REPORT

Power to Ontario.
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System Impact Assessment Report

CONNECTION ASSESSMENT & APPROVAL PROCESS

Issue 1.0

Final Report

Project: Barwick TS

Applicant: Hydro One Networks Inc.

CAA ID 2010-378

IESO Market Facilitation Department

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System Impact Assessment Report

Acknowledgement

The IESO wishes to acknowledge the assistance of Hydro One in completing this assessment.

Disclaimers

IESO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the IESO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether the IESO should issue a notice of conditional approval or disapproval of the proposed connection under Chapter 4, section 6 of the Market Rules.

Conditional approval of the proposed connection is based on information provided to the IESO by the connection applicant and Hydro One at the time the assessment was carried out. The IESO assumes no responsibility for the accuracy or completeness of such information, including the results of studies carried out by Hydro One at the request of the IESO. Furthermore, the conditional approval is subject to further consideration due to changes to this information, or to additional information that may become available after the conditional approval has been granted.

If the connection applicant has engaged a consultant to perform connection assessment studies, the connection applicant acknowledges that the IESO will be relying on such studies in conducting its assessment and that the IESO assumes no responsibility for the accuracy or completeness of such studies including, without limitation, any changes to IESO Base case models made by the consultant. The IESO reserves the right to repeat any or all connection studies performed by the consultant if necessary to meet IESO requirements.

Conditional approval of the proposed connection means that there are no significant reliability issues or concerns that would prevent connection of the proposed facility to the IESO-controlled grid. However, the conditional approval does not ensure that a project will meet all connection requirements. In addition, further issues or concerns may be identified by the transmitter(s) during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with physical or equipment limitations, or with the Transmission System Code, before connection can be made.

This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. This report has been prepared solely for use by the connection applicant and the IESO in accordance with Chapter 4, section 6 of the Market Rules. The IESO assumes no responsibility to any third party for any use, which it makes of this report. Any liability which the IESO may have to the connection applicant in respect of this report is governed by Chapter 1, section 13 of the Market Rules. In the event that the IESO provides a draft of this report to the connection applicant, the connection applicant must be aware that the IESO may revise drafts of this report at any time in its sole discretion without notice to the connection applicant. Although the IESO will use its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that the most recent version of this report is being used.

Hydro One

The results reported in this report are based on the information available to Hydro One, at the time of the study, suitable for a System Impact Assessment of this transmission system reinforcement proposal.

The short circuit and thermal loading levels have been computed based on the information available at the time of the study. These levels may be higher or lower if the connection information changes as a result of, but not limited to, subsequent design modifications or when more accurate test measurement data is available.

This study does not assess the short circuit or thermal loading impact of the proposed facilities on load and generation customers.

In this report, short circuit adequacy is assessed only for Hydro One circuit breakers. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One circuit breakers and identifying upgrades required to incorporate the proposed facilities. These results should not be used in the design and engineering of any new or existing facilities. The necessary data will be provided by Hydro One and discussed with any connection applicant upon request.

The ampacity ratings of Hydro One facilities are established based on assumptions used in Hydro One for power system planning studies. The actual ampacity ratings during operations may be determined in real-time and are based on actual system conditions, including ambient temperature, wind speed and facility loading, and may be higher or lower than those stated in this study.

The additional facilities or upgrades which are required to incorporate the proposed facilities have been identified to the extent permitted by a System Impact Assessment under the current IESO Connection Assessment and Approval process. Additional facility studies may be necessary to confirm constructability and the time required for construction. Further studies at more advanced stages of the project development may identify additional facilities that need to be provided or that require upgrading.

Table of Contents

Executive Summary

Description

The purpose of this System Impact Assessment is to examine the effect of connecting the new station, Barwick TS, on the reliability of the IESO-controlled grid. This station is proposed to be tapped to the 115 kV circuit K6F at the Ainsworth Junction. The new station has been proposed by Hydro One to supply the Fort Frances - Rainy River area loads currently being supplied from an autotransformer located at Fort Frances TS, which is estimated to be close to its end-of-life.

SIA Findings

The assessment concludes that the connection of the new station, Barwick TS, will not materially affect the reliability of the IESO-controlled grid if the IESO's requirements for connection are satisfied.

The findings of the assessment are summarized below:

(1) The thermal loading assessment shows that the pre-contingency and post-contingency thermal loadings of the local transmission elements are within acceptable limits with Barwick TS in service. The highest level of loading is observed on the section between Margach Junction to Sioux Narrows Junction of the 115 kV circuit K6F. Under specific conditions the loading of this section may reach its long term emergency rating (LTE) following the loss of the 230 kV circuit K24F. The loading of K6F is highly dependent on flows on the interconnections with Manitoba and Minnesota, i.e. Ontario Manitoba Transfer East (OMTE) and Minnesota Power Flow South (MPFS).

(2) The power transfer capability assessment shows that with Barwick TS in service, under specific conditions, the power transfer capability over the interconnections may slightly decrease, within the limits permitted under section 4.1 of the Ontario Resource and Transmission Assessment Criteria (ORTAC).

(3) The voltage assessment shows that the connection of Barwick TS does not reduce the system's ability to maintain pre-contingency and post-contingency voltage levels in the area, within the acceptable limits indicated in sections 4.2 and 4.3 of the ORTAC.

(4) The switching study assessment shows that switching operation of the proposed capacitor bank at Barwick TS is not expected to exceed the voltage change criteria specified in section 4.3.2 of the ORTAC.

IESO's Requirements for Connection

The Barwick TS project shall satisfy the requirements and standards specified in the Market Rules and the Transmission System Code including, but not limited to, the following general requirements (detailed requirements are stated in Section 2 of this report):

(1) Hydro One shall ensure that all 115 kV equipment at Barwick TS is capable of continuously operating at a voltage level of up to 132 kV as specified in Appendix 4.1 of the Market Rules. Fault interrupting devices must be able to interrupt fault currents at the maximum continuous voltage of 132 kV. Protective relaying must be set to ensure that transmission equipment remains in service for voltages between 94% of the minimum continuous voltage and 105% of the maximum continuous voltage specified in Appendix 4.1 of the Market Rules.

