-001-AB-0, TPL-002-AB-0, and TPL-003-AB-0 reference Applicable Ratings when specifying the required system performance under Category A, Category B, and Category C events. For the purpose of applying the TPL standards to the studies documented in this report Applicable Ratings are defined as follows:

- Applicable Rating refers to the applicable normal and emergency facility thermal and voltage rating, as applied by the facility owner, or to the system voltage limit, as determined and consistently applied by the ISO. Applicable ratings may include emergency ratings applicable for short durations as required to permit the operating steps necessary to maintain system control. All ratings must be established by the applicable entity consistent with applicable ISO rules addressing facility ratings.
- For Category A conditions: Voltage range under normal operating condition is in accordance with AESO *Information Document ID# 2010-007RS, General Operating Practice – Voltage Control*.
- For Category B conditions: The extreme voltage range, as applicable, is taken from Table 2-1 in the *Transmission Planning Criteria – Basis and Assumptions*.

The acceptable post-contingency voltage change limits for three defined post-event timeframes are as provided in Table 2-1 below.

The post-contingency voltage deviations following Category B events were compared with the guidelines in Table 2-1 below.

**Table 2-1: 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 Rules

The AESO *Information Document ID # 2010-007RS* will be applied to establish pre-contingency voltage profiles in the study region. The Section 302.1 of the ISO rules, *Real Time Constraint Management* (the TCM Rule) will be followed in setting up the study scenarios and assessment of the connection impact. 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

Studies were conducted for 2017SP and 2017WP scenarios to align with the requested ISD of July 1, 2017. The AESO Planning Base Case Suite was used to develop the study cases. The 2024WP scenario was considered to calculate short-circuit current levels for 2024.

Table 2-2 shows the load distribution amoung the Rosyth 296S, the Clipper 656S, and the proposed Battle Sands 594S substations for pre-connection and post-connection scenarios considering the total DTS of 60.3 MW.

**Table 2-2: Studied Load Distribution between the Rosyth 296S, the Clipper 656S, and the proposed Battle Sands 594S Substations**

| Scenario | Year / Condition | Load @ Clipper 656S (MW DTS) | Load @ Rosyth 296S (MW DTS) | Load @ Proposed Battle Sands 594S (MW DTS) | Total Load (MW DTS) |
|---|---|---|---|---|---|
| 2017SP Pre-Connection* | 2017SP | 15.1 | 45.2 | 0 | 60.3 |
| 2017WP Pre-Connection* | 2017WP | 15.1 | 45.2 | 0 | 60.3 |
| 2017WP Post-Connection* | 2017WP | 12 | 22.3 | 26 | 60.3 |

* 2017 Scenarios were considered without the HRTD Stage 2 system developments.

### 2.2.1. Load Assumptions

The forecasted SP and WP load levels for the relevant study years from the AESO 2014 Long-term Outlook is presented in Table 2-3. The ratio of active power to reactive power in the study cases was maintained when scaling of the loads was required.

**Table 2-3: Forecast Area Load**

| Area Name and Number | Season | Year | Forecast Peak Load (MW) |
|---|---|---|---|
| Central Region* | Summer | 2017 | 1,602 |
| | Winter | 2017 | 1,847 |
| | Winter | 2024 | 2,153 |
| Alberta Internal Load without losses | Summer | 2017 | 11,440 |
| | Winter | 2017 | 12,796 |
| | Winter | 2024 | 15,532 |

*The Central Region comprises of the following AESO Planning Areas: 13, 29, 30, 32, 34, 35, 36, 37, 38, 39, 42, and 56

### 2.2.2. Generation and Intertie Flow Assumptions

One of the major sources of power supply to the Study Area is the Battle River Generation Plant located in the Battle River / Alliance area. Table 2-4 shows the dispatch from the Battle River generators for different seasons and study years.

The selection of one Battle River unit out of service was determined as the most critical unit for an N-G condition. This unit is out of service for power flow and voltage stability studies. All the remaining generators were dispatched based on economic merit in accordance with the generation dispatch provided by the AESO.

**Table 2-4: Summary of Local Generators in the Study Cases**

| Name | Units | Generation Level Modelled in the Study Case (MW) | |
|---|---|---|---|
| | | 2017SP | 2017WP |
| Battle River | 3 | 153 | 153 |
| Battle River | 4 | 163 | 163 |
| Battle River | 5 | OFF | OFF |

Power import through the intertie with British Columbia had no impact on this study and therefore the intertie assumptions used were consistent with that in the AESO base cases. The intertie with Saskatchewan was considered at zero. The study case assumed no wind as the most stressed case and consequently all wind generation in the Study Area was set offline.

## 2.3. System Projects

Table 2-5 lists the approved CETD plan, which was considered in the study.

**Table 2-5: CETD Developments Included in the Connection Study**

| Project | Subproject | Subproject Name and Description | Scheduled ISD / Complete / Cancelled |
|---|---|---|---|
| 811 | 1 | Bourque 970S Substation (Partial Stage 1) | Complete |
| 811 | 1 | Bourque 970S Substation (Partial Stage 2) | Complete |
| 811 | 2 | 138 kV transmission line 7L146 from Bonnyville 700S Substation to Bourque 970S substation | Complete |
| 811 | 3 | St. Paul Area Upgrades - Watt Lake 956S substation | Complete |
| 811 | 4 | St. Paul Upgrades St. Paul 707S substation and the 138 kV transmission lines 7L139/ 7L70 in and out | April 2016 |
| 811 | 5 | Vermillion 710S Substation Upgrade | Complete |
| 811 | 6 | Heisler Area Upgrades | Complete |
| 811 | 7 | Kitscoty 705S substation and 138 kV transmission lines 7L14 and 7L130 in and out | Complete |
| 811 | 9 | 144 kV transmission line 7L701 Line Clearance Mitigation | Complete |
| 811 | 10 | 144 kV Transmission Line 7L157 from the Bourque 970S substation to the Mahihkan 837S substation | Complete |
| 811 | 11 | 138 kV transmission line 7L574 from the Bourque 970S substation to the Wolf Lake 822S substation | Complete |
| 811 | 12 | 138 kV transmission line 7L583 from Bourque 970S substation to the Leming Lake 715S substation | Complete |
| 811 | 13 | 144 kV transmission line 7L160 from the Bourque 970S substation to the Mahihkan 837S substation | Complete |
| 811 | 14 | St. Paul Area Upgrades – 138 kV transmission line 7LA92 T-tap to Watt Lake 956S substation | Complete |
| 811 | 16 | 138 kV transmission line 7L24 Termination at the Bonnyville 700S substation | Complete |

| Project | Subproject | Subproject Name and Description | Scheduled ISD / Complete / Cancelled |
|---|---|---|---|
| 811 | 20 | 144 kV transmission line 7L587 from the Marguerite Lake 826S substation to the Wolf Lake 822S substation | Complete |
| 811 | 22 | 138 kV transmission line 7L14 Line Clearance Mitigation | Cancelled |
| 811 | 23 | 138 kV transmission line 7L53/7L117 Line Clearance Mitigation | Cancelled |
| 811 | 24 | St. Paul Area Upgrades - Whitby Lake 819S Circuit Breaker addition | June 2014 |
| 811 | 25 | Bonnyville 700S substation Transformer addition | April 2016 |
| 811 | 26 | Kitscoty 69 kV transmission line 6L06 Decommission | Complete |
| 811 | 27 | New 138 kV transmission line 408L from the Jarrow 252S substation to the Wainwright 51S substation | Cancelled |

Table 2-6 lists the HRTD Stage 2 system reinforcement project developments. The HRTD Stage 2 developments were not considered in the 2017 study scenarios.

**Table 2-6: Summary of HRTD System Projects Not Included in the Connection Study, Stage 2**

| Project | Subproject | Subproject Name and Description | Scheduled ISD |
|---|---|---|---|
| 1113 | 1 | Energization 1 - 240 kV D/C transmission line 9L49 from the Cordel 755S substation to the Halkirk 401S substation | Q2 2017 |
| 1113 | 2 | Energization 2 - 240 kV D/C transmission line 9L31 from the Oakland 946S substation to the Coyote Lake 963S substation - second side strung | Q2 2017 |
| 1113 | 3 | Energization 3 - 240 kV D/C transmission line 9L65 from the Oakland 946S substation to the Lanfine 959S substation - String second side | Q2 2017 |
| 1113 | 4 | Energization 4 - Convert the existing 72 kV Hanna 763S substation to a 144 kV substation and add a new 144 kV transmission line 7L108L from the Coyote Lake 963S substation to the upgraded Hanna 763S substation | Q2 2017 |
| 1113 | 5 | Energization 5 - Pemukan 932S substation – add a second 240/144 kV, 300 MVA transformer | Q2 2017 |
| 1113 | 6 | Energization 6 - Lanfine 959S substation – add a second 240/144 kV, 300 MVA transformer | Q2 2017 |
| 1113 | 7 | Energization 7 - Youngstown 772S substation - 5 MVAr | Q2 2017 |

| Project | Subproject | Subproject Name and Description | Scheduled ISD |
|---|---|---|---|
| | | Capacitor Bank | |
| 1113 | 9 | Energization 9 - Metiskow 648S substation – add one 27 MVAr (138 kV) capacitor bank | Q2 2017 |
| 1113 | 10 | Energization 10 - Hansman Lake 650S substation – add a second 240/144 kV - 200 MVA transformer | Q2 2017 |
| 1113 | 11 | Energization 11 - Hansman Lake 650S substation – add two 36 MVAr (240 kV) and one 27 MVAr (138 kV) capacitor banks | Q2 2017 |
| 1113 | 12 | Energization 12 - Coronation 773S substation- add 2.4 MVAr (25 kV) capacitor bank | Q2 2017 |
| 1113 | 13 | Energization 13 - Nilrem 574S substation – add two 27 MVAr (138 kV) capacitor banks | Q2 2017 |

Notes:

1. As Part of HRTD Stage 2, 138 kV transmission line 7L224 will be open at Monitor 774S substation, and 144 kV transmission line 7L141 will be energized. Based on the AESO 2013 LTP, 72 kV transmission line 6L56 (between Hanna 763S and Michichi Creek 802S substations) will still be required after HRTD Stage 2.
2. 138 kV transmission Line 7L760 will no longer be open at Oyen 767S substation after HRTD Stage 2.

## 2.4. Customer Connection Projects

Table 2-7 shows the new load connection projects that passed Gate 2 and can be found on the AESO’s website.

**Table 2-7: Summary of Relevant Facility Assumption included in the Connection Study, Market Participant Projects past Gate 2**

| Project No | Project Name | Planning Area | Generation (MW) | Load (MW) | MW Type | Scheduled/ Actual ISD |
|---|---|---|---|---|---|---|
| 851 | TransCanada Keystone KXL Pump station #2-Eyre | 37-Provost | 0.0 | 25.0 | Load | Jan 1, 2017 (on hold) |
| 863 | TransCanada Keystone KXL Pump station #3-Current | 42- Hanna | 0.0 | 25.0 | Load | Jul 2, 2016 (on hold) |
| 864 | TransCanada Keystone KXL Pump station #4-Armitage | 42- Hanna | 0.0 | 25.0 | Load | Jul 1, 2016 (on hold) |
| 1319 | ATCO 774S Monitor Substation Upgrades | 42-Hanna | 0.0 | 4.3 | Load | Feb 10, 2015 |
| 1366 | Enbridge Sunken Lake 221S Substation Expansion | 37-Provost | 0.0 | 14 | Load | Jun 2014 |
| 1284 | Nilrem 574S Substation | 32- | 0.0 | 24.1 | Load | Dec 1, |

| Project No | Project Name | Planning Area | Generation (MW) | Load (MW) | MW Type | Scheduled/ Actual ISD |
|---|---|---|---|---|---|---|
| | Expansion (formerly Lagstaff) | Wainwright | | | | 2014 |
| 1390 | Fortis Tucuman 478S Substation-25KV Breaker Addition | 32-Wainwright | 0.0 | 41.7 | Load | Aug 2014 |
| 1454 | Fortis Tucuman 478S Substation-T2 25KV Feeder Breaker Addition | 32-Wainwright | 0.0 | 12.4 | Load | Nov 2014 |
| 1495 | Fortis Hayter 277S Substation 42 MVA Transformer and 25 kV Breaker Add. | 37-Provost | 0.0 | 0.0 | Equipment Change | Sep 16, 2015 |
| 1311 | ATCO Irish Creek 706S Substation Upgrades | 13-Lloydminster | 0.0 | 7.3 | Load | Nov 2014 |

## 2.5. Additional Projects

Apart from those specified in Section 2.4, no other market participant facilities prior to Gate 2 need to be included in the study cases.

## 2.6. Facility Ratings

Table 2-8 shows key transmission lines in the Study Area operating at 69 kV and above.

**Table 2-8: Summary of Key Transmission Lines in the Study Area**

| Nominal Voltage (kV) | Transmission Line | From | To | Summer Rate (MVA) | Winter Rate (MVA) | Emergency Summer Rate (MVA) | Emergency Winter Rate (MVA) |
|---|---|---|---|---|---|---|---|
| 138 | 769L | Hardisty 377S | Clipper Tap Point | 86 | 115 | 95 | 127 |
| 138 | 769L | Rosyth 296S | Clipper Tap Point | 86 | 115 | 95 | 127 |
| 138 | 769AL | Clipper 656S | Clipper Tap Point | 122 | 150 | 134 | 165 |
| 138 | 703BL | HRT Express 329S | Express Tap Point | 123 | 150 | 135 | 165 |
| 138 | 703L | Hardisty 377S | Express Tap Point | 83 | 83 | 83 | 83 |
| 138 | 885L | Metiskow 648S | Hansman Lake 650S | 287 | 287 | 287 | 287 |
| 138 | 749L | Metiskow 648S | Killarney Tap Point | 121 | 148 | 133 | 163 |

| Nominal Voltage (kV) | Transmission Line | From | To | Summer Rate (MVA) | Winter Rate (MVA) | Emergency Summer Rate (MVA) | Emergency Winter Rate (MVA) |
|---|---|---|---|---|---|---|---|
| 138 | 703L | Metiskow 648S | 703AL Tap Point | 122 | 143 | 134 | 162 |
| 138 | 703L | Hughenden 213S | Express Tap Point | 122 | 147 | 134 | 162 |
| 138 | 703L | Hughenden 213S | 703AL Tap Point | 121 | 145 | 133 | 160 |
| 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 Point | 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 | 150.5 |
| 240 | 9L948/948L | Hansman Lake 650S | PaintEarth 863S | 332 | 332 | 432 | 432 |
| 240 | 1047L | Hansman Lake 650S | Nilrem 574S | 499 | 499 | 680 | 748 |
| 240 | 9L966 | Hansman Lake 650S | Pemukan 932S | 332 | 332 | 432 | 432 |
| 138 | 749L | Killarnery T-tap | Metiskow 648S | 121 | 149 | 133 | 164 |
| 138 | 749L/7L749 | Edgerton 899S | Briker Tap Point | 88 | 96 | 97 | 140 |
| 138 | 7L749 | Briker Tap Point | Lloydminster 716S | 109.25 | 138.99 | 123.6 | 150.45 |
| 138 | 7L42 | Lloydminster 716S | Hill 751S | 94.88 | 94.88 | 123.63 | 123.63 |
| 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 2-9 shows the key transformers in the Study Area.

**Table 2-9: Summary of Ratings of Key Transformers in the Study Area**

| Transformers | | | |
|---|---|---|---|
| **Substation Name and Number** | **Transformer ID** | **Transformer Voltages (kV)** | **Rating (MVA)** |
| Metiskow 648S | T3 | 240/138 | 200 |
| Hansman Lake 650S | T1 | 240/138 | 200 |
| Nilrem 574S | T1 | 240/138 | 400 |
| Nilrem 574S | T2 | 240/138 | 400 |
| Tucuman 478S | T1/T2 | 138/25 | 42 |

Table 2-10 shows the relevant key shunt elements in the Study Area.