(2) Under-load tap changers (ULTC) must be available at Barwick TS. Hydro One shall install and maintain facilities at Barwick TS to provide 3% and 5% voltage reduction within five minutes of receipt of the direction from the IESO.

(3) Hydro One shall have the capability to maintain the power factor at the defined meter point of Barwick TS within the range of 0.9 lagging to 0.9 leading, as specified in Appendix 4.3 of the Market Rules.

(4) New protection systems at Barwick TS shall be designed to satisfy all the requirements of the Transmission System Code and any additional requirements identified by the transmitter. New protection systems must be coordinated with existing protection systems. In addition, Hydro One shall have adequate provision in the design of protections and controls at the facility to allow for future installation of Special Protection Scheme (SPS) equipment. From the IESO's perspective, Barwick TS is not currently designated as essential to the power system reliability. Thus, the IESO does not require the facility to be protected by two redundant protection systems.

(5) Hydro One shall ensure that the new equipment at Barwick TS be designed to sustain the fault levels in the area. If any future system enhancement results in an increased fault level higher than the equipment's capability, Hydro One is required to replace the equipment at its own expense with higher rated equipment capable of sustaining the increased fault level, up to the maximum fault level specified in Appendix 2 of the Transmission System Code.

(6) Hydro One is required to install all the equipment needed to provide telemetry data to the IESO on a continuous basis, as required by the Market Rules.

(7) Hydro One shall ensure that the revenue metering installations at Barwick TS comply with the IESO's requirements specified in Chapter 6 of the Market Rules.

(8) Hydro One must complete the IESO Facility Registration/Market Entry process in a timely manner before IESO final approval for connection is granted.

Notification of Conditional Approval

The connection of the new station, Barwick TS, to the IESO-controlled grid does not adversely impact the reliability of the grid. It is recommended that a Notification of Conditional Approval for Barwick TS be issued to Hydro One, subject to the IESO's requirements being met.

– End of Section –

1. Project Description

The Fort Frances - Rainy River area load is supplied from the tertiary winding of an autotransformer located inside Fort Frances TS that is estimated to be close to its end-of-life. This load is supplied via a single 98.4 km long, 44 kV feeder (designated M1) that is difficult to protect and has low supply reliability.

The Applicant has proposed to build a new transformer station, Barwick TS, near the town of Chapple, and eventually retire the Fort Frances TS end-of-life autotransformer. Barwick TS will be located approximately in the center of the load area, and will be equipped with two 25/42 MVA, 115.5 kV - 44 kV transformers and one 5 Mvar capacitor bank, for voltage support. The transformer station will be supplied from the 115 kV line K6F at the Ainsworth Junction via a 0.1 km, 115 kV circuit with 211.6 kcmil ACSR conductor. After Barwick TS is built, the 44 kV feeder M1 will be disconnected from Fort Frances TS, and the feeder will be split approximately in half with each section connecting to the new station. The load supplied from the station will have a peak of 20 MW at 0.9 lag power factor.

The planned in-service date is October 31, 2012.

The purpose of this System Impact Assessment is to identify the effect of the new facilities on system reliability.

– End of Section –

2. General Requirements

2.1 Voltage Requirements

Appendix 4.1, reference 2 of the Market Rules states that under normal conditions voltages in northern Ontario are maintained within the range of 113 kV to 132 kV. Thus, the IESO requires that 115 kV equipment in northern Ontario must have a maximum continuous voltage rating of at least 132 kV.

Fault interrupting devices must be able to interrupt fault current at the maximum continuous voltage.

Protective relaying at grid connected facilities must be set to ensure that transmission equipment remains in-service for voltages between 94% of the minimum continuous and 105% of the maximum continuous values in the Market Rules, Appendix 4.1.

Hydro One shall ensure that all 115 kV equipment at Barwick TS is capable of continuously operating at a voltage level of up to 132 kV. Fault interrupting devices must be able to interrupt fault currents at the maximum continuous voltage of 132 kV. Protective relaying at Barwick TS must be set to ensure that transmission equipment remains in service for voltages between 94% of the minimum continuous and 105% of the maximum continuous values.

2.2 Voltage Reduction Facilities Requirements

The Market Rules (Chapter 4, Appendix 4.3) requires that distributors connected to the IESO controlled grid with directly connected load facilities of aggregated rating of 20 MVA or more and with the capability to regulate distribution voltage under load, shall install and maintain facilities to provide voltage reduction capability. This is required to achieve load reduction during periods when supply resources are limited. Voltage reduction capability represents the capability of reducing demand by lowering the customer voltage by 3% and 5% within five minutes of receipt of the direction from the IESO.

Under-load tap changers (ULTC) must be available at Barwick TS. Hydro One shall install and maintain facilities at Barwick TS to provide 3% and 5% voltage reduction within five minutes of receipt of the direction from the IESO.

2.3 Power Factor Requirements

Appendix 4.3 of the Market Rules requires the connected wholesale customers and distributors connected to the IESO-controlled grid to have the capability to maintain a power factor within the range of 0.9 lagging and 0.9 leading as measured at the defined meter point of the facility.

Hydro One shall have the capability to maintain the power factor at the defined meter point of Barwick TS within the range of 0.9 lagging to 0.9 leading.

2.4 Under Frequency Load Shedding Requirements

Hydro One has a total peak load at all stations to be fed from Barwick TS that is less than 25 MW, therefore it is not required to participate in the under frequency load shedding (UFLS) according to Section 4.5 of the Market Manual Part 7.4. If the total peak load at stations fed from Barwick TS is greater than 25 MW in the future, Hydro One will be required to participate in UFLS.

2.5 Protection Systems

Protection systems must be designed to satisfy all the requirements of the Transmission System Code (TSC) as specified in Schedules E, F and G of Appendix 1 and any additional requirements identified by Hydro One. New protection systems must be coordinated with existing protection systems.

Facilities designated as essential to power system reliability must be protected by two redundant protection systems according to section 8.2.1a of the TSC. These redundant protections systems must satisfy all requirements of the TSC but in particular they may not use common components, common battery banks or common secondary CT or PT windings. As currently assessed by the IESO, Barwick TS is not designated as essential to power system reliability and therefore the above protection requirements do not apply. In the future, as the electrical system evolves, this facility may be designated as such and at that time the above requirements will apply.

Hydro One is required to have adequate provision in the design of protections and controls at the facility to allow for future installation of Special Protection Scheme (SPS) equipment.

Hydro One is required to initiate an assessment of the protection systems proposed for the new facility. Hydro One shall identify any protection relay modifications (e.g. equipment and settings) required to incorporate Barwick TS into the integrated power system. To allow sufficient time to assess the impact on power system reliability, Hydro One must submit any proposed protection relay modifications to the IESO as soon as the protection assessment for the new facility is finished or at least six (6) months before any actual modifications are to be implemented on the existing protection systems.

The IESO will evaluate the impact on system reliability due to any protection relay modifications and any modifications to functionality, timing or reach. The IESO will not assess aspects of protection systems which are solely the accountability of the transmitter (e.g. coordination of protection relays).

Hydro One can send documentation for protection modifications triggered by new or modified primary equipment (i.e. new or replacement relays) to connection.assessments@ieso.ca.

For protection modifications that are not associated with new or modified equipment (i.e. protection setting modifications), Hydro One can send the documentation to protection.settings@ieso.ca.

New protection systems at Barwick TS must be designed to satisfy all the requirements of the Transmission System Code and any additional requirements identified by Hydro One. New protection systems must be coordinated with existing protection systems.

Hydro One shall have adequate provision in the design of protections and controls at the facility to allow for future installation of Special Protection Scheme (SPS) equipment.

2.6 Fault Levels

The Transmission System Code (TSC) requires that new equipment be designed to sustain the fault levels in the area where the equipment is installed. If any future system enhancement results in an increased fault level higher than the equipment's capability, the owner is required to replace the equipment at its own expense with higher rated equipment capable of sustaining the increased fault level, up to the maximum fault level specified in Appendix 2 of the TSC.

Appendix 2 of the TSC establishes maximum fault levels for the transmission system. For the 115 kV system, the maximum 3 phase and single line to ground symmetrical fault levels are 50 kA.

Hydro One shall ensure that the new equipment at Barwick TS be designed to sustain the fault levels in the area. If any future system enhancement results in an increased fault level higher than the equipment's capability, Hydro One is required to replace the equipment at its own expense with higher rated equipment capable of sustaining the increased fault level specified in Appendix 2 of the Transmission System Code.

2.7 Telemetry Requirements

In accordance with the telemetry requirements for connected wholesale customers and distributors specified in Appendices 4.17 and 4.22 of the Market Rules, Hydro One must install equipment at Barwick TS with specific performance standards to provide telemetry data to the IESO. The data is to consist of certain equipment status and operating quantities which will be identified during the IESO Market Entry Process.

As part of the IESO Facility Registration/Market Entry process, Hydro One must also complete end to end testing of all necessary telemetry points with the IESO to ensure that standards are met and that sign conventions are understood. All found anomalies must be corrected before IESO final approval to connect any phase of the project is granted.

Hydro One is required to install all the equipment needed to provide telemetry data to the IESO on a continuous basis, as required by the Market Rules.

2.8 Revenue Metering Requirements

Revenue metering equipment is being installed as part of this project and Hydro One shall ensure that revenue metering installations comply with Chapter 6 of the Market Rules. For more details, Hydro One is encouraged to seek advice from their Metering Service Provider (MSP) or from the IESO metering group.

Hydro One shall ensure that the revenue metering installations at Barwick TS comply with the IESO's requirements specified in Chapter 6 of the Market Rules.

2.9 Facility Registration/Market Entry Requirements

Hydro One must complete the IESO Facility Registration/Market Entry process in a timely manner before IESO final approval for connection is granted. Models and data, including any controls that would be operational, must be provided to the IESO. This information should be submitted at least seven months before energization to the IESO-controlled grid, to allow the IESO to incorporate this project into IESO work systems and to perform any additional reliability studies.

As part of the IESO Facility Registration/Market Entry process, Hydro One must provide evidence to the IESO confirming that the equipment installed meets the Market Rules requirements and matches or exceeds the performance predicted in this assessment. This evidence shall be either type tests done in a controlled environment or commissioning tests done on-site. In either case, the testing must be done not only in accordance with widely recognized standards, but also to the satisfaction of the IESO. Until this evidence is provided and found acceptable to the IESO, the Facility Registration/Market Entry process will not be considered complete and the connection applicant must accept any restrictions the IESO may impose upon this project's participation in the IESO-administered markets or connection to the IESO-controlled grid.

The evidence must be supplied to the IESO within 30 days after completion of commissioning tests. Failure to provide evidence may result in disconnection from the IESO-controlled grid.

If the submitted models and data differ materially from the ones used in this assessment, then further analysis of the project will need to be done by the IESO.

Hydro One must complete the IESO Facility Registration/Market Entry process in a timely manner before IESO final approval for connection is granted.

– End of Section –

3. Review of Connection Proposal

3.1 Proposed Connection Arrangement

The applicant proposes building a new transformer station that would be supplied via 115 kV line taps from Ainsworth Junction to the existing Ainsworth 4J line tapped from 115 kV circuit K6F.