**Table 2-10: Summary of Key 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)** | **Number of Switched Shunt Blocks** | **Total at Nominal Voltage (MVAr)** |
| Amoco Empress 163S | 138 | 2x24.35 | 48.70 | - | - |
| McNeil 840S | 138 | 2x24.80 | 49.6 | - | - |
| Tilley 498S | 138 | 1 | 27.17 | - | - |
| Lanfine 959S | 138 | 2x27.55 | 55.1 | - | - |
| | 34.5 (SVC) | 1x200 | 200 | 1x-100 | -100 |
| Stettler 769S | 138 | 1 | 13.78 | - | - |
| Michichi Creek 802S | 138 | 1 | 9.18 | - | - |
| Youngstown 772S | 69/25 | 1x4.6+1x2.4 | 7 | - | - |
| Hanna 763S | 25 | 1 | 4.95 | - | - |
| Sullivan Lake 775S | 69 | 1 | 9.19 | - | - |
| Bull Pound 803S | 25 | 2 | 2x2.4 | - | - |
| Battle River 757S | 69 | 1x9.19 | 9.19 | - | - |
| Three Hills 770S | 138/25 | 1x18.37/1x4.95 | | - | - |

| Substation Name and Number | Nominal Bus Voltage (kV) | Capacitors | | Reactors | |
|---|---|---|---|---|---|
| | | Number of Switched Shunt Blocks | Total at Nominal Voltage (MVAr) | Number of Switched Shunt Blocks | Total at Nominal Voltage (MVAr) |
| Hansman Lake 650S | 18.0 (SVC) | 1x200 | 200 | 1x-100 | -100 |
| Hardisty 377S | 138 | 1x27+1x44.9 | 71.9 | - | - |
| Killarney Lake 267S | 138 | 1x9.1+2x10.9 | 30.9 | - | - |
| Tucuman 478S | 138 | 1x27.17 | 27.17 | - | - |
| Pemukan 932S | 138 | 2x27.55 | 55.1 | - | - |
| Sunken Lake 221S | 138 | 1x18.10 | 18.10 | - | - |
| Monitor 774S | 138 | 1x18.38+1x27.55 | 45.93 | - | - |
| Hill 751S | 138 | 1x18.12 + 1x22.96 | 41.08 | - | - |
| Lloydminster 716S | 138 | 1x18.12 | 18.12 | - | - |
| Vermilion 710S | 138 | 1x22.96 | 22.96 | - | - |

## 2.7. Voltage Profile Assumptions

The typical voltage set-point for Hansman Lake 650S substation Static VAR Compensator (SVC) is 253 kV and the normal operating range is -20 to 20 MVAr. The typical Lanfine 959S substation SVC set-point is 258 kV with the same MVAr range.

The AESO *Information Document* ID# 2010-007RS was used to establish normal system (i.e. pre-contingency) voltage profiles for all busses in the Study Area prior to commencing any studies. All bus voltages in the Study Cases were established in the 'Desired Range' column of this document. A selection of the key substation voltage ranges from this ID is listed in Table 2-11. Voltage standards listed in Table 2-11 are applied where the ID does not specify voltage ranges for the study region bus nodes.

**Table 2-11: Summary of Voltages at Key Substation in the Study Area**

| Substation Names and Number | Nominal Voltage (kV) | Minimum Operating Limit (kV) | Desired Range (kV) | Maximum Operating Limit (kV) |
|---|---|---|---|---|
| Battle River 757S | 144 | 144 | 146 - 150 | 155 |

| Substation Names and Number | Nominal Voltage (kV) | Minimum Operating Limit (kV) | Desired Range (kV) | Maximum Operating Limit (kV) |
|---|---|---|---|---|
| Cordel 755S | 240 | 253 | 254 - 257 | 260 |
| Nevis 766S | 240 | 246 | 248 - 255 | 265 |
| | 144 | 145 | 149 -152 | 155 |
| Oyen 767S | 144 | 140 | 143 - 146 | 155 |
| Killarney Lake 267S | 138 | 138 | 138-144 | 145 |
| Metiskow 648S | 240 | 250 | 250-260 | 260 |
| | 138 | 140 | 140-144 | 145 |
| Hardisty 377S | 138 | 140 | 140-144 | 145 |
| Lloydminster 716S | 138 | 137 | 142 - 149 | 151 |

# 3. Study Methodology

All studies were performed using the PSS/E software Version 33.

## 3.1. Study Objectives

The objective of this study was to analyze the impacts of connecting the Project to the transmission system upon the following parameters:

- Thermal loading of the branches/transformers in the Study Area under Category A, Category B, and selected Category C5 contingency conditions
- Voltage profile of the Study Area under Category A, Category B, and selected Category C5 contingency conditions
- Voltage stability of the Study Area busses under the increased loading condition
- Short-circuit analysis
- Maximum voltage dip under “across-the-line” starting of one motor at the proposed Battle Sands 594S substation without a Variable Frequency Drive (VFD)

## 3.2. Study Scenarios

The following load scenarios were selected for the Project analyses:

- 2017SP – Pre-connection System

- 2017WP – Pre-connection System
- 2017WP – Post-connection System
- 2024WP – Post-connection System

The pre-connection system is defined as the 2017 system configuration immediately prior to the connection of the Project. The post-connection system is defined as the 2017 system configuration immediately following the connection of the Project and the post-connection system in 2024.

## 3.3. Connection Studies Performed

The following pre-connection analyses were performed:

- Power flow analysis (Category A, B, and selected Category C5 for 2017SP pre-connection and 2017WP pre-connection scenarios)
- Voltage stability analysis (Category A, B, and selected Category C5 for 2017WP pre-connection scenarios)
- Short-circuit analysis (with all generators on, for 2017WP)

The following studies were performed for the post-connection analysis: [6]

- Short-circuit analysis (with all generators on, for 2017WP and 2024WP)
- Motor starting analysis (Category A, B, and selected Category C5 for 2017WP post-connection scenarios)

## 3.4. Power Flow Analysis

Pre-connection power flow analysis was performed to assess the system performance for Category A, Category B, and selected Category C5 contingencies within the Study Area and for the tie lines from the Study Area to the surrounding areas. All branches in the Study Area at 69 kV and above and all tie lines to the surrounding areas were monitored for thermal violation. All busses within the Study Area at 69 kV and above were monitored for voltage violation.

### 3.4.1. Contingencies Studied for Power Flow Analysis

The study included all Category B and selected Category C5 contingencies (69 kV and above) within the Study Area and for the tie lines from the Study Area to the surrounding areas shown in Table 3-1.

[6] The Project connection will not impact the customer DTS; therefore, post-connection power flow analysis was not undertaken.

**Table 3-1: Contingencies Found in the Power Flow and the Voltage Stability Analyses**

| System Condition | Contingency | From Substation | To Substation |
|---|---|---|---|
| Category B (N-1) | 7L130 | Vermillion 710S | Kitscoty 705S |
| Category B (N-1) | 7L14 | Kitscoty 705S | Hill 751S |
| Category B (N-1) | 749L | Metiskow 648S | Edgerton 899S |
| Category B (N-1) | Edgerton 899S - T3 | Edgerton 899S | Edgerton 899S |
| Category B (N-1) | 681L | Hardisty 377S | Tucuman 478S |
| Category B (N-1) | 702L/7L702 | Hardisty 377S | Battle River 757S |
| Category B (N-1) | 703L/703BL/703AL | Metiskow 648S | Sunken Lake 221S/Hardisty 377S |
| Category C5 (N-2) | 9L953/953L/1047L | Nilrem 574S | Hansman Lake 650S/Cordel 755S |
| Category C5 (N-2) | 679L/680L | Nilrem 574S | Tucuman 478S |

## 3.5. Voltage Stability Analysis

The objective of the voltage stability analysis is to determine the ability of a power system to maintain acceptable voltages at the busses in the system under normal conditions and after being subjected to a contingency. In the study, PV (Power-Voltage) voltage stability analysis was performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology, as described in detail in the AESO Alberta Reliability Standards. The reference load level is the forecasted peak load level. The WECC voltage stability criteria states, “for load areas, post-transient voltage stability is required for the area modelled at a minimum of 105% of the reference load level for the system normal conditions (Category A) and for single contingencies (Category B). For multiple contingencies (Category C), post-transient voltage stability is required with the area modelled at a minimum of 102.5% of the reference load level.”[7]

The studies were performed using the PV method as follows:

- The PV analysis was performed by increasing load in the Wainwright area and increasing generation in the areas remote from the Study Area (i.e., AESO Planning Areas 6, 30, 33, 35, 40, 43, 53, 54, 55, 57 and 60).
- The analysis was performed with all discrete switched capacitors and reactors, LTC transformers and phase shifting transformers locked.

[7] *System Performance Regional Business Practice, TPL–001–WECC–RBP–2.1*, developed by Western Electricity Coordinating Council (WECC), https://www.wecc.biz/Reliability/TPL-001-WECC-RBP-2.1.pdf

- Results were generated for the Category A, Category B, and selected Category C5 contingencies and the worst-case contingencies as identified by power flow studies.

## 3.6. Short-Circuit Analysis

All generators in Study Area and the neighboring area were switched on to evaluate the maximum fault current under three-phase and single-line-to-ground faults for the short-circuit analysis.

The automatic sequencing fault calculation function in PSS/E 33 was used to perform the study.

## 3.7. Motor Starting Analysis

Motor starting analysis was performed for the proposed motors under system normal (Category A) conditions and worst case contingencies identified in the voltage stability and power flow analyses. The analysis considered the starting of one motor, with its VFD out of service, while the other motors were running at full load.

# 4. Pre-Connection System Assessment

## 4.1. Pre-Connection Power Flow Analysis

The steady-state performance was assessed under the 2017SP and 2017WP pre-connection scenarios. The power flow analyses were based on the Reliability Criteria, System Data and Study Assumptions as described in Section 2.

### 4.1.1. 2017SP Scenario

The steady state performance of the system under normal conditions (Category A), single contingency (Category B), and selected Category C5 contingencies was assessed using the 2017SP pre-connection scenario.

**Results for System Normal Category A:**

No thermal loading or voltage violation was observed for the 2017SP pre-connection scenario.

**Results for System Category B and Selected Category C5:**

No voltage violation was observed for the 2017SP pre-connection scenario. A number of thermal loadings above the continuous 100% thermal limit were observed for the 2017SP pre-connection scenario under several Category B contingencies and consist of the following:

- The 2017SP case with the contingency of Metiskow 648S substation transformer T1 did not converge in the PSS/E simulation. There are no breakers separating the AIES from T1. As a result, the transformer contingency will trip the 138 kV transmission lines 749L, 703L, and 885L simultaneously. This contingency would cause loss of load in the local area and is currently managed by the AESO and TFO real time operating practices.
- The 138 kV transmission line 749L (Metiskow 648S to the Killarney Tap Point) shows a thermal loading of 108.5% for the contingency of 138 kV transmission line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation). This is below the emergency rating of the 138 kV transmission line 749L. This thermal loading is mitigated in real time by the AESO and TFO operating practices.
- The 138 kV transmission line 749L also shows a thermal loading of 105.6% when there is an outage to the 138 kV transmission line 7L14 (from the Kitscoty 705S substation to the Hill 751S substation). This is below the emergency rating of the 138 kV transmission line 749L.This thermal loading is mitigated in real time by the AESO and TFO operating practices.
- The 138 kV transmission line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation) shows a thermal loading of 112.1% for the contingency of the 138 kV transmission line 749L (from the Metiskow 648S substation to the Edgerton 899S substation). This is above the emergency rating of the 138 kV transmission line 7L130. Under this contingency, the area load is fed radially through line 138 kV transmission line 7L130. This thermal loading will be mitigated in real time by the AESO and TFO operating practices.
- The 138 kV transmission line 7L14 (from the Kitscoty 705S substation to the Hill 751S substation) shows a thermal loading of 105.5% for the contingency of 138 kV transmission line 749L (from the Metiskow 648S substation to the Edgerton 899S substation). This is above the emergency rating of the 138 kV transmission line 7L14. Under this contingency, the area load is fed radially through the 138 kV transmission line 7L14. This thermal loading is mitigated in real time by the AESO and TFO operating practices.
- The 138 kV transmission lines 7L130 and 7L14 also show thermal loadings of 106.2% and 100.9%, respectively for the contingency Edgerton 899S substation transformer T3. These thermal loadings are above the emergency ratings (see Table 2-8). Under this contingency, the area load is fed radially through line 138 kV transmission lines 7L130 and 7L14. This thermal loading will be mitigated in real time by the AESO and TFO operating practices.

The results of the power flow analysis are shown in Table 4-1. The power flow single line diagrams (SLDs) are presented in Attachment A.

**Table 4-1: 2017SP Pre-Connection Category B Line Loadings**

| Contingency | Branch | 2017SP Pre-Connection | | |
|---|---|---|---|---|
| | | Nominal Line Rating (MVA) | Power Flow (MVA) | % Loading |
| Category B: 138 kV transmission line 7L130 (Vermillion 710S substation to Kitscoty 705S substation) | 749L (Metiskow 648S substation to Killarney Tap Point) | 120.9 | 131.2 | 108.5 |
| Category B: 138 kV transmission line 7L14 (Kitscoty 705S substation to Hill 751S substation) | 749L (Metiskow 648S substation to Killarney Tap Point) | 120.9 | 127.7 | 105.6 |
| Category B: 138 kV transmission line 749L (Metiskow 648S substation to Edgerton 899S substation) | 7L130 (Vermillion 710S substation to Kitscoty 705S substation) | 71.9 | 80.6 | 112.1 |
| | 7L14 (Kitscoty 705S substation to Hill 751S substation) | 71.9 | 75.9 | 105.5 |
| Category B: Edgerton 899S substation Transformer T3* | 7L130 (Vermillion 710S substation to Kitscoty 705S substation) | 71.9 | 76.4 | 106.2 |
| | 7L14 (Kitscoty 705S substation to Hill 751S substation) | 71.9 | 72.6 | 100.9 |

* The transformer does not have a high side breaker and will trip the high voltage bus, taking several transmission lines out of service.

### 4.1.2. 2017WP Scenario

The steady state performance of the system under normal conditions, single contingency and selected Category C5 contingency was assessed using the 2017WP pre-connection scenario.

**Results for System Normal Category A:**

No thermal loading or voltage violation was observed for the 2017WP pre-connection scenario.

**Results for System Category B and Selected Category C5:**

No voltage violation was observed for the 2017WP pre-connection scenario.

Thermal loading above the continuous 100% thermal limit was observed for the 2017WP pre-connection scenario and consists of the following:

- The 2017WP case with the contingency of Metiskow 648S substation transformer T1 did not converge in the PSS/E simulation. There are no breakers separating the AIES from T1. As a result, the transformer contingency will trip the 138 kV transmission lines 749L, 703L, and 885L simultaneously. This contingency would cause loss of load in the local area and is currently managed by the AESO and TFO real time operating practices.

- The 138 kV transmission line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation) shows thermal loading of 103.7% for the contingency of the 138 kV transmission line 749L (from Metiskow 648S substation to Edgerton 899S substation). This line loading is above the emergency rating of the 138 kV transmission line 7L130. Under this contingency the area load is fed radially through the 138 kV transmission line 7L130. This thermal loading is mitigated in real time by the AESO and TFO operating practices.

The results of the 2017WP pre-connection scenario power flow analysis are shown in Table 4-2. The power flow SLDs are presented in Attachment A.

**Table 4-2: 2017WP Pre-Connection Category B Transmission Line Loading**

| Contingency | Branch | 2017WP Pre-Connection | | |
|---|---|---|---|---|
| | | Nominal Rating (MVA) | Power Flow (MVA) | % Loading |
| Category B: 138 kV transmission line 749L (from the Metiskow 648S substation to the Edgerton 899S substation) | 138 kV transmission line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation) | 86.3 | 89.5 | 103.7 |

## 4.2. Voltage Stability Analysis

To estimate the maximum load that can be served while meeting the performance requirements of the AESO Reliability Criteria, a PV analysis was conducted using the 2017WP pre-connection scenario to identify the worst-case contingency conditions. The analysis was performed under the following conditions.

- Pre-connection
- Under Category B and selected Category C5 contingencies

Table 4-3 lists the worst-case contingency scenarios used in the voltage stability analysis.

**Table 4-3: Worst Contingency Scenarios**

| Contingency | Category | Transmission Line | Line Voltage (kV) | From | To |
|---|---|---|---|---|---|
| 681L | B | 681L | 138 | Hardisty 377S | Tucuman 478S |
| 9L953 and 1047L | C5 | 9L953 | 240 | Nilrem 574S | Cordel 755S |
| | | 1047L | 240 | Nilrem 574S | Hansman Lake 650S |
| 679L and 680L | C5 | 679L | 138 | Nilrem 574S | Tucuman 478S |

| Contingency | Category | Transmission Line | Line Voltage (kV) | From | To |
|---|---|---|---|---|---|
| | | 680L | 138 | Nilrem 574S | Tucuman 478S |
| 702L | B | 702L | 138 | Sedgewick 137S | Hardisty 377S |
| | | 702L | 138 | Sedgewick 137S | Battle River 757S |
| 703L | B | 703L | 138 | 703AL Tap Point | Metiskow 648S |
| | | 703L | 138 | 703AL Tap Point | Sunken Lake 221S |
| | | 703L | 138 | 703AL Tap Point | Hansman Lake 650S |
| | | 703L | 138 | Express Tap Point | HRT Express 329S |
| | | 703L | 138 | Express Tap Point | Hughenden 213S |
| | | 703L | 138 | Express Tap Point | Hardisty 377S |

The initial 2017WP pre-connection load (reference load) in the Wainwright area is 205.50 MW.

The sink sub-system included only the loads in the Wainwright area.

The source sub-system was chosen to consist of the surrounding and neighbouring generation in the AESO Planning Areas 6, 30, 33, 35, 40, 43, 57, 60, 53, 54, and 55. The PV analysis was performed with the switched capacitors, reactors and transformer taps locked. The results of PV analysis confirm that there is no voltage stability violation prior to the connection of the proposed development. The Wainwright area voltage stability results under Category A, Category B, and selected Category C5 system conditions are given in Attachment B.

# 5. Connection Alternatives

## 5.1. Overview

Four connection alternatives were identified for the Project. For each of the four alternatives the addition of a 138 kV breaker at Rosyth 296S substation has been included. This breaker will improve reliability by ensuring the isolation of local faults at Rosyth 296S substation from the rest of 138 kV transmission system.

**Alternative 1: T-Tap Connection to the 138 kV Transmission Line 769L**

This alternative includes:

- Connecting the proposed Enbridge Battle Sands 594S substation to the existing 138 kV transmission line 769L through a T-tap configuration between the Rosyth

296S substation and the 138 kV transmission line 769AL T-tap that connects the Clipper 656S substation to 138 kV transmission line 769L.

**Alternative 2: Radial Connection to the Rosyth 296S or the Clipper 656S Substations**

This alternative includes:

- Connecting the proposed Enbridge Battle Sands 594S substation radially to the existing Rosyth 296S or Clipper 656S substation.
- Adding a new 138 kV bay to the Rosyth 296S or Clipper 656S substation to supply Battle Sands 594S substation.

**Alternative 3: In-and-Out Connection to the 138 kV Transmission Line 769L**

This alternative includes:

- Connecting the proposed Enbridge Battle Sands 594S substation to the existing 138 kV transmission line 769L by an in-and-out configuration through a new switching station.
- Constructing a new switching station located adjacent to the Battle Sands 594S substation, which will consist of two incoming 138 kV bays to terminate the 138 kV transmission line 769L and one bay to terminate the outgoing 138 kV transmission line to Battle Sands 594S substation. The new switching station will include three 138 kV circuit breakers.

**Alternative 4: In-and-Out Connection to the 138 kV Transmission Line 703L**

This alternative includes:

- Connecting the proposed Enbridge Battle Sands 594S substation to the existing 138 kV transmission line 703L by an in-and-out configuration through a new switching station.
- Constructing a new switching station located adjacent to the Battle Sands 594S substation, which will consist of two incoming 138 kV bays to terminate the 138 kV transmission line 703L and one bay to terminate the outgoing 138 kV transmission line to the Battle Sands 594S substation. The new switching station will include three 138 kV circuit breakers.

## 5.2. Evaluation of Connection Alternatives

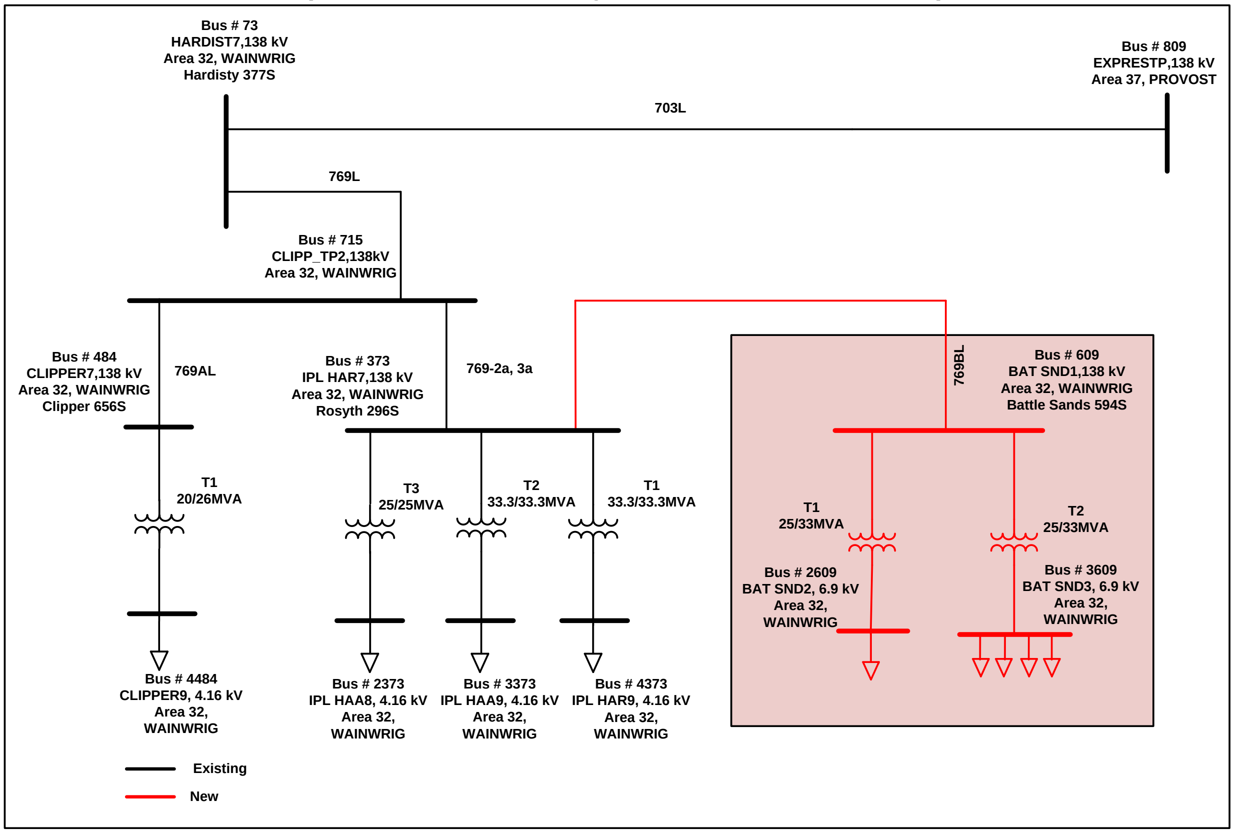
### 5.2.1. Connection Alternatives Eliminated

As indicated below, Alternatives 2, 3, and 4 were ruled out and were not selected for further studies, as they were either not considered viable due to space constraints or had significantly higher capital costs.

#### 5.2.1.1. Alternative 2

Alternative 2 was ruled out because there is no space within the Rosyth 296S or Clipper 656S substation to accommodate an additional circuit breaker bay and there are right-of-way constraints surrounding the existing substations (see Figure 5-1).

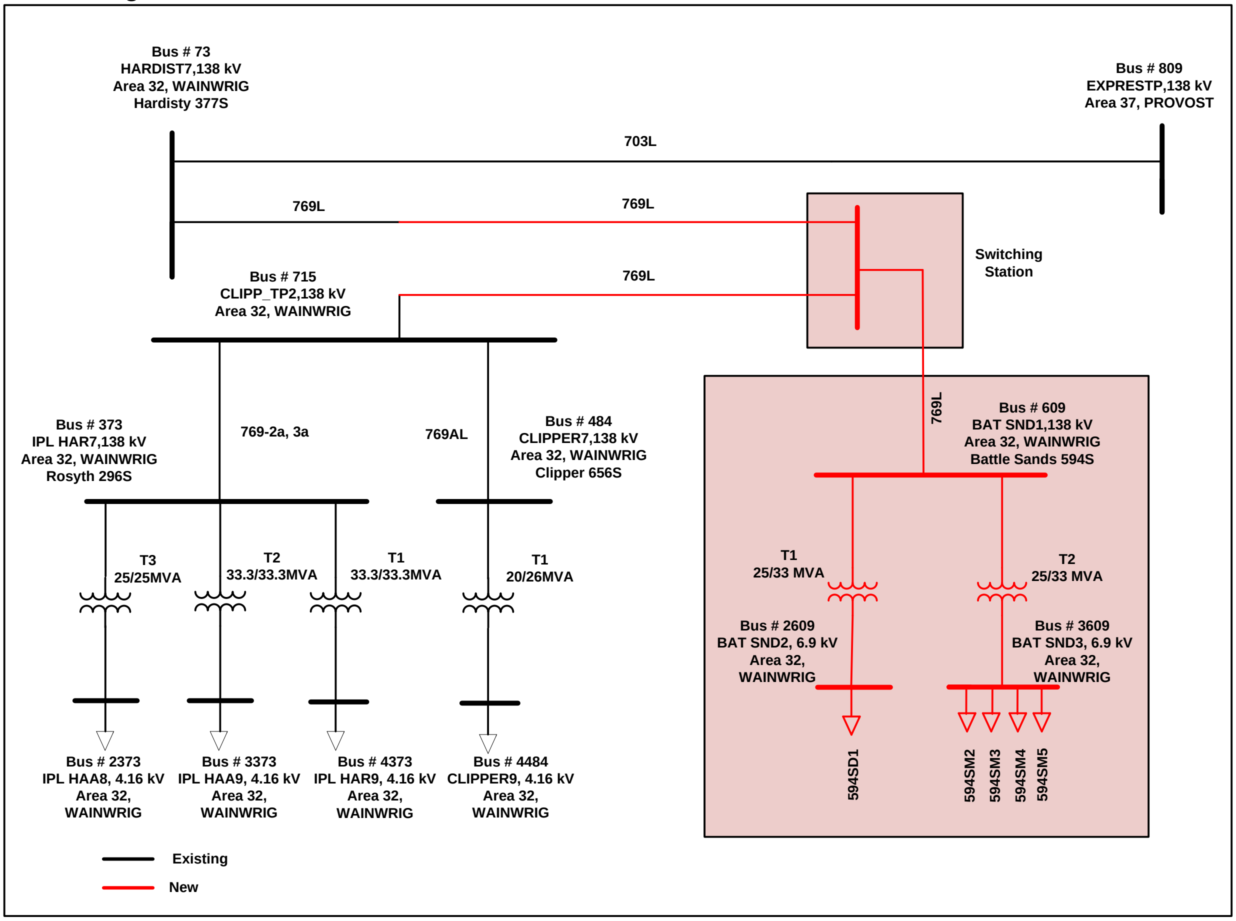
**Figure 5-1: Alternative 2 – Radial Connection from Rosyth 296S (or Clipper 656S) Substation (connection to the Rosyth 296S substation shown)**




#### 5.2.1.2. Alternative 3

Alternative 3 was ruled out because it would require two circuits and an additional TFO switching station (see Figure 5-2), and hence would result in a higher capital cost than Alternative 1. This in-and-out configuration on the radial 138 kV transmission line 769L would not result in any improvement in reliability for the Customer.

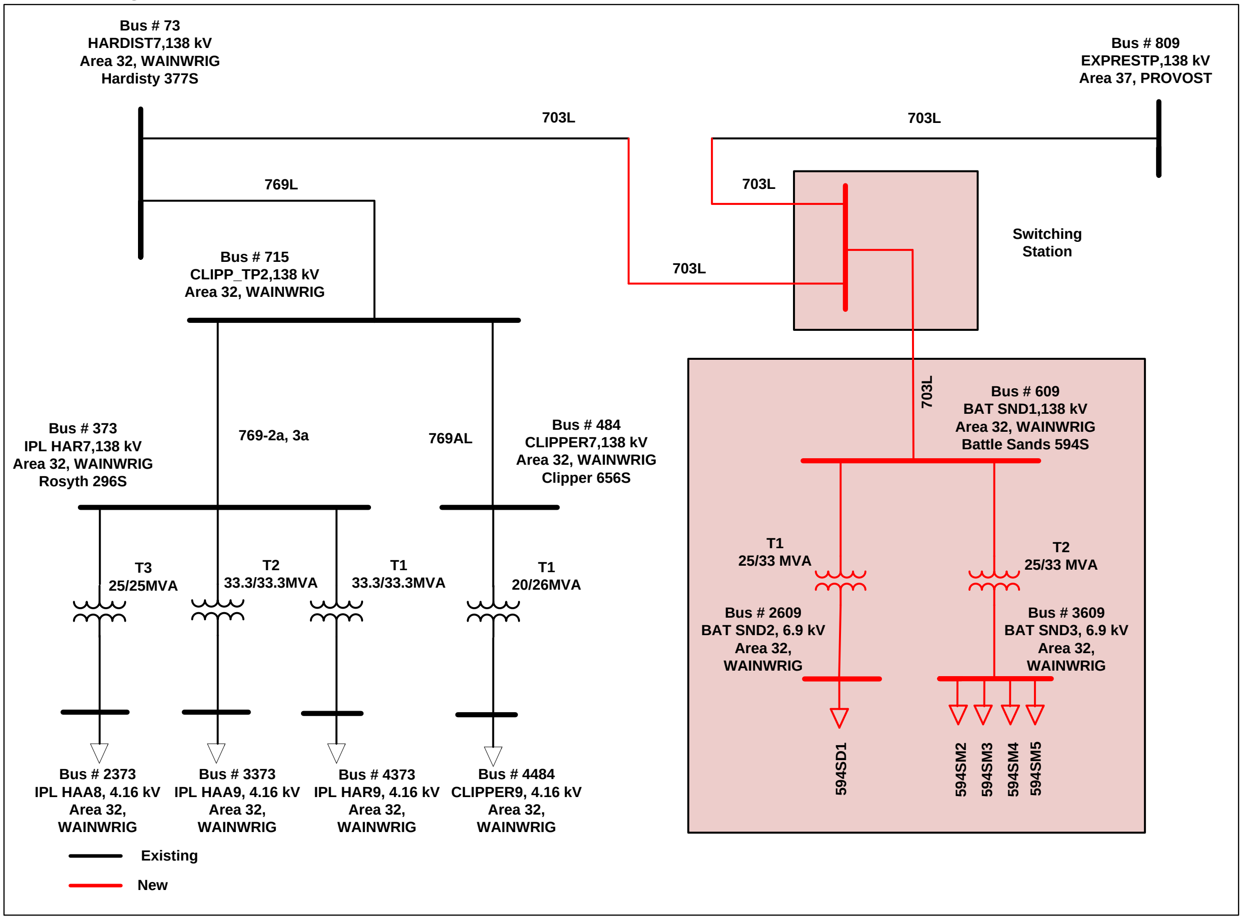
**Figure 5-2: Alternative 3 – In-and-Out Connection to 138 kV Transmission Line 769L**




### 5.2.1.3. Alternative 4

Alternative 4 is similar to Alternative 3 in that it would also require two circuits and an additional TFO switching station (see Figure 5-3), and hence would result in a higher capital cost than Alternative 1. An improvement in reliability for the Customer over Alternative 1 is possible because 138 kV transmission line 703L is capable of being fed from both ends. However this advantage is not considered significant due to the overall system configuration in the area, therefore Alternative 4 was rejected.

**Figure 5-3: Alternative 4 – In-and-Out Connection to 138 kV Transmission Line 703L**



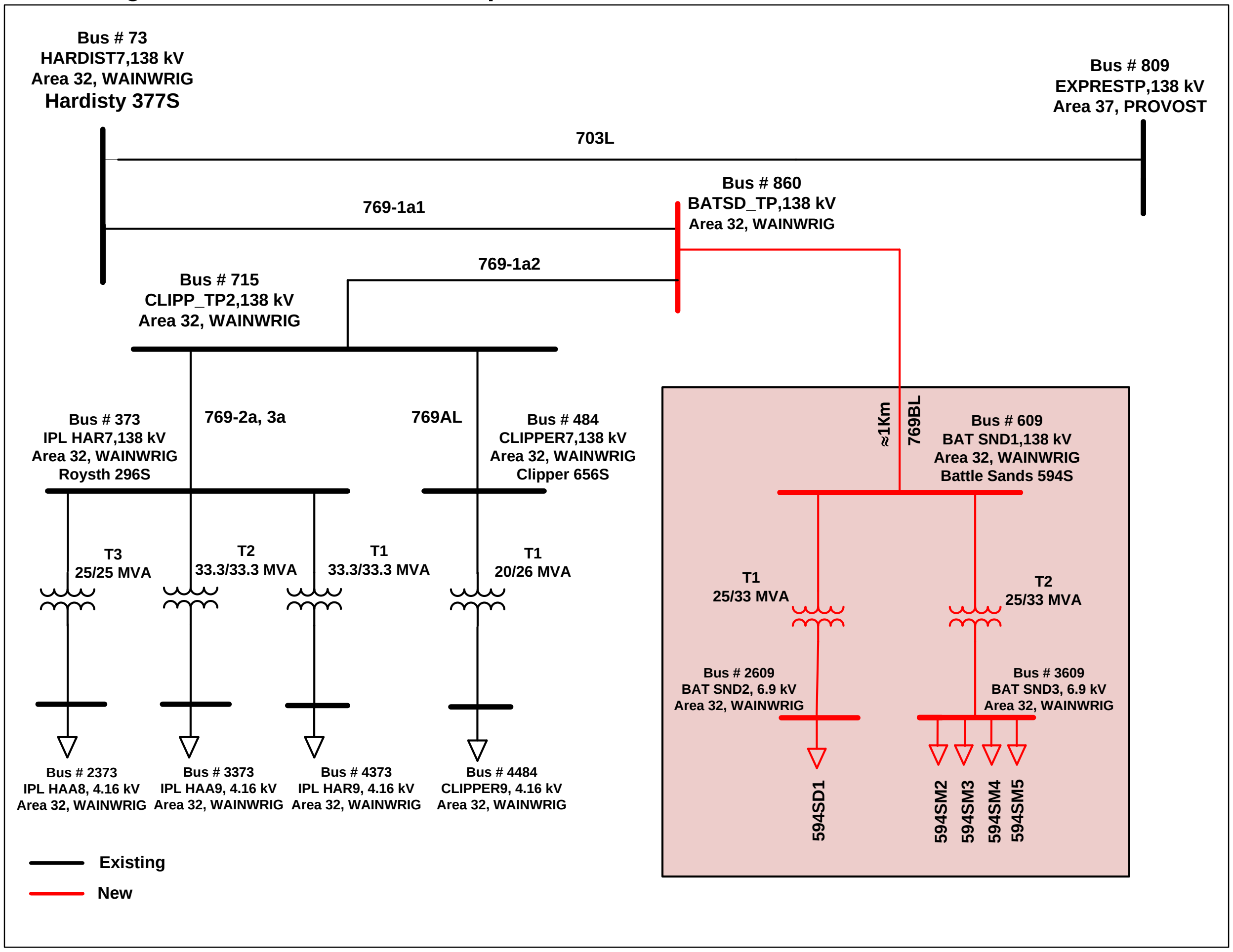

## 5.2.2. Connection Alternative Selected for Further Studies

The connection alternative selected for further studies was Alternative 1.