The transformer station would be equipped with two 115.5 kV - 44kV, 25/42 MVA transformers (ONAN/ONAF). The HV and LV windings would be connected Wye-Wye, and the tertiary winding would be buried. The neutral point of the transformer LV winding would be solidly grounded. The transformers would be equipped with an Under Load Tap Changer (ULTC) with the range of +/- 8.8 kV in 32 steps.

The new transformers would be protected against surges on the HV and LV side by station class surge arresters.

Each of the new transformers would be connected to the 115 kV bus via a 138 kV disconnect switch and SF6 circuit switcher with a rated symmetrical short circuit capability of 20 kA.

The high-voltage switches and connections would be capable of carrying a load of 56 MVA each in both summer and winter. The high-voltage switches and circuit switchers would be capable of operating up to minus 50^{o}C.

Initially two 44 kV feeder positions would be installed, with feeder breakers to isolate the LV side of the transformer during fault conditions. Provision would also be made for two additional feeder breakers for future feeders.

One 5 Mvar capacitor bank and circuit breaker would be installed on the 44 kV side of the transformer, to provide voltage support.

Figure 1 shows the single line diagram of the proposed connection.

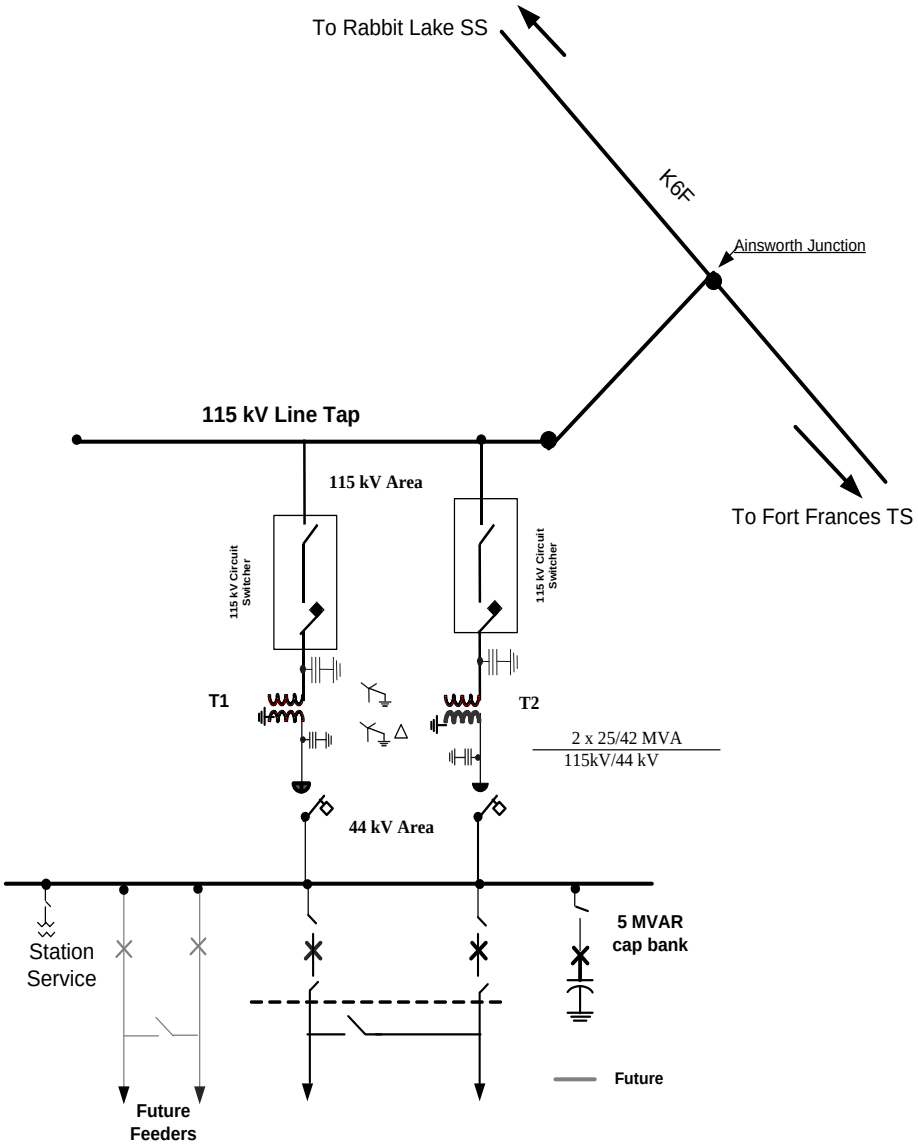


FIGURE 1. BARWICK TS SUPPLIED FROM 115 kV CIRCUIT K6F AT AINSWORTH JUNCTION

3.2 Existing System

Historical data consisting of hourly average samples for the summers from 2006 to 2009 were obtained from IESO real-time telemetry for the following quantities:

- Total Generation into Rabbit Lake from Caribou Falls, Whitedog Falls, Norman and Kenora (MW)
- Active Power flow on K6F at Rabbit Lake (MW)
- Interface flows on Ontario Manitoba Transfer East at Kenora, Minnesota Power Flow South at Fort Frances and East West Transfer East at Wawa (MW)

Graphs for these quantities are shown in Figures 2 to 6. Note that for active power flows, positive values represent flows out of the station.

FIGURE 2: RABBIT LAKE CONNECTED GENERATION (OUTPUT)

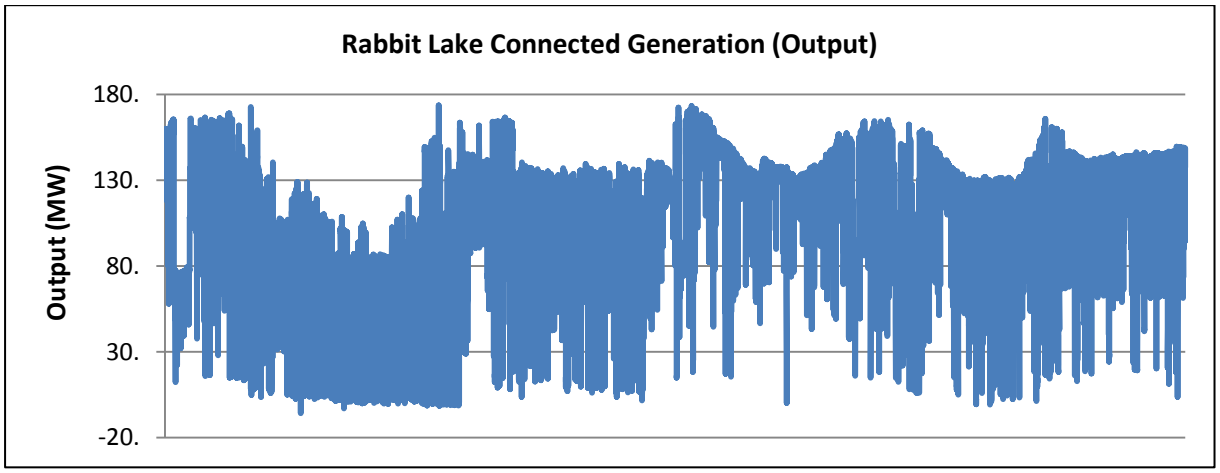


FIGURE 3: ACTIVE POWER FLOW ON K6F AT RABBIT LAKE

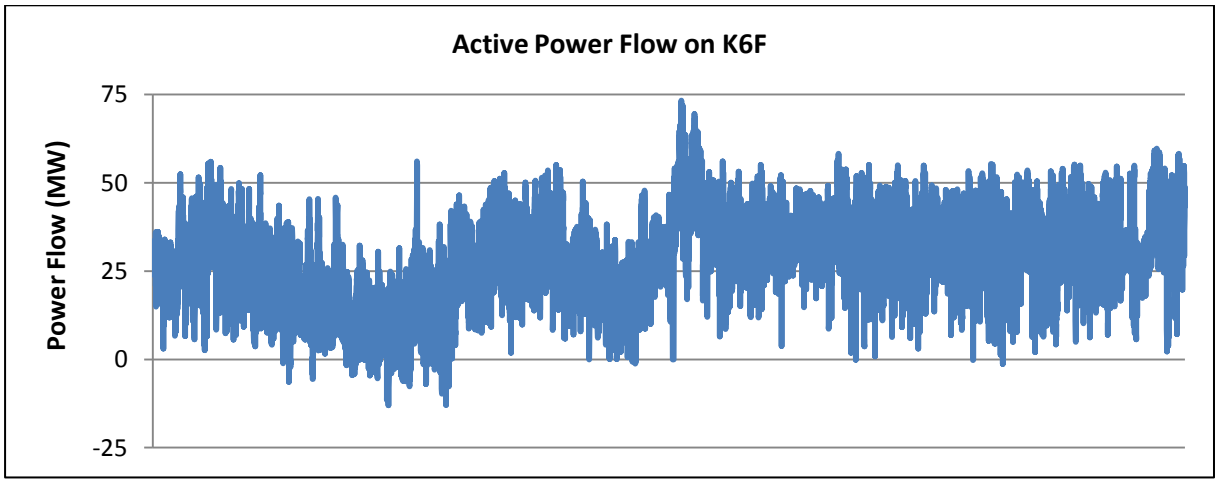


FIGURE 4: ACTIVE POWER FLOW AT KENORA ON K21W AND K22W

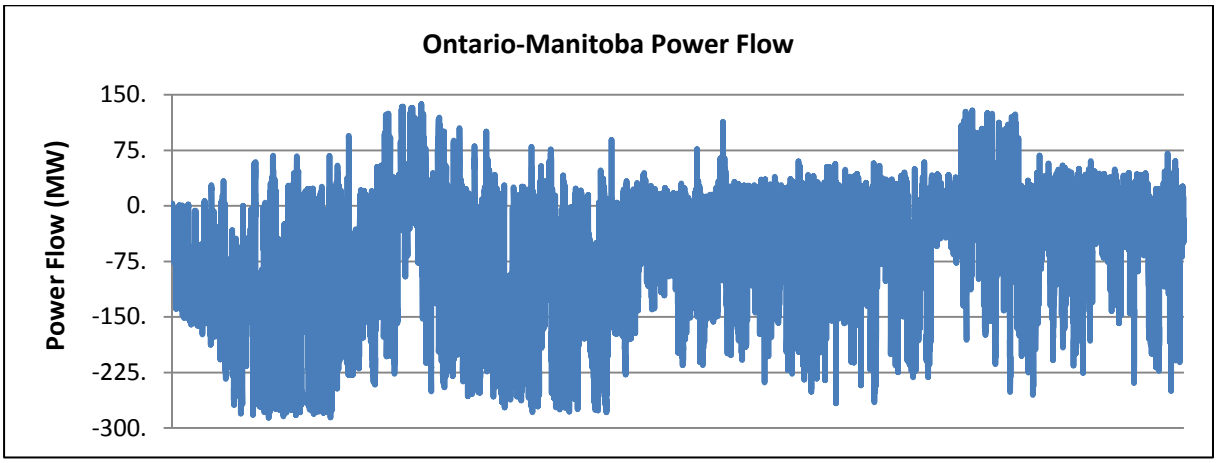


FIGURE 5: ACTIVE POWER FLOW AT FORT FRANCES ON F3M

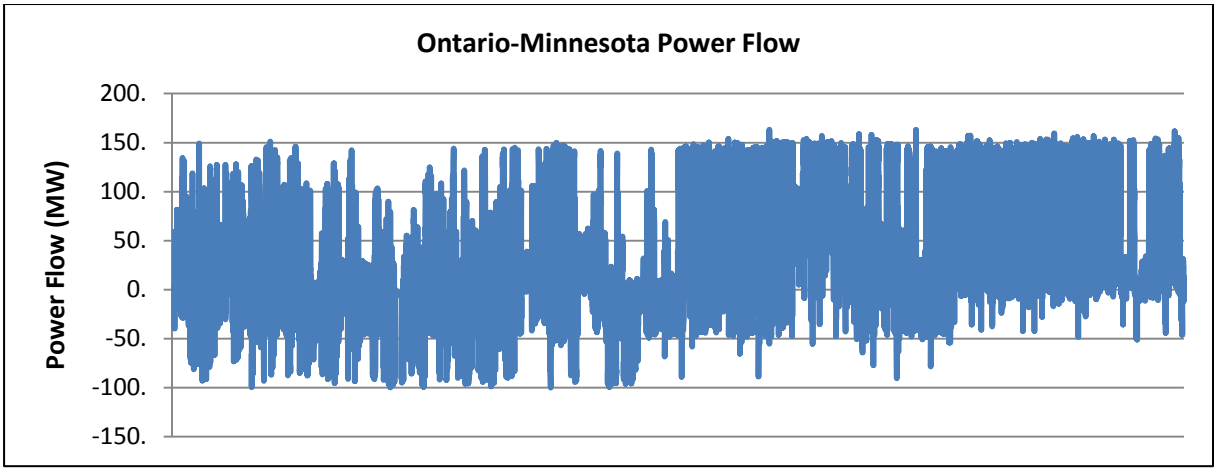
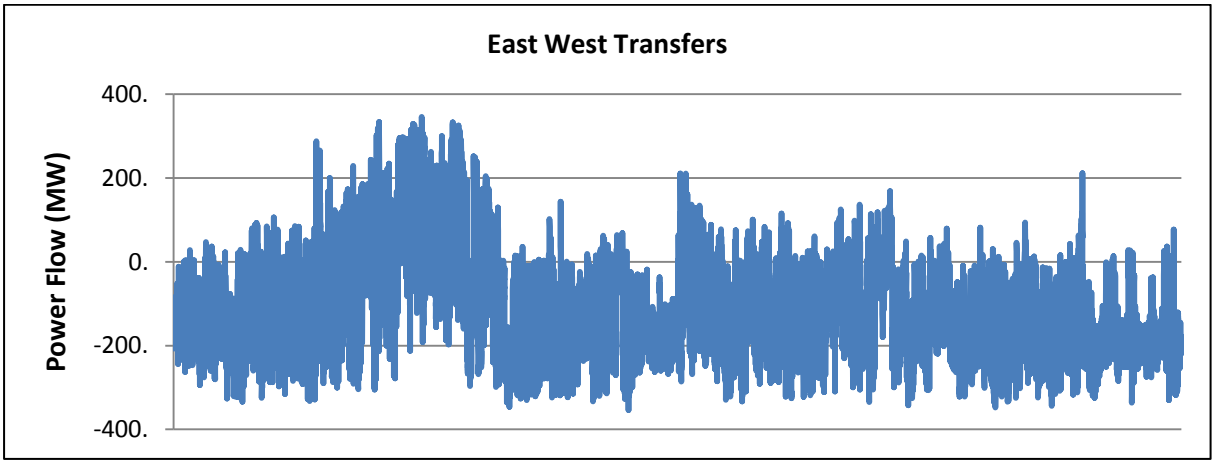


FIGURE 6: ACTIVE POWER FLOW AT WAWA ON W21M AND W22M



From the above graphs, it can be observed that:

Quantity	Maximum	Minimum
Generation into Rabbit Lake	173 MW	-5.7 MW
Active Flow on K6F out of Rabbit Lake	73.3 MW	-13 MW
Ontario-Manitoba Transfers	138 MW	-286 MW
Ontario-Minnesota Transfers	163 MW	-100 MW
East-West Transfers	346 MW	-354 MW

The above quantities were taken into consideration when determining the study scenarios and assumptions for this System Impact Assessment.

3.3 Data Verification

This section verifies the specifications for the new equipment proposed by Hydro One to be installed at Barwick TS.

Tap Line

Type	Overhead
Voltage	115 kV
Continuous current rating	450 A
Length	0.1 km
Conductor	211.6 ACSR 6/1
Impedance (p.u. on 118.05 kV, 100 MVA)	0.00032 + j0.00041 p.u.

115 kV Transformer Disconnect Switches

Quantity	2
Type	SF6 circuit interrupter with motorized disconnect switch