### 5.2.2.1. Alternative 1

Alternative 1 includes connecting the proposed Battle Sands 594S substation to the existing 138 kV transmission line 769L through a T-tap configuration between the Rosyth 296S substation and the 138 kV transmission line 769AL T-tap that connects the Clipper 656S substation to 138 kV transmission line 769L. Figure 5-4 shows the connection diagram for Alternative 1.

**Figure 5-4: Alternative 1 – T-Tap Connection to the 138 kV Transmission Line 769L**




Figures 5-1 to 5-4 contain simplified versions of the system configuration. Technical detail has been reduced for illustration purposes. It does not indicate geographical location of facilities.

# 6. Technical Analysis of the Connection Alternative

## 6.1. Power Flow Analysis

The Project connection will not impact the customer DTS. As a result, post-connection power flow analysis is expected to yield the same results as pre-connection; therefore, post-connection power flow analysis was not undertaken.

### 6.2. Voltage Stability Analysis

The Project will not impact the DTS on the radial 138 kV transmission line 769L. As a result, post-connection voltage stability analysis is expected to yield the same results as pre-connection; therefore, post-connection voltage stability analysis was not undertaken.

## 7. Short-Circuit Analysis

The short-circuit analysis involved calculating three-phase and single-line-to-ground fault current levels for the substations in the Study Area.[8]

### 7.1. Pre-Connection Short-Circuit Analysis

Short-circuit analysis was performed using the 2017WP pre-connection scenario. The results of the short-circuit analysis are shown in Table 7-1.

**Table 7-1: Pre-Connection Short-Circuit Current Levels (2017WP)**

| Substation / Tap Point | Bus | Base Voltage (kV) | Pre-Fault Voltage (kV) | Pre-Fault Voltage (pu) | 3-Phase Fault (A) | Single-line-to-ground Fault (A) | Positive Sequence Impedance (pu) | Zero Sequence Impedance (pu) |
|---|---|---|---|---|---|---|---|---|
| Hardisty 377S | 73 | 138 | 143.20 | 1.0377 | 6943.1 | 5950.3 | 0.02182+j0.05860 | 0.02247+j0.09117 |
| Rosyth 296S | 373 | 138 | 143.00 | 1.0361 | 6671.9 | 5602.2 | 0.02295+j0.06078 | 0.02485+j0.09918 |
| Clipper 656S | 484 | 138 | 143.00 | 1.0361 | 6657.3 | 5582.9 | 0.02300+j0.06090 | 0.02499+j0.09971 |
| Clipper Tap Point | 715 | 138 | 143.00 | 1.0361 | 6682.7 | 5615.3 | 0.02290+j0.06069 | 0.02478+j0.09890 |
| Express Tap Point | 809 | 138 | 143.20 | 1.0374 | 6732.0 | 5662.0 | 0.02272+j0.06033 | 0.02433+j0.09815 |

Note: Pu values have been calculated using base voltage and 100 MVA as base power.

### 7.2. Alternative 1 Post-Connection Short-Circuit Analysis

Short-circuit analysis was performed using 2017WP and 2024WP post-connection scenarios to determine the fault levels after the proposed T-tap connection to line 769L.

[8] The information provided in the study should not be used as the sole source of information for electrical equipment specifications or for the design of safety-grounding systems. Short-circuit analysis was based on modelling information provided to the AESO by third parties. The authenticity of the modelling information has not been validated. Fault levels could change as a result of system developments, new customer connections, or additional generation in the area. It is recommended that these changes be monitored and fault levels reviewed to ensure that the fault levels are within equipment operating limits.

The results of the short-circuit analysis for Alternative 1 are shown in Table 7-2 and Table 7-3.

**Table 7-2: Post-Connection Short-Circuit Current Levels for Alternative 1 (2017WP)**

| Substation / Tap Point | Bus | Base Voltage (kV) | Pre-Fault Voltage (kV) | Pre-Fault Voltage (pu) | 3-Phase Fault (A) | Single-line-to-ground Fault (A) | Positive Sequence Impedance (pu) | Zero Sequence Impedance (pu) |
|---|---|---|---|---|---|---|---|---|
| Hardisty 377S | 73 | 138 | 142.20 | 1.0306 | 6960.3 | 6022.3 | 0.02143+j0.05813 | 0.02095+j0.08855 |
| Rosyth 296S | 373 | 138 | 142.00 | 1.0292 | 6684.8 | 5664.6 | 0.02257+j0.06033 | 0.02334+j0.09657 |
| Clipper 656S | 484 | 138 | 142.00 | 1.0292 | 6670.1 | 5643.8 | 0.02263+j0.06046 | 0.02348+j0.09711 |
| Clipper Tap Point | 715 | 138 | 142.00 | 1.0293 | 6695.8 | 5677.1 | 0.02253+j0.06023 | 0.02327+j0.09629 |
| Express Tap Point | 809 | 138 | 142.20 | 1.0306 | 6746.4 | 5722.9 | 0.02234+j0.05986 | 0.02287+j0.09561 |
| Battle Sands | 609 | 138 | 142.00 | 1.0288 | 6445.2 | 5368.4 | 0.02362+j0.06246 | 0.02558+j0.10401 |

Note: Pu values have been calculated using base voltage and 100 MVA as base power.

**Table 7-3: Post-Connection Short-Circuit Current Levels for Alternative 1 (2024WP)**

| Substation / Tap Point | Bus | Base Voltage (kV) | Pre-Fault Voltage (kV) | Pre-Fault Voltage (pu) | 3-Phase Fault (A) | Single-line-to-ground Fault (A) | Positive Sequence Impedance (pu) | Zero Sequence Impedance (pu) |
|---|---|---|---|---|---|---|---|---|
| Hardisty 377S | 73 | 138 | 145.08 | 1.0513 | 7579.5 | 6469.7 | 0.0193+j0.0547 | 0.0195+j0.0858 |
| Rosyth 296S | 373 | 138 | 144.89 | 1.0499 | 7259.3 | 6066.3 | 0.0195+j0.0858 | 0.0219+j0.0938 |
| Clipper 656S | 484 | 138 | 144.89 | 1.0499 | 7242.3 | 6042.9 | 0.0219+j0.0938 | 0.0221+j0.0943 |
| Clipper Tap | 715 | 138 | 144.89 | 1.0499 | 7272 | 6080.3 | 0.0204+j0.0569 | 0.0218+j0.0935 |
| Express Tap | 809 | 138 | 145.06 | 1.0511 | 7333.6 | 6131.6 | 0.0202+j0.0565 | 0.0215+j0.0929 |
| Battle Sands | 609 | 138 | 144.82 | 1.0495 | 6982.9 | 5734.1 | 0.0215+j0.0591 | 0.0242+j0.1012 |

Note: Pu values have been calculated using base voltage and 100 MVA as base power.

It can be seen from Table 7-2 and Table 7-3 that Alternative 1 does not negatively impact the short-circuit current levels in the Study Area.

# 8. Motor Starting Analysis

Motor starting analysis was performed to assess the feasibility of the "across-the-line" starting of the 7,000 HP motors at the proposed Battle Sands 594S substation. Although Enbridge has indicated that VFDs will be used to start the motors, the analysis assesses the voltage dip at the transmission busses in the case of a VFD failure (VFD by-pass condition) and to determine if starting restrictions would be imposed.

Motor starting analysis was conducted for the start-up of a single motor with all other motors in the station already running at full load. All four motors were supplied by one 138/6.9 kV, 25/33 MVA transformer. The 2017WP post-connection scenario was used in the analysis. The analysis were based on the dynamic analysis method in PSS/E 33.

Table 8-1 shows the nameplate data of the 7,000 HP induction motors.

**Table 8-1: Motor Nameplate and Calculated Data**

| Motor Rating | Value |
|---|---|
| Rated power | 7,000 HP |
| Rated voltage | 6,600 V |
| Rated current | 516 A |
| Rated speed | 1780 rpm |
| Rated torque | 20,676 lb-ft |
| Nominal power factor | 0.92 |
| Nominal efficiency | 0.964 |
| Moment of inertia (motor) | 4667 lb-ft$^2$ |
| Moment of inertia (Driven Machine) | 400 lb-ft$^2$ |
| Locked-rotor torque | 75.7% |
| Breakdown torque | 196.2% |
| Locked-rotor current | 650% |
| MVA base | 5.889 MVA |
| Rated motor speed pu | 0.9889 |
| Driven machine torque pu @ n=ns | 0.8 |
| H (combined motor and driven machine) | 0.6297 |

Figure 8-1 shows the equivalent circuit that was used to model the motors.

**Figure 8-1: Equivalent Circuit of Induction Motor**

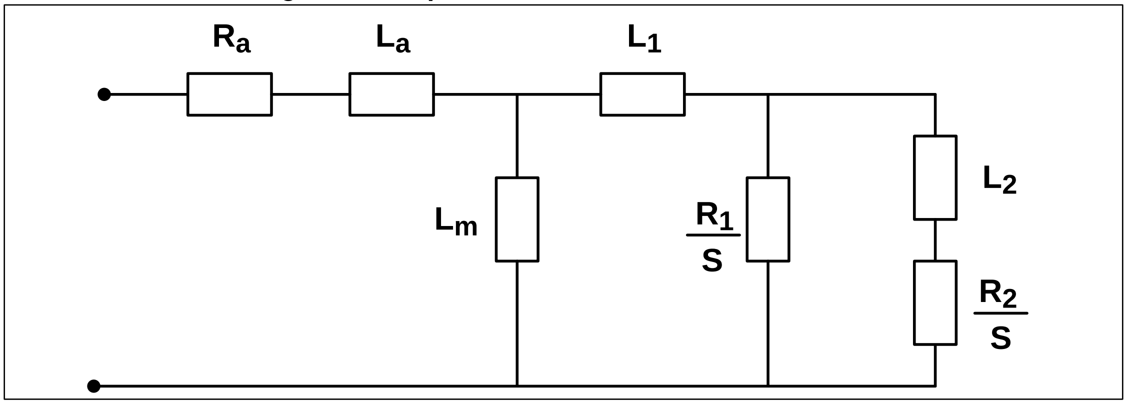



Table 8-2 lists the equivalent circuit parameters.

**Table 8-2: Equivalent Circuit Data**

| Equivalent Circuit Parameter | Value in Per Unit |
|---|---|
| $R_a$ | 0.037 |
| $L_a$ | 0.071 |
| $L_m$ | 3.4 |
| $R_1$ | 0.025 |
| $L_1$ | 0.07 |
| $R_2$ | 0.0195 |
| $L_2$ | 0.024 |

## 8.1. Motor Starting Assumptions

The following assumptions were used in conducting motor starting analysis:

- The transient voltage dip at the 138 kV transmission bus should not exceed 5% when starting a single motor.
- The motors will not start simultaneously. Only one motor will be allowed to start in VFD bypass mode while the other motors are running at full load.
- Motor starting was investigated for the following system scenario:
  - 2017WP Post-connection Alternative 1

## 8.2. Motor Starting Results for Alternative 1

Motor starting analysis was conducted for the 2017WP post-connection Alternative 1 configuration. The analysis was conducted under system normal Category A and critical contingency conditions extracted from the power flow analysis. Table 8-3 shows the summary for Alternative 1.

**Table 8-3: Motor Starting Performance for Alternative 1**

| Condition | Contingency | Substation | | Proposed Battle Sands 594S Substation Nominal Voltage (kV) | Before Motor Start (kV) | After Motor Start (kV) | Voltage Dip (kV) | % Voltage Dip |
|---|---|---|---|---|---|---|---|---|
| | | From | To | | | | | |
| Category A (N-0) | Normal | N/A | N/A | 138 | 142.83 | 139.66 | 3.17 | 2.22 |
| Category B (N-1) | 681L | Hardisty 377S | Tucuman 478S | 138 | 129.38 | 123.86 | 5.52 | 4.27 |
| Category C5 (N-2) | 679L and 680L | Nilrem 574S | Tucuman 478S | 138 | 129.38 | 123.86 | 5.52 | 4.27 |
| Category C5 (N-2) | 953L and 1047L | Nilrem 574S | Hansman Lake 650S/ Cordel 755S | 138 | 126.01 | 120.57 | 5.44 | 4.31 |
| Category B (N-1) | 702L | Hardisty 377S | Battle River 757S | 138 | 129.38 | 123.86 | 5.52 | 4.27 |
| Category B (N-1) | 703L | Metiskow 648S | Sunken Lake 221S/ Hardisty 377S | 138 | 129.38 | 123.86 | 5.52 | 4.27 |

The motor starting results show that the voltage dip caused by “across-the-line” motor starting at the proposed Battle Sands 594S substation 138 kV bus is below 5% under both system normal and contingency conditions. The simulation results suggest that the impact on the voltage due to “across-the-line” starting of one motor is acceptable. The induction motor curves and the voltages at the proposed Battle Sands 594S substation busses are provided in Attachment C.

# 9. Project Interdependencies

The Project is not dependent on any other planned developments in the Study Area.

# 10. Summary and Conclusion

Enbridge submitted a SASR to the AESO requesting the connection of the proposed Enbridge Battle Sands 594S substation. The substation DTS will be totalized with the DTS at the Rosyth 296S and Clipper 656S substations. The requested ISD for the connection to the proposed Battle Sands 594S substation is July 1, 2017.

The Project to connect the proposed Battle Sands 594S substation is located in the Wainwright area, near the Hardisty 377S, Rosyth 296S, and Clipper 656S substations. The Rosyth 296S and Clipper 656S substations only serve Enbridge load. The Rosyth 296S substation is fed radially from the Hardisty 377S substation via the 138 kV transmission line 769L. The Clipper 656S substation is connected to the 138 kV transmission line 769L through a T-tap, designated 138 kV transmission line 769AL.

Four possible alternatives were identified to meet the needs of the Project. Only one of the four alternatives, Alternative 1, was selected for further study. Three of the alternatives were eliminated either due to space constraints or because they would require more facilities and hence result in higher capital costs than Alternative 1.

Alternative 1 consists of a tapped connection, designated 138 kV transmission line 769BL, from the existing 138 kV transmission line 769L to the proposed Battle Sands 594S substation between Rosyth 296S substation and Clipper 656S substation T-tap, 138 kV transmission line 769AL.

This Engineering Study Report details the system performance studies undertaken to assess the impact of the connection of the proposed Battle Sands 594S substation on the AIES. In order to identify the existing system constraints, pre-connection power flow and voltage stability analyses were performed. No voltage violation was observed in the power flow analysis for the 2017SP and 2017WP pre-connection scenarios. A number of thermal loadings above the continuous 100% thermal limit were observed for the 2017SP and 2017WP pre-connection scenarios, under several Category B contingencies. These thermal loadings are existing and known to the AESO. They are currently being mitigated in real time by the AESO and TFO operating practices. The results of voltage stability analysis confirm that there is no voltage stability violation prior to the connection of the proposed development.

The connection of the Battle Sands 594S substation will not impact the customer's DTS. As a result, post-connection power flow and voltage stability analyses are expected to yield the same results as the pre-connection analyses. Therefore, post-connection power flow and voltage stability analyses were not undertaken.