Maximum continuous rated voltage	138 kV
Continuous current rating	350 A
Rated symmetrical short circuit capability	20 kA RMS symmetrical

Step-down Transformer

Quantity	2
Thermal ratings	25/33/42 MVA (ONAN, ONAF, OFAF)
Rated voltage	115.5 kV/44 kV
Under-load tap changer (ULTC)	$\pm$8.8 kV in $\pm$16 steps (on the 44 kV side)
Transformer connections	HV: Wye

	LV: Wye (neutral solidly grounded)
	Tertiary: Buried
Long Term Emergency Rating	56.3 MVA
Impedance	HX: 0.00201 + j0.07725 pu on 25 MVA base
	HY: 0.00335 + j0.12862 pu on 10 MVA base
	XY: 0.00082 + j0.03141 pu on 10 MVA base

The proposed equipment at Barwick TS satisfies the IESO requirements for connection.

Appendix 2 of the Transmission System Code (TSC) specifies that the maximum 3-phase single line to ground symmetrical fault levels for 115 kV systems is 50 kA. However, the rated symmetrical short circuit capability of the circuit interrupters at Barwick TS is 20 kA, sufficient to accommodate the current short circuit level. If future system enhancements result in increased fault level in excess of the equipment's capability, Hydro One Networks Inc. is required to replace the equipment at its own expense with higher rated equipment capable of sustaining the increased fault level, up to the maximum fault level specified in Appendix 2 of the Transmission System Code.

– End of Section –

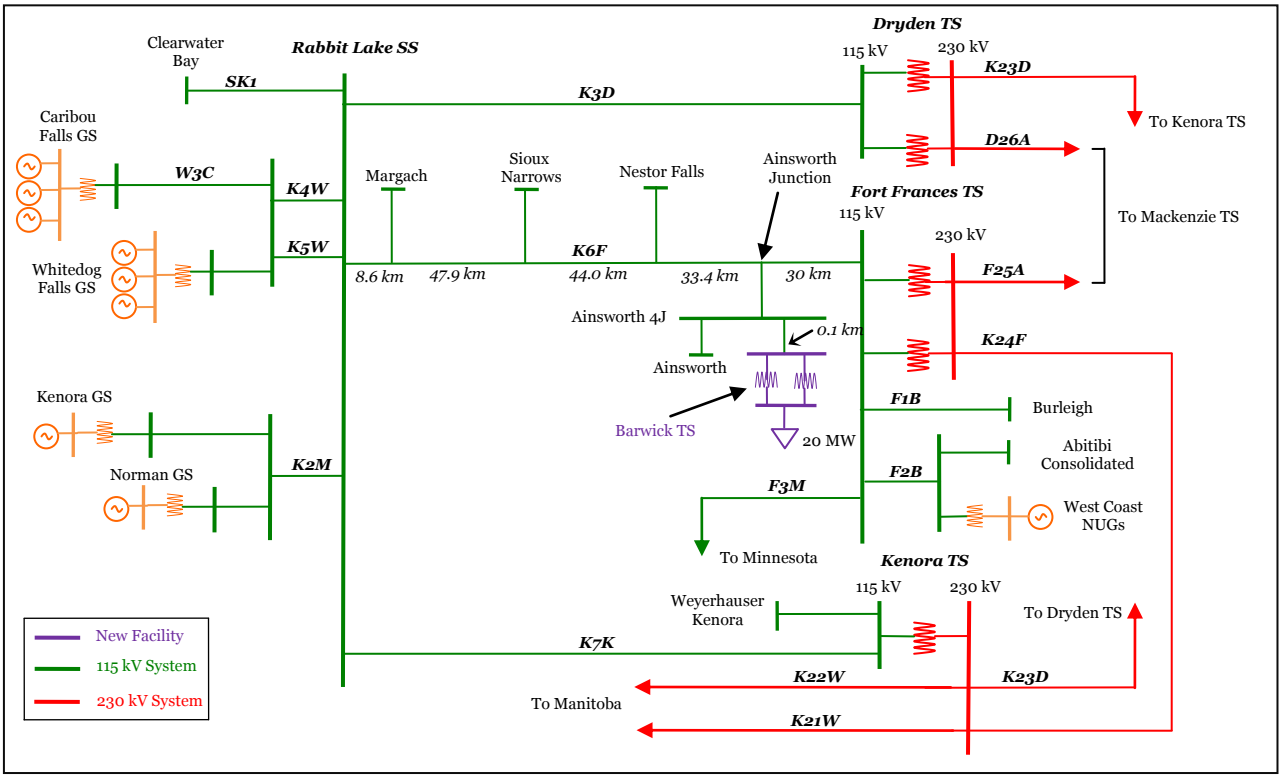
4. System Impact Studies

4.1 Description

This connection assessment was performed to identify the effect of the proposed facility on the reliability of the IESO-controlled grid. This included examining the thermal loading of the transmission system encompassed by Rabbit Lake and Fort Frances, and the impact on system voltages for pre and post contingency scenarios and capacitor switching operations.

Figure 7 provides an overview of the transmission system in the vicinity of the proposed Barwick TS project.

FIGURE 7: TRANSMISSION SYSTEM IN THE VICINITY OF BARWICK TS



4.2 Study Criteria

The following criteria are an excerpt from the Ontario Resource and Transmission Assessment Criteria (ORTAC) and apply to this study:

- Section 4.1: New or modified connections to the IESO-controlled grid are not permitted to lower power transfer capability or operating security limits by 5% or more.

- Section 4.2: Pre-contingency voltages for 230 kV buses are to be within 220 kV and 250 kV, and 115 kV are buses to be within 113 kV and 132 kV.

- Section 4.3: Post-contingency voltages for 230 kV buses are to be within 207 kV and 250 kV, and 115 kV buses are to be within 108 kV and 127 kV. In addition, post contingency voltage changes before tap changer action should not be more than 10%, and after tap changer action should not be more than 10% at the 230 kV and 115 kV buses.

- Section 4.3.2: Capacitive devices should be sized to ensure that voltage declines or rises at delivery point buses on switching operations will not exceed 4% of steady state rms voltage for line switching operations, per Chapter 4 of the "Market Rules". This 4% is based on load flows before tap changer action using a voltage dependent load model.

- Section 4.7.2: All equipment loadings shall be within their continuous ratings with all elements in service and within their long-term emergency ratings with any one element out of service. Immediately following contingencies, lines may be loaded up to their short-term emergency ratings (STE) where control actions are available to reduce the loadings to the long-term emergency ratings (LTE).

4.3 Study Assumptions

- The studies were performed using summer conditions to represent more limited thermal capability of the lines. Although the Northwest zone is generally winter peaking, the substantial reduction in line ratings during the summer causes a more significant impact than the difference in load peaks between summer and winter.

- Ontario demand was scaled to summer 2013 values.

- All generation into Rabbit Lake was considered to be in-service and at full capacity, to simulate higher flows across K6F. Historically, the highest generation that occurred over the four consecutive summers from 2006 to 2009 was an output of 173 MW (Figure 2 of Section 3.2), corresponding to 3 units in service at each of Caribou Falls GS and Whitedog Falls GS, and 1 unit in service at each of Kenora GS and Norman GS. Over the four summers considered in the study, the scenario with all 8 units in service occurred over 20% of the time.