The post-connection short-circuit and motor starting analyses were performed in order to identify post-connection system constraints of Alternative 1.

The short-circuit analysis showed that Alternative 1 does not negatively impact short-circuit current levels. The motor starting analysis results show that the impact of "across-the-line" starting of one motor, in VFD bypass mode, is acceptable during both system normal (Category A) and contingency (Category B and C5) conditions.

The results of the engineering study indicate that Alternative 1, a tapped connection to radial 138 kV transmission line 769L, will not adversely impact the AIES in the Study Area. Based on these results, Teshmont recommends Alternative 1 to meet the request for a connection to Enbridge's proposed Battle Sands 594S substation.

# 11. Revision History

| Revision | Issue Date | Author | Change Tracking |
|---|---|---|---|
| Revision 04 | 2015-10-15 | Ashraf Haque | Final Draft |
| Revision 03 | 2015-10-08 | Ashraf Haque | Fourth Draft |
| Revision 02 | 2015-09-25 | Ashraf Haque | Third Draft |
| Revision 01 | 2015-08-07 | Ashraf Haque | Second Draft |
| Revision 00 | 2015-06-24 | Mahmud Rashid | First Draft |

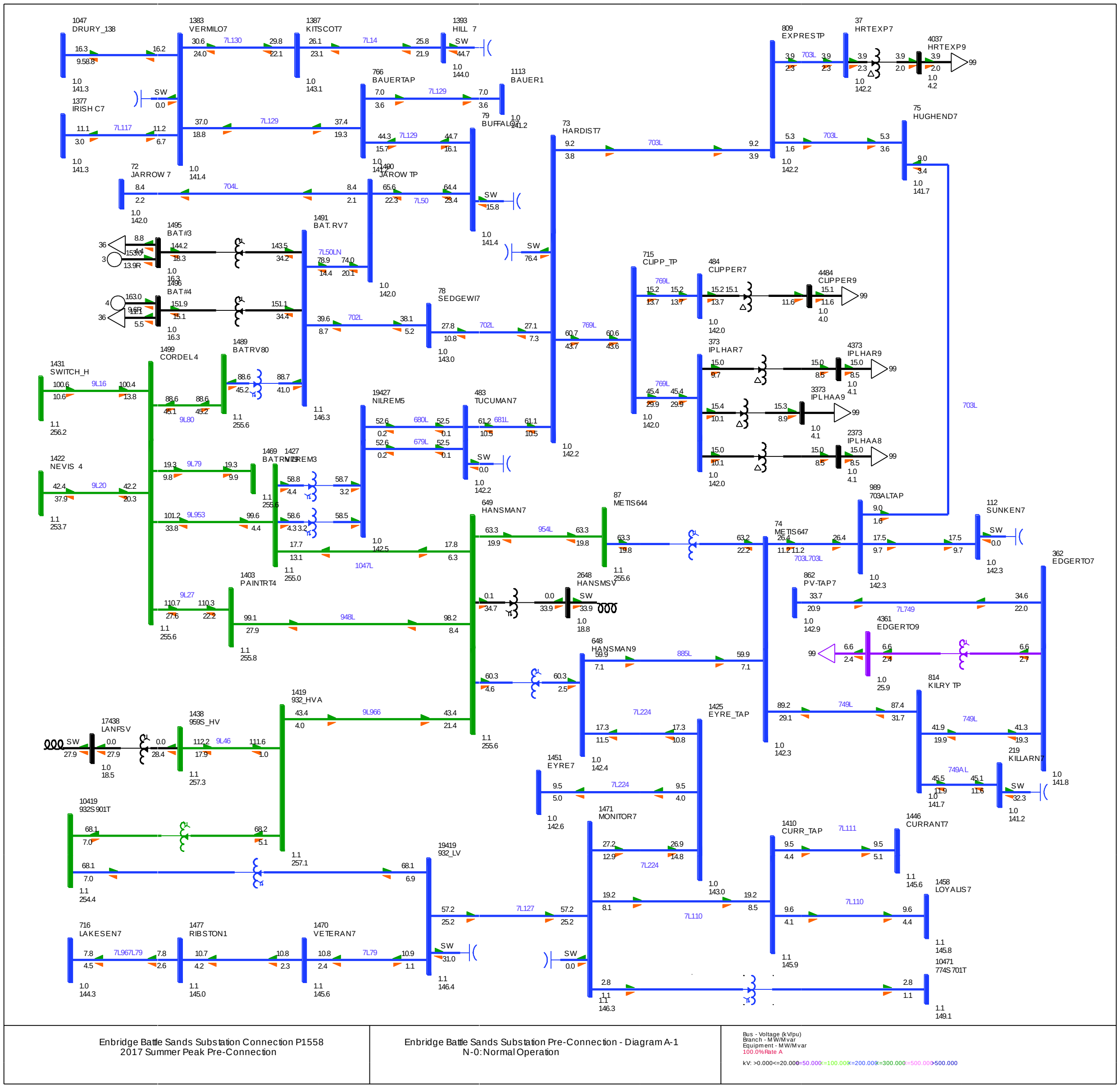
# Attachment A

Power Flow Single Line Diagrams

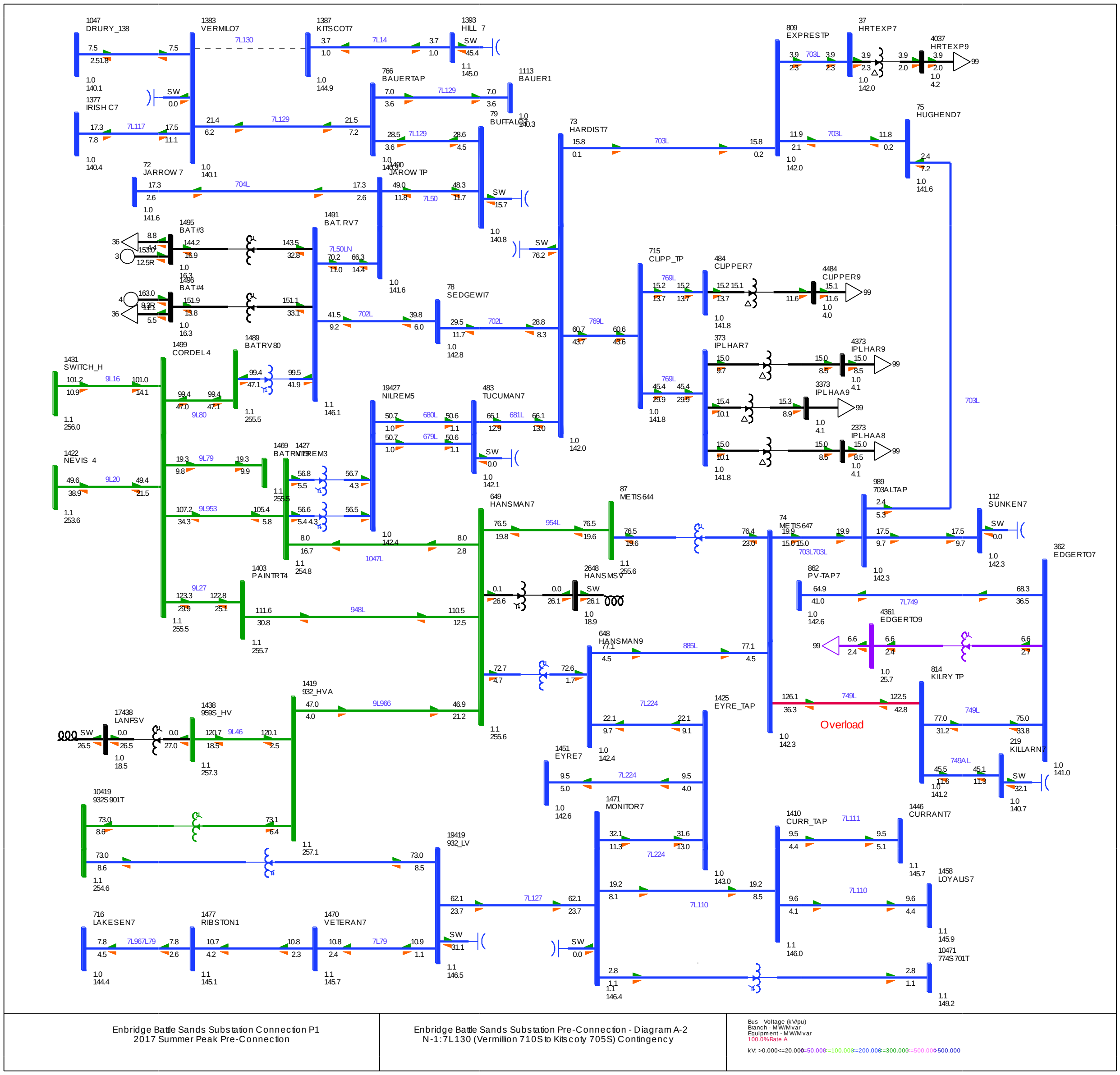
**Table A-1: SLD List for Thermal Loadings**

| Scenario | System Condition | Thermal Loadings | % of Overload | Figure in Attachment A |
|---|---|---|---|---|
| 2017SP Pre-Connection | Category A : Normal Operation | None | -- | A-1 |
| | Category B: 138 kV Transmission Line 7L130 Contingency (from the Vermillion 710S substation to the Kitscoty 705S substation) | 138 kV Transmission Line 749L (from the Metiskow 648S substation to the Killarney 267S substation T-tap) | 108.5 | A-2 |
| | Category B: 138 kV Transmission Line 7L14 Contingency (from the Kitscoty 705S substation to the Hill 751S substation) | 138 kV Transmission Line 749L (from the Metiskow 648S substation to the Killarney 267S substation T-tap) | 105.6 | A-3 |
| | Category B: 138 kV Transmission Line 749L (from the Metiskow 648S substation to the Edgerton 899S substation) | 138 kV Transmission Line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation) | 112.1 | A-4 |
| | | 138 kV Transmission Line 7L14 (from the Kitscoty 705S substation to the Hill 751S substation) | 105.5 | |
| | Category B: Edgerton 899S substation transformer T3* | 138 kV Transmission Line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation) | 106.2 | A-5 |
| | Category B: Edgerton 899S substation transformer T3* | 138 kV Transmission Line 7L14 (from the Kitscoty 705S substation to the Hill 751S substation) | 100.9 | |
| 2017WP Pre-Connection | Category A: Normal Operation | None | -- | A-6 |
| | Category B: 138 kV Transmission Line 749L (from the Metiskow 648S substation to the Edgerton 899S substation) | 138 kV Transmission Line 7L130 (from the Vermillion 710S substation to the Kitscoty 705S substation) | 103.7 | A-7 |

## Figure A-1: 2017SP Pre-Connection, Category A: Normal Operation

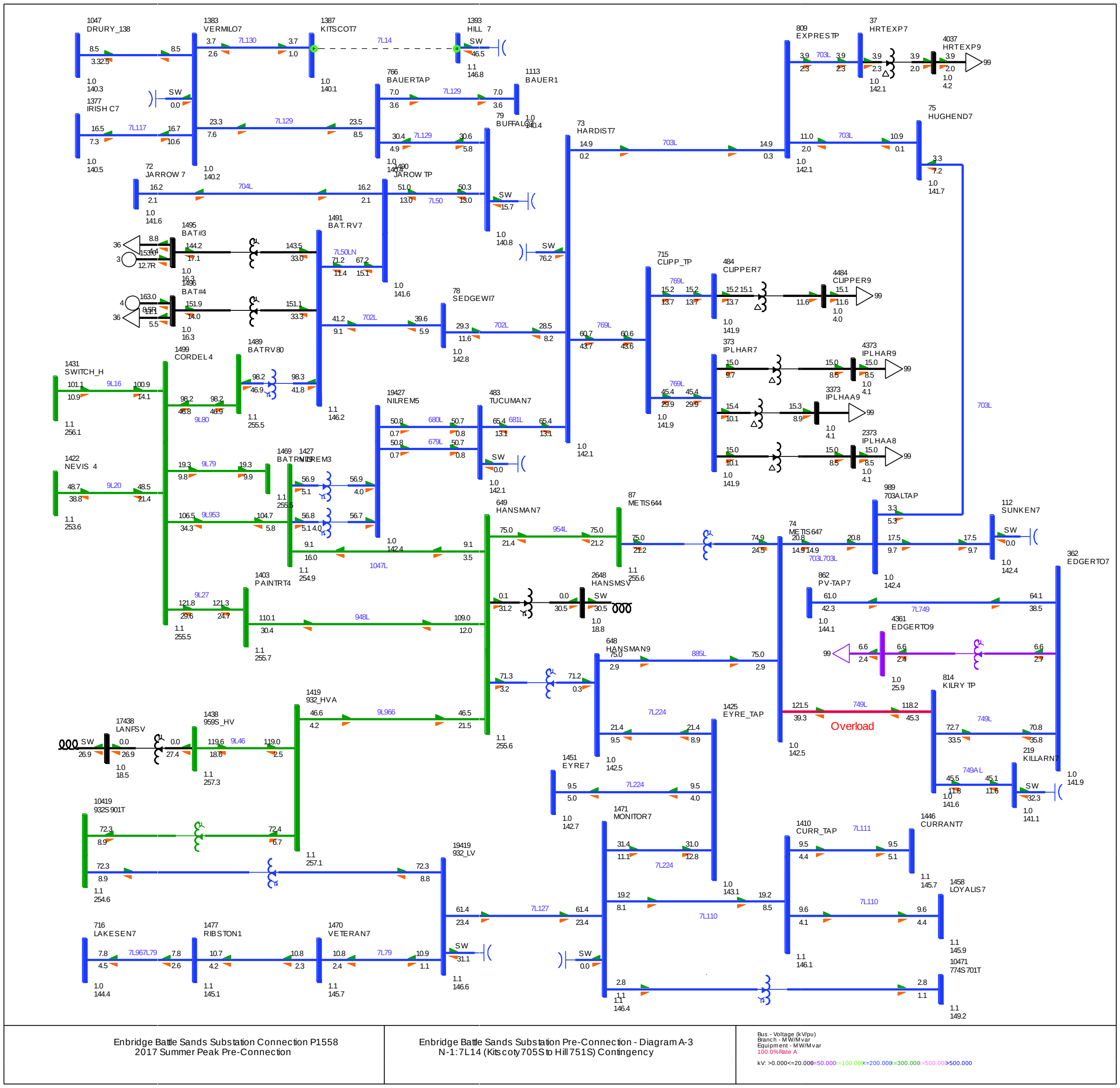


## Figure A-2: 2017SP, Pre-Connection, Category B: 7L130 (Vermillion 710S to Kitscoty 705S) Contingency



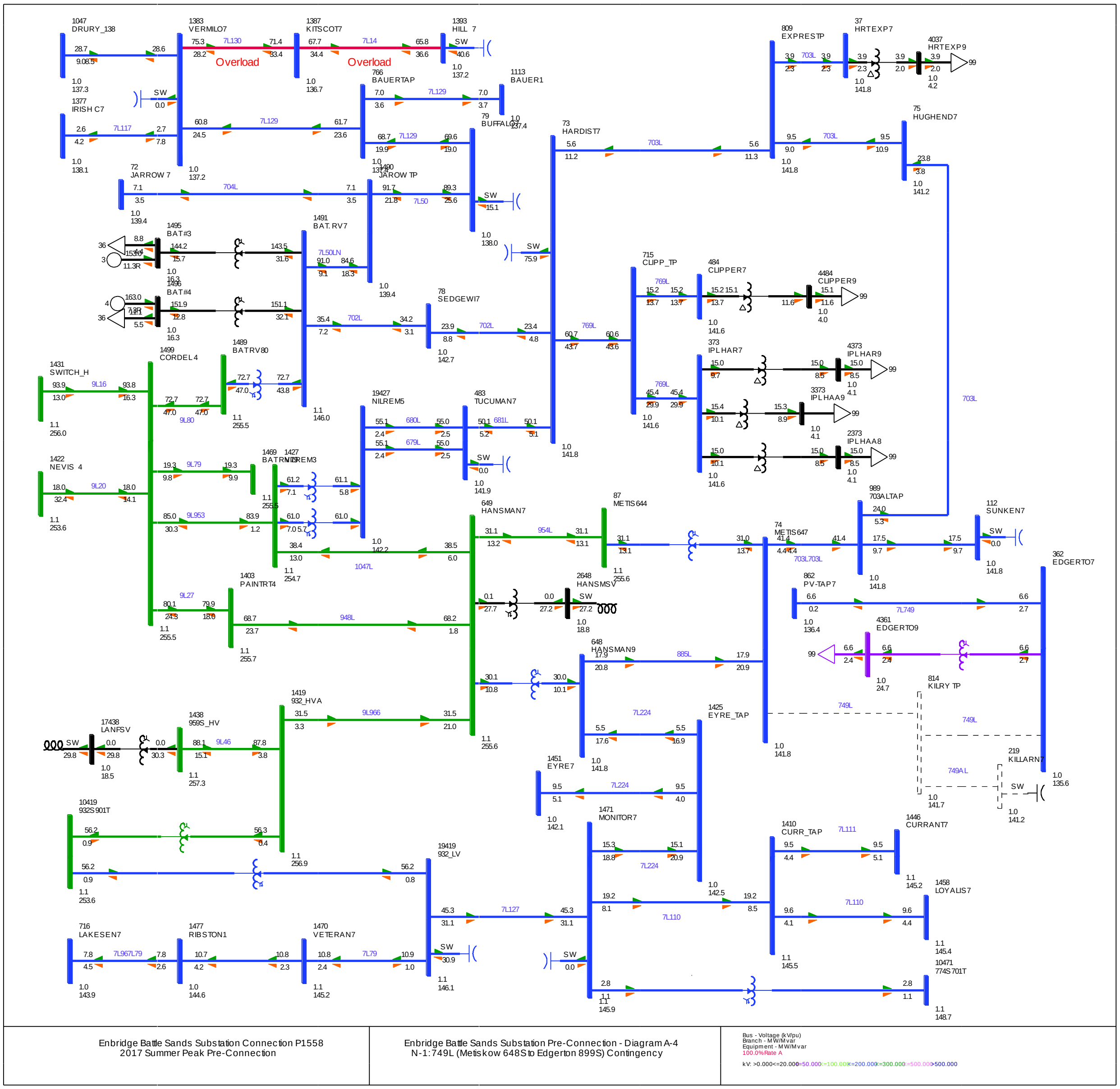

Note: Dashed black lines mark the contingencies and solid red lines mark the thermal loadings.