- West Coast NUGs were considered to be out of service to further stress K6F.

- Imports from Manitoba and exports to Minnesota were found to have the greatest impact on K6F flows, hence transfers were created by scheduling generation between Manitoba, Minnesota and Ontario. To reach the post-contingency thermal limitation of K6F before the addition of the proposed station, Ontario Manitoba Transfer East (OMTE) was set at 143.2 MW and Minnesota

Power Flow South (MPFS) was set at 72.6 MW. East West Transfer East (EWTE) flows were maintained below 325 MW, as per system limits.

- The most thermally-limiting section of the 115 kV circuit K6F is from Margach Junction to Sioux Narrows Junction, with a continuous rating of 430 A (88 MVA assuming a 118.1 kV operating voltage). The Long Term Emergency rating (LTE) and Short Term Emergency rating (STE) of the line are the same as the continuous rating. The ratings assume an ambient temperature of 30°C and a wind speed of 4 km/h. The thermal ratings of all sections of K6F are given in Appendix A, as obtained from Hydro One.
- A 0.90 lagging power factor, as required under section 2.4 of the ORTAC, was assumed for the loads at all stations in the area from Rabbit Lake to Fort Frances.
- The load data provided by Hydro One for Fort Frances TS gives a peak load of 20 MW at 0.9 lagging power factor.
- Due to the low level of load and expected load growth in Northwest Ontario over the next ten years, as well as the uncertainty surrounding industrial loads, historical data for loads from summers 2006 to 2009 was used for modelling. Data for loads in the Rabbit Lake and Fort Frances areas were obtained, and coincident data was found for the scenario with maximum total loading of the Fort Frances area loads and minimum total loading of Rabbit Lake area loads. This was done in order to simulate a scenario that would cause the greatest load differential between Fort Frances and Rabbit Lake, and thus increase flows across K6F. The loads used in this study are given in Appendix B.
- A constant power load model was used to represent Ontario loads.

4.4 Thermal Loading Assessment

The purpose of this assessment is to determine the impact of the proposed Barwick TS project on the thermal loading of circuits in the vicinity of the station. Of the circuits monitored, the 115 kV circuit K6F was identified to be the most restrictive. With all elements in service, equipment loadings must be within the continuous ratings and with any one element out of service, equipment loadings must be within the Long Term Emergency (LTE) ratings, as per section 4.7.2 of the ORTAC.

The percentage loading of each K6F section was calculated as follows:

$$\%\ Loading = \frac{(Equipment\ Loading)}{Continuous\ Rating}\ x\ 100$$

For the post-contingency scenario, the following set of contingencies was studied:

- Loss of 230 kV circuit K24F
- Loss of Kenora TS
- Loss of 230 kV circuit K23D
- Loss of 115 kV circuit K3D

The worst contingency was found to be the loss of K24F, which resulted in the highest loading of circuit K6F. With imports from Manitoba and exports to Minnesota set at the values given in Section 4.3, flows on the most limiting section of K6F will cause the circuit to be at its maximum thermal capability for the

loss of K24F, as shown in the results in Appendix C. The highest loaded section of circuit K6F is from Margach Junction to Sioux Narrows Junction, with a post Barwick TS connection loading of 100%, which satisfies Section 4.7.2 of the ORTAC. Detailed results of the study are presented in Appendix C.

4.5 Power Transfer Capability Assessment

The purpose of this assessment is to determine the impact of the proposed Barwick TS project on the power transfer capability of the system, by comparing the transfer capability of the current system to the future system. New or modified connections to the IESO-controlled grid are not permitted to lower the power transfer capability by 5% or more, as per Section 4.1 of the ORTAC.

Following the loss of K24F and before the addition of the proposed station, imports from Manitoba over the Ontario-Manitoba interconnection and exports to Minnesota over the Ontario-Minnesota interconnection were recorded at the point where the most limiting section of K6F reached its maximum thermal capability. These transfers were then compared to the OMTE and MPFS flows after the addition of the proposed station, and with the loss of K24F.

The change in power transfer capability was calculated as follows:

$$\%\, Transfer_{ch} = \frac{Transfer_{Before\ addition} - Transfer_{After\ addition}}{Transfer_{Before\ addition}}$$

The results show that following the connection of Barwick TS, the most limiting section of circuit K6F (Margach Junction to Sioux Narrows Junction) will reach its thermal capability for OMTE and MPFS flows reduced from $OMTE_{Before\ addition}$ and $MPFS_{Before\ addition}$ to $OMTE_{After\ addition}$ and $MPFS_{After\ addition}$, respectively. This represents a power transfer capability reduction of 1.6 MW from Manitoba and 1.3 MW to Minnesota, or 1.1% and 1.8% respectively, which satisfies section 4.1 of the ORTAC. The results for the power transfer capability assessment are displayed in Appendix D.

4.6 System Voltage Assessment

The purpose of this assessment is to determine the impact on system voltages of the proposed Barwick TS with all elements in service and following the loss of various transmission elements. The loss of K24F was identified as causing the largest voltage changes in the area.

With all elements in service, the voltages at all monitored buses fall within the limits given in Section 4.2 of the ORTAC, and are given in Appendix E.

The percentage change in voltage was calculated as follows:

$$\%\, V_{ch} = \frac{V_{Pre-contingency} - V_{Post-contingency}}{V_{Pre-contingency}}$$

For the loss of K24F, following the load transfer from Fort Frances TS to Barwick TS, the highest voltage changes were recorded at the 115 kV Barwick TS and Ainsworth 4J buses. The pre-ULTC and post-ULTC voltage changes for these buses were 4.4% and 4.0%, respectively, and are within acceptable

limits as per Section 4.3 of the ORTAC. Detailed results of the system voltage assessment for the loss of K24F are presented in Appendix E.

4.7 Switching Studies

The purpose of this assessment is to determine the impact on system voltages after switching the proposed 5 Mvar capacitor