## Figure A-3: 2017SP, Pre-Connection, Category B: 7L14 (Kitscoty 705S to Hill 751S) Contingency



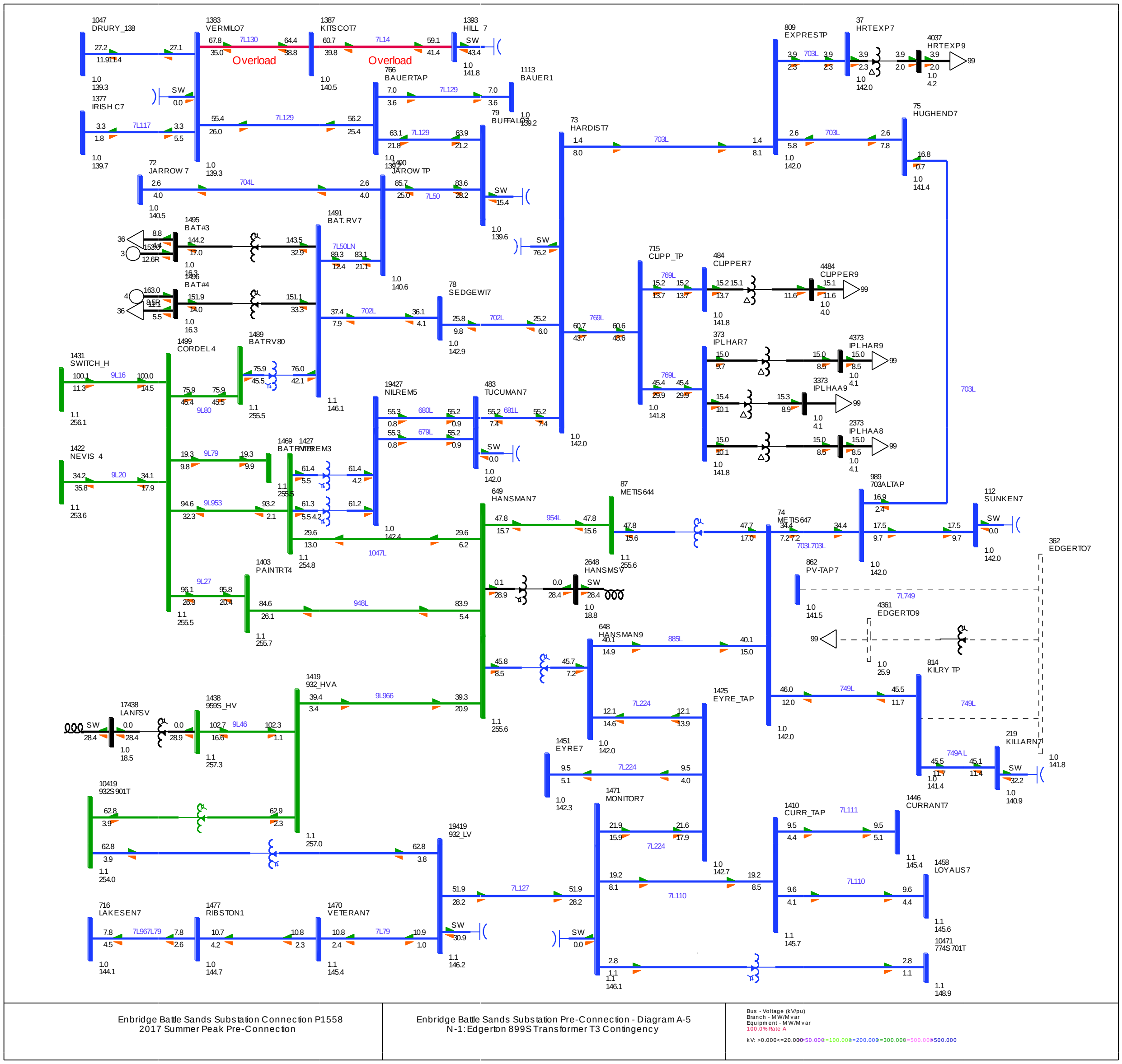

Note: Dashed black lines mark the contingencies and solid red lines mark the thermal loadings.

**Figure A-4: 2017SP, Pre-Connection, Category B: 749L (Metiskow 648S to Edgerton 899S) Contingency**




Note: Dashed black lines mark the contingencies and solid red lines mark the thermal loadings.

**Figure A-5: 2017SP, Pre-Connection, Category B: Edgerton 899S Transformer T3 Contingency**




Note: Dashed black lines mark the contingencies and solid red lines mark the thermal loadings.

## Figure A-6: 2017WP, Pre-Connection, Category A: Normal Operation

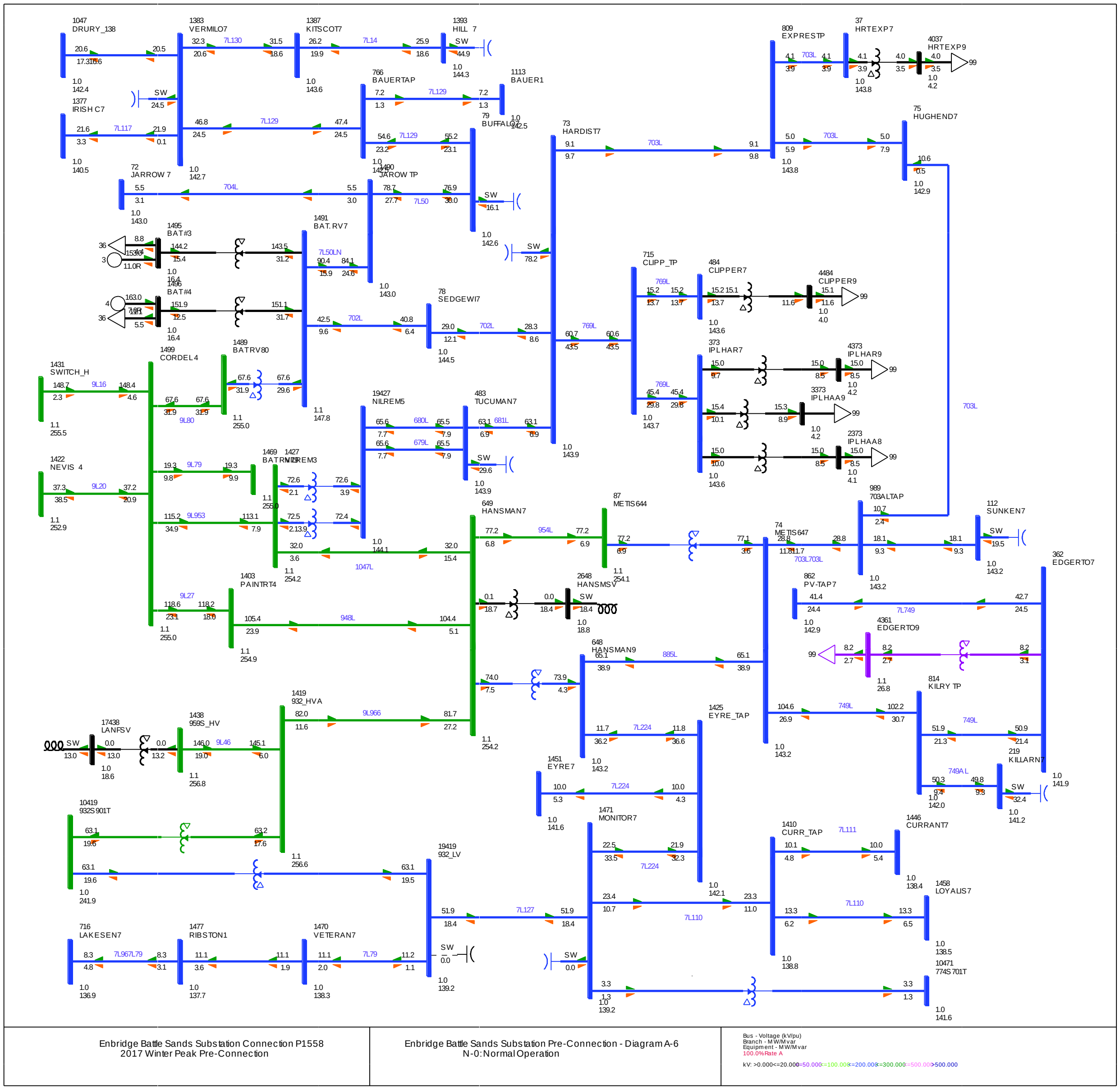
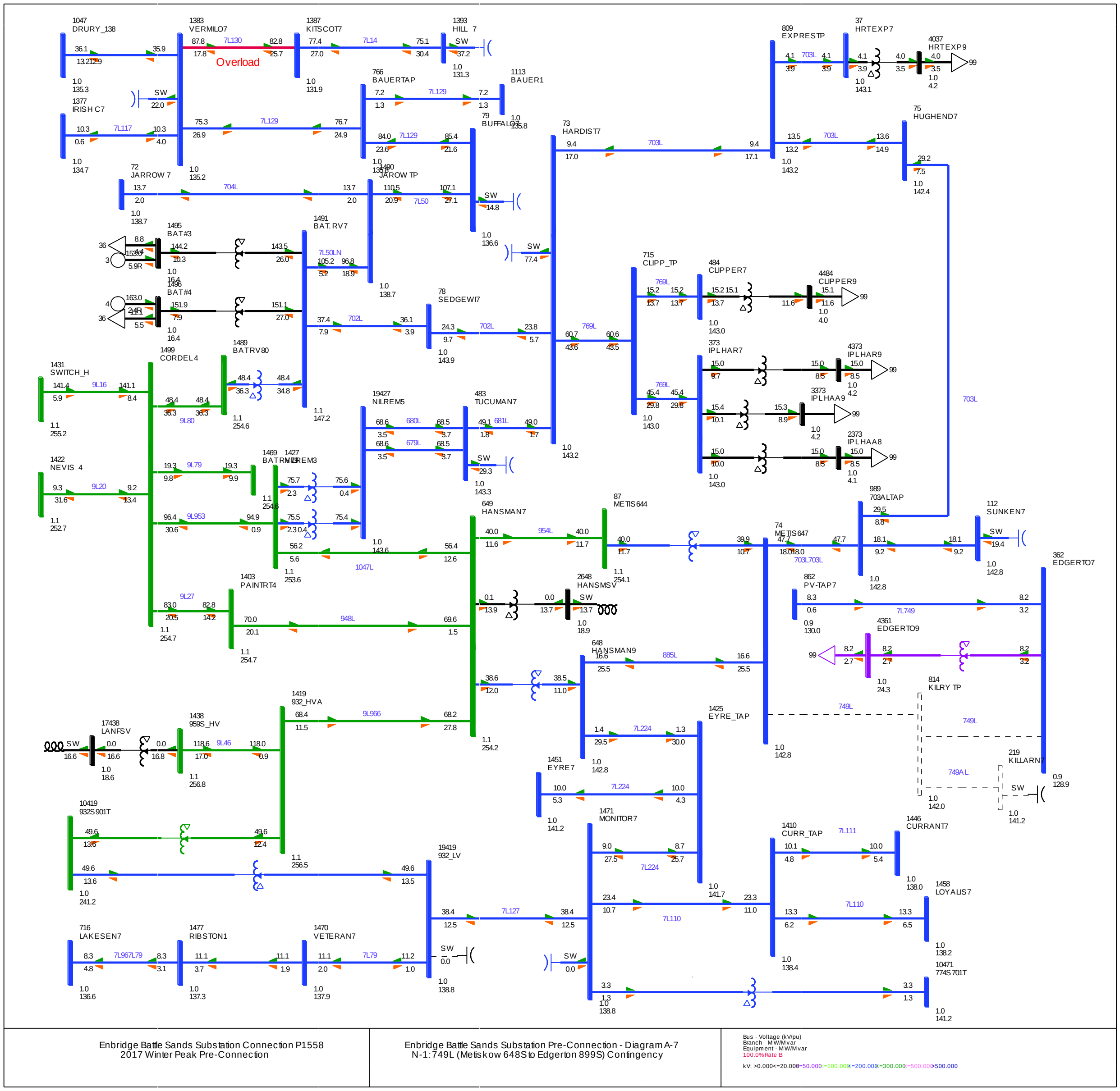


**Figure A-7: 2017WP, Pre-Connection, Category B: Edgerton 899S Transformer T3 Contingency**




Note: Dashed black lines mark the contingencies and solid red lines mark the thermal loadings.

# Attachment B

Pre-Connection Voltage Stability Results

**Table B-1: 2017WP Pre-Connection PV Results**

| Condition | Contingency | Substation From | Substation To | 2017WP Pre-Connection Reference Load (MW) | Margin (MW) | Nose Point (MW) | Voltage Criteria |
|---|---|---|---|---|---|---|---|
| Category A (N-0) | Normal | N/A | N/A | 205.50 | 215.78 (105%) | 475 | Meets voltage stability criteria |
| Category B (N-1) | 681L | Hardisty 377S | Tucuman 478S | 205.50 | 215.78 (105%) | 421 | Meets voltage stability criteria |
| Category C5 (N-2) | 679L and 680L | Nilrem 574S | Tucuman 478S | 205.50 | 210.64 (102.5%) | 294 | Meets voltage stability criteria |
| Category C5 (N-2) | 953L and 1047L | Nilrem 574S | Hansman Lake 650S/ Cordel 755S | 205.50 | 210.64 (102.5%) | 273 | Meets voltage stability criteria |
| Category B (N-1) | 702L | Hardisty 377S | Battle River 757S | 205.50 | 215.78 (105%) | 471 | Meets voltage stability criteria |
| Category B (N-1) | 703L | Metiskow 648S | Sunken Lake 221S/ Hardisty 377S | 205.50 | 215.78 (105%) | 471 | Meets voltage stability criteria |

**Table B-2: Figure Description of Voltage Stability Analysis**

| Figure Number | PV Curve Description |
|---|---|
| Figure B-1 | PV curve at the Hardisty 377S substation for 2017WP pre-connection |
| Figure B-2 | PV curve at the Clipper 656S substation T-tap for 2017WP pre-connection |
| Figure B-3 | PV curve at the Express 329S substation T-tap for 2017WP pre-connection |

**Figure B-1: 2017WP Pre-Connection PV Curve for the Hardisty 377S Substation**

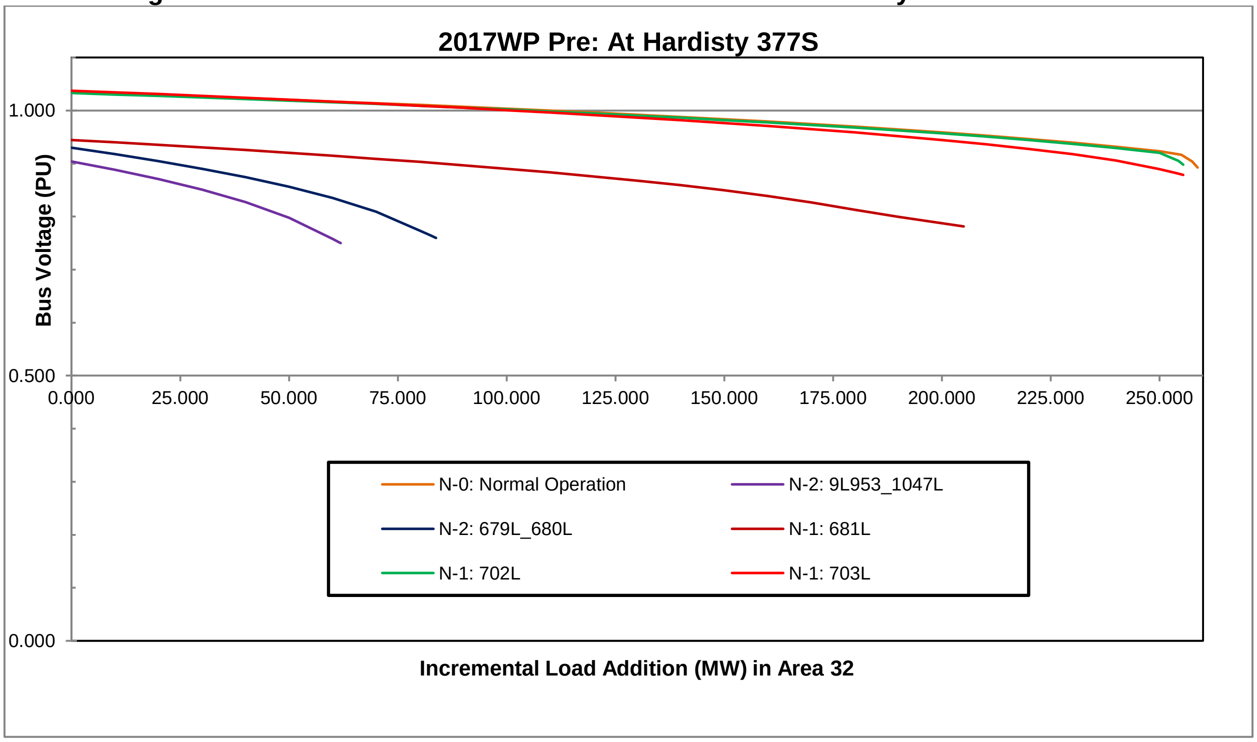


**Figure B-2: 2017WP Pre-Connection PV Curve for the Clipper Tap Bus**

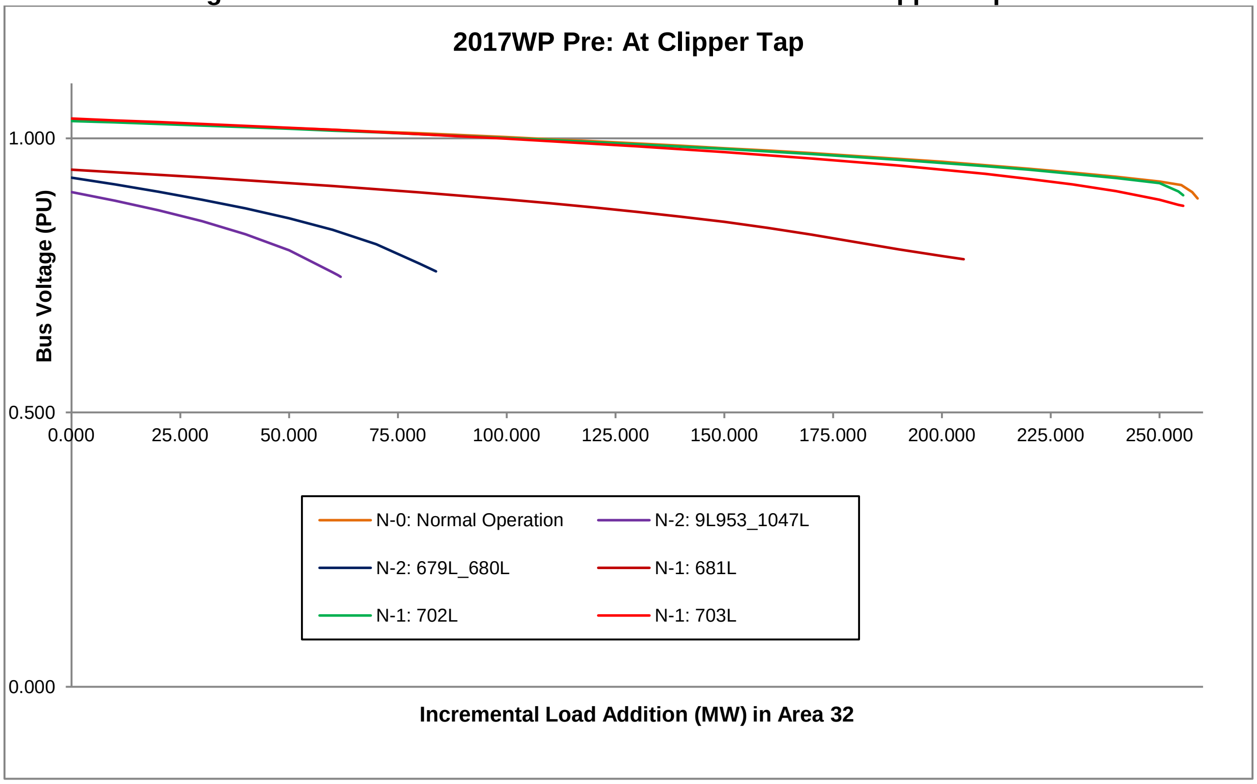
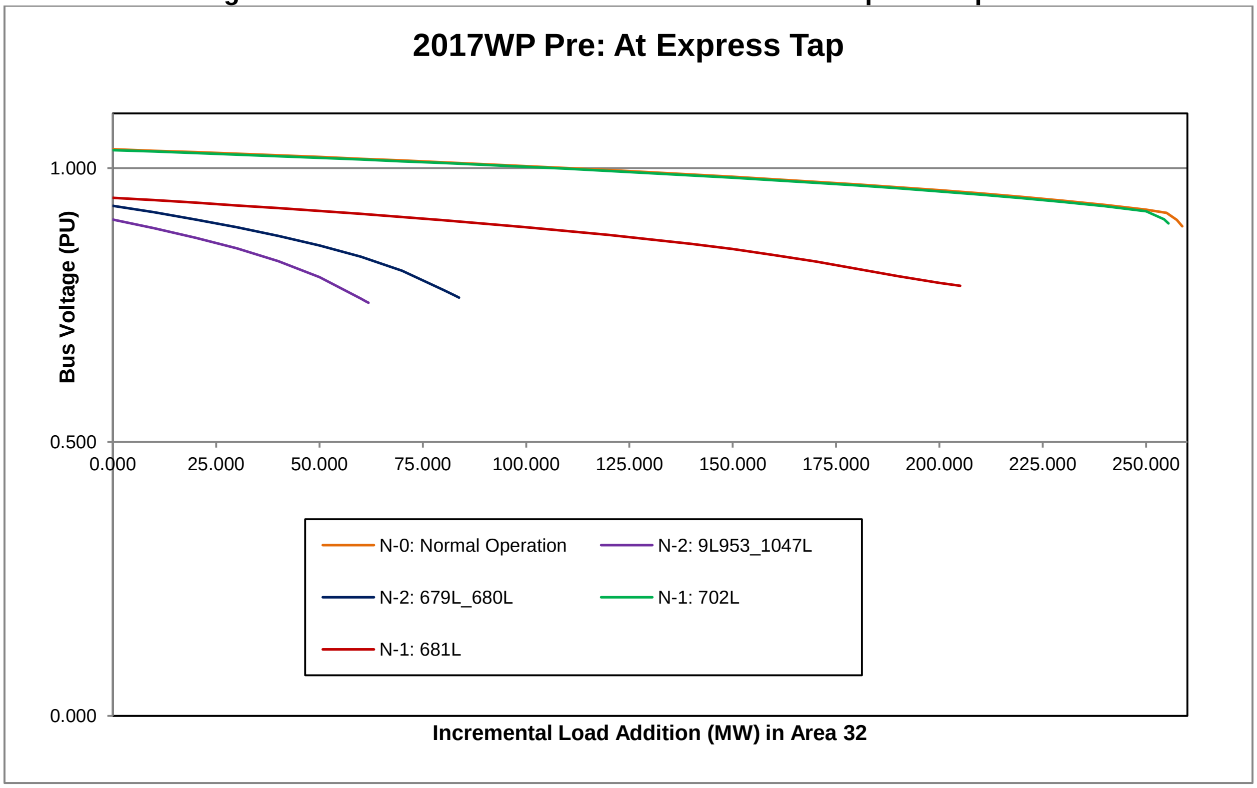


**Figure B-3: 2017WP Pre-Connection PV Curve for Express Tap Bus**



# Attachment C

Motor Starting Analysis Results for
Post-Connection (Alternative 1)

**Table C-1: Figure Description of Motor Starting Analysis**

| Figure Number | Contingency Description |
|---|---|
| Figure C-1 | Induction Motor Curve |
| Figure C-2 | Bus voltages during motor start under system normal condition for the Alternative 1 configuration |
| Figure C-3 | Bus voltages during motor start under a contingency of the 138 kV transmission line 681L for Alternative 1 configuration |
| Figure C-4 | Bus voltages during motor start under a contingency of the 138 kV transmission lines 679L and 6807L for the Alternative 1 configuration |
| Figure C-5 | Bus voltages during motor start under a contingency of the 138 kV transmission lines 953L and 1427L for the Alternative 1 configuration |
| Figure C-6 | Bus voltages during motor start under a contingency to the 138 kV transmission line 702L for the Alternative 1 configuration |
| Figure C-7 | Bus voltages during motor start under a contingency to the 138 kV transmission line 703L for the Alternative 1 configuration |

**Figure C-1: Induction Motor Curve, Torque, Current and Power Factor (in per unit)**

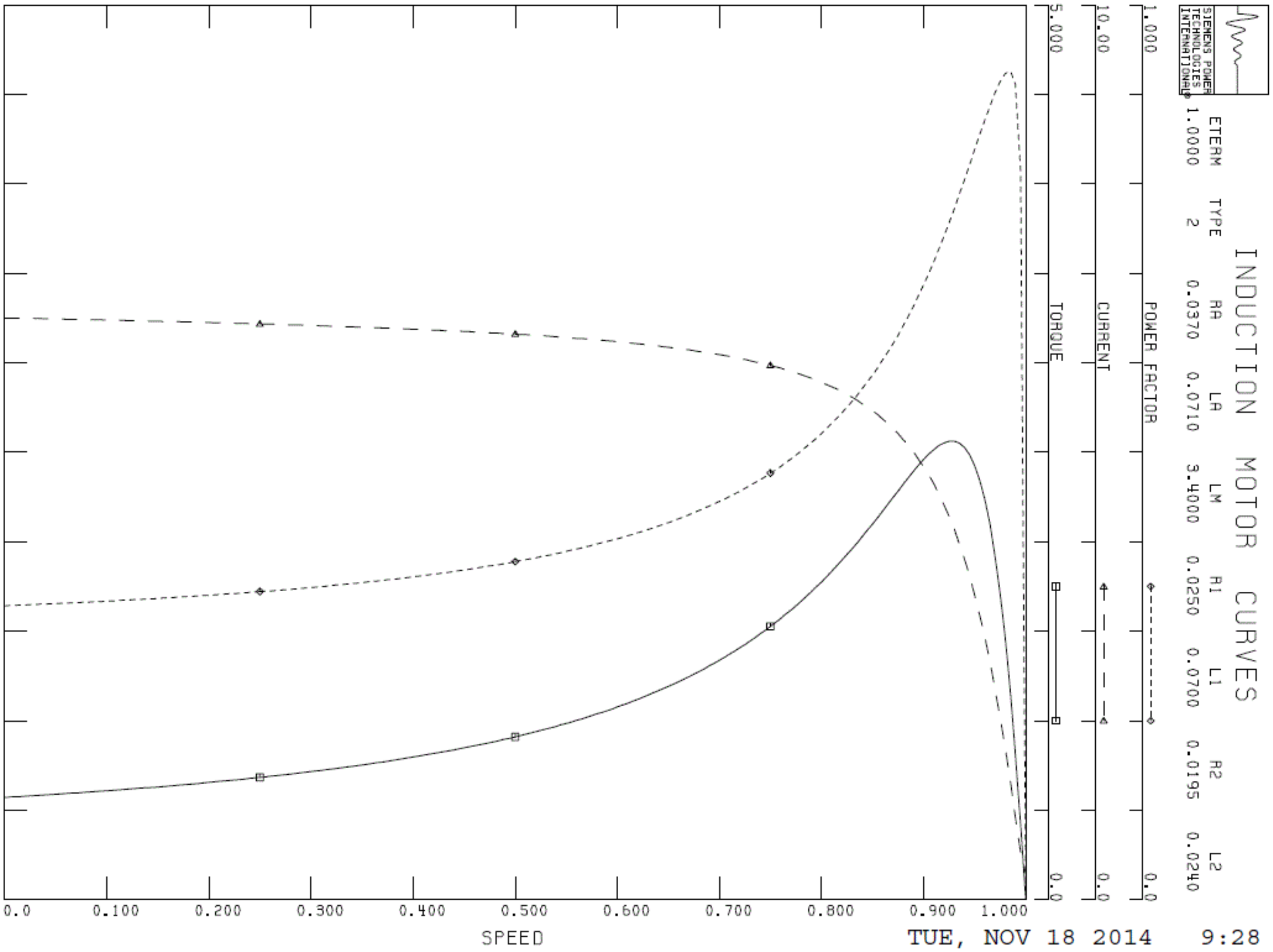


**Figure C-2: Voltage at the Proposed Battle Sands 594S Substation for 2017WP Alternative 1, Category A**

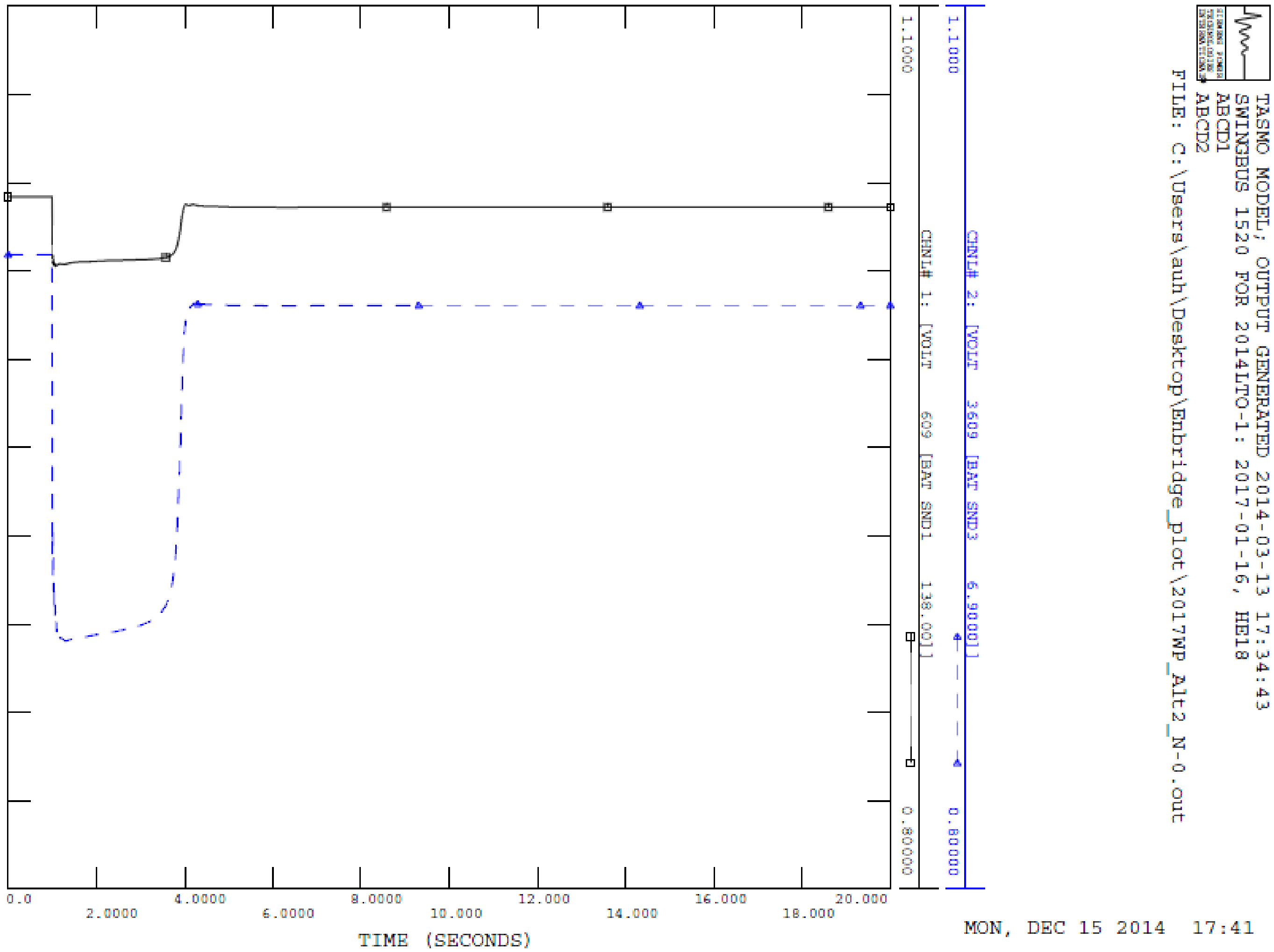


**Figure C-3: Voltage at the Proposed Battle Sands 594S Substation for 2017WP Alternative 1, for the 138 kV Transmission Line 681L Contingency**

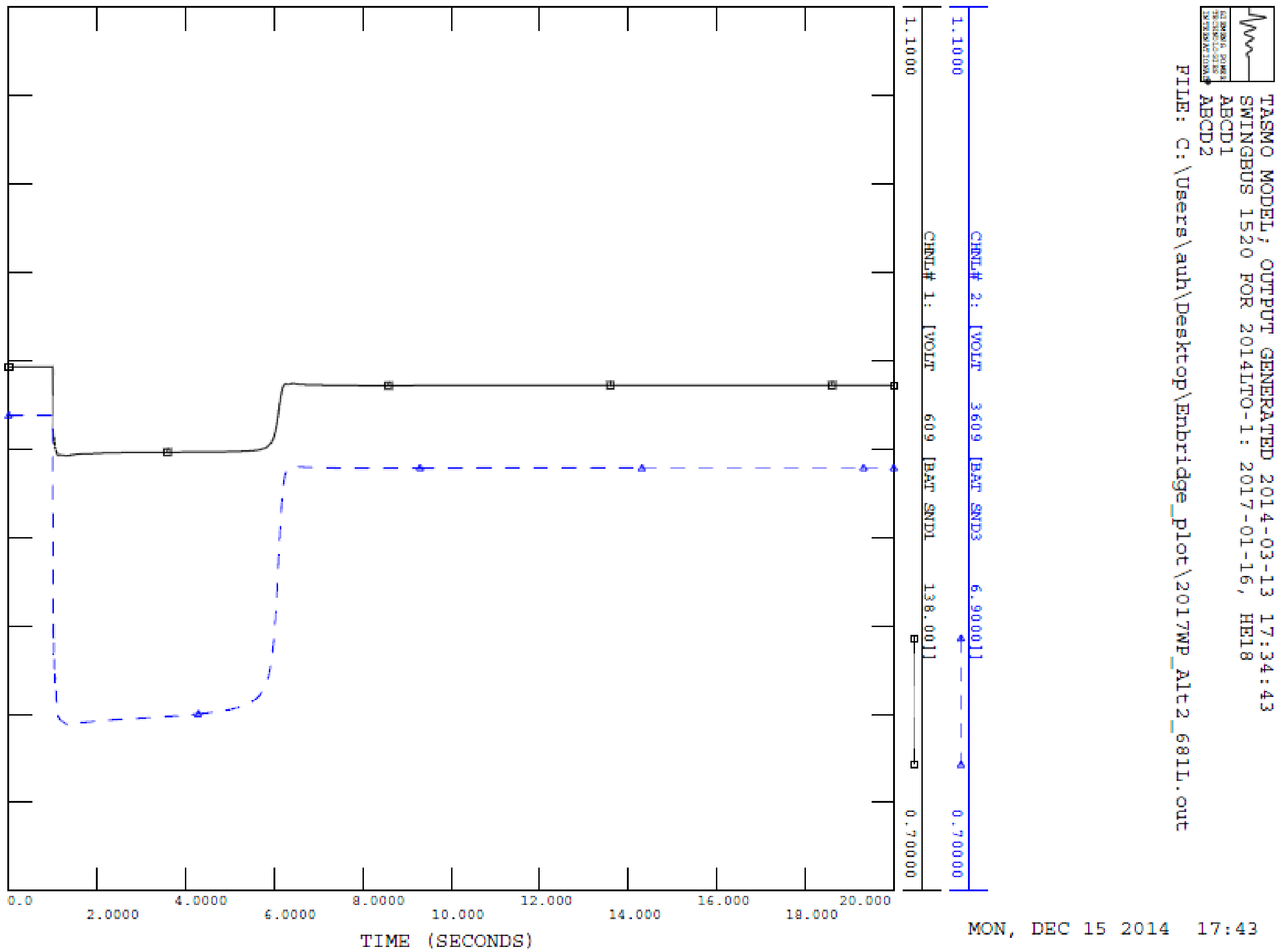


**Figure C-4: Voltage at the Proposed Battle Sands 594S Substation for 2017WP Alternative 1, for the 138 kV Transmission Line 679L and 680L Contingencies**

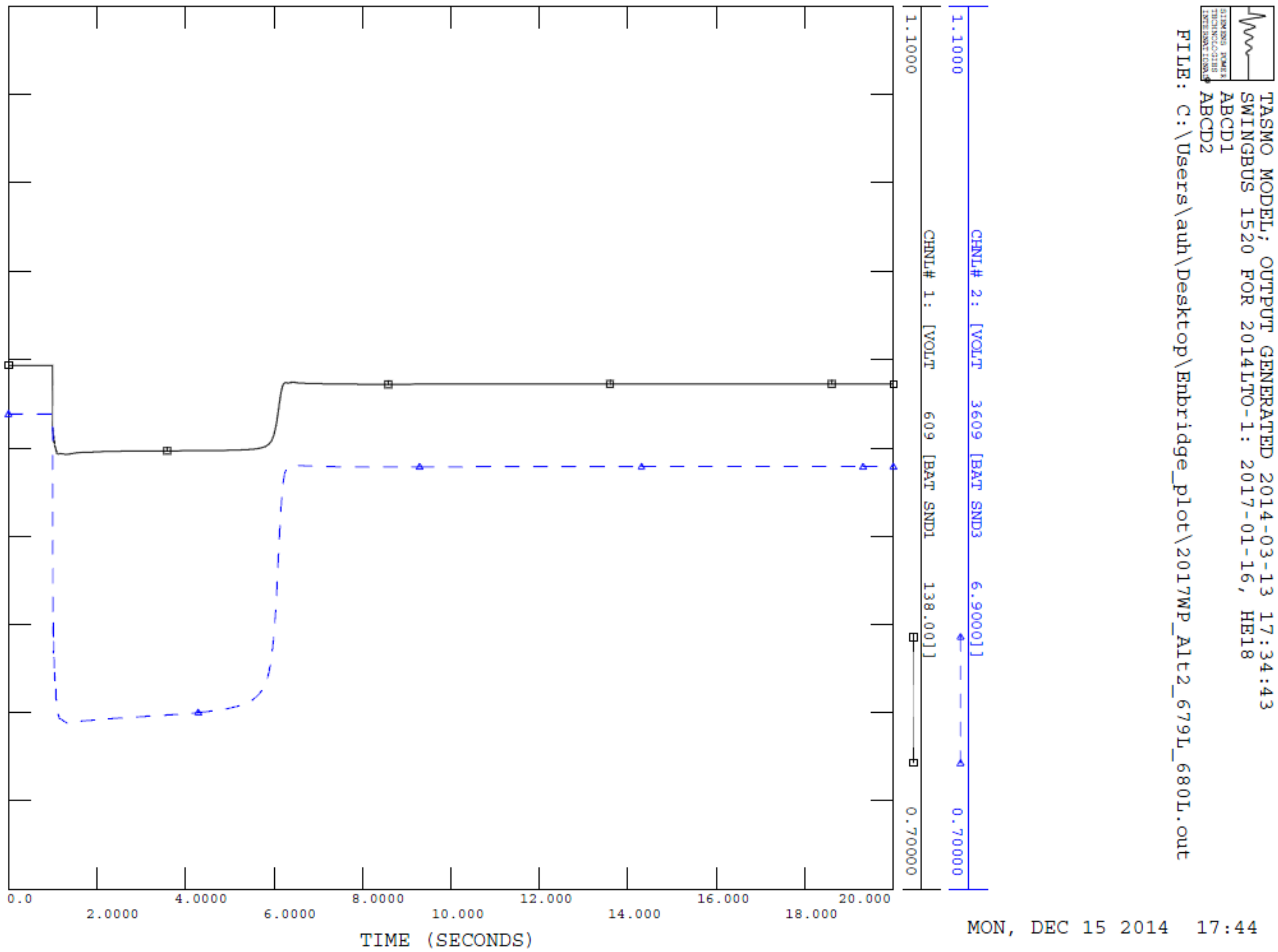


**Figure C-5: Voltage at the proposed Battle Sands 594S Substation for 2017WP Alternative 1, Category C5, for the 138 kV Transmission Line 953L and 1047L Contingencies**

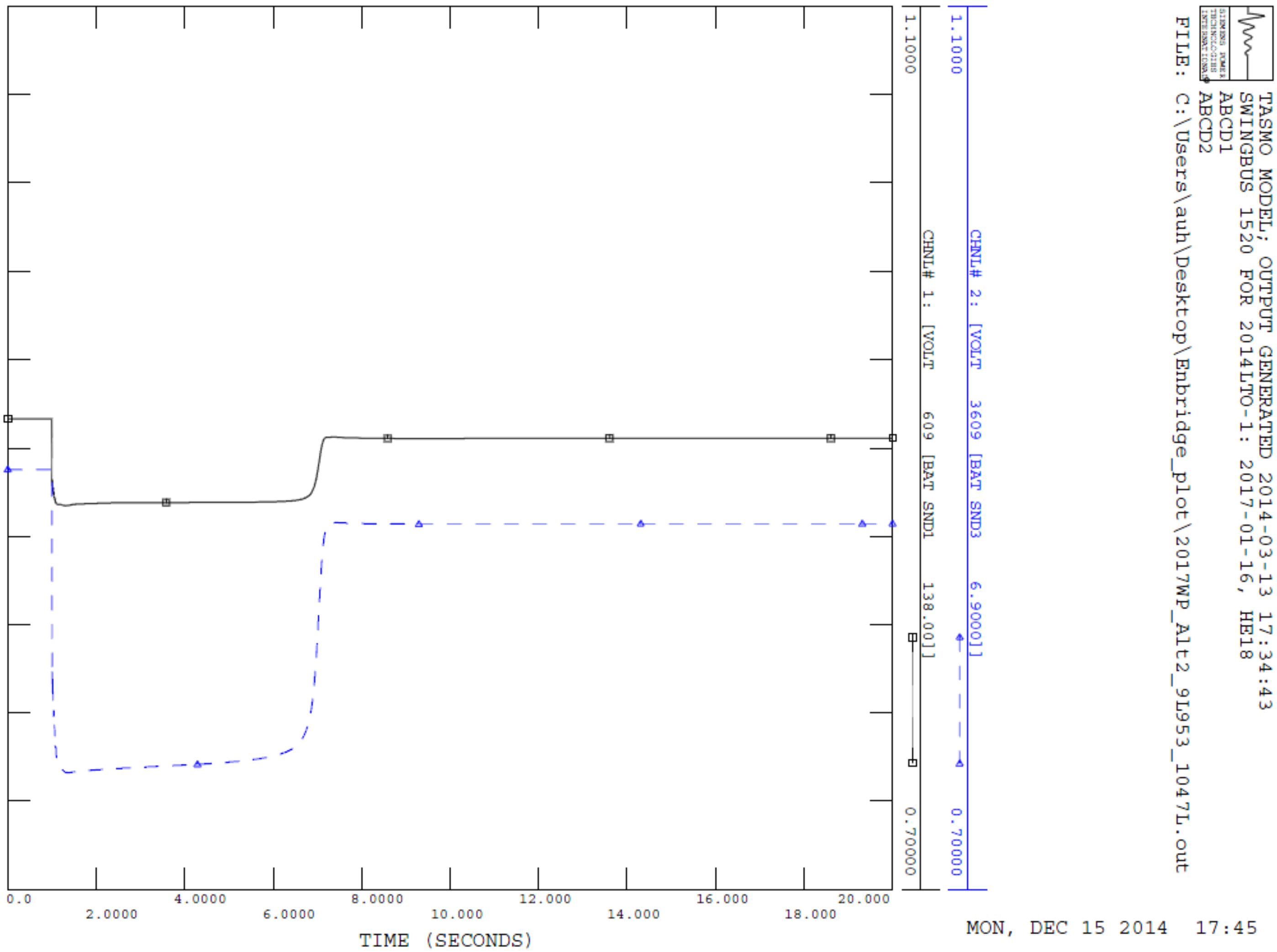


**Figure C-6: Voltage at the proposed Battle Sands 594S Substation for 2017WP Alternative 1, for the 138 kV Transmission Line 702L Contingency**

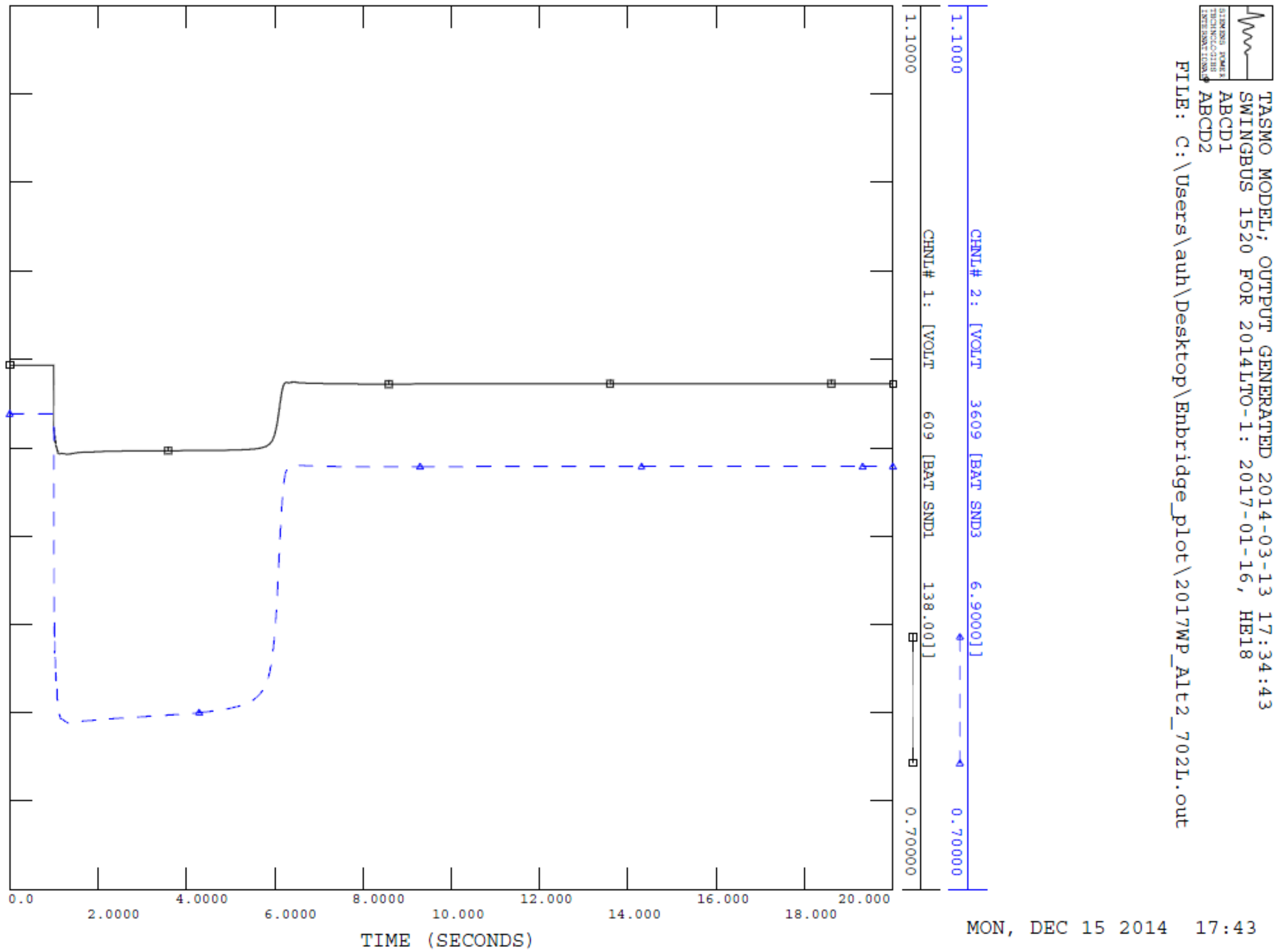


**Figure C-7: Voltage at the Proposed Battle Sands 594S Substation for 2017WP Alternative 1, for the 138 kV Transmission Line 703L Contingency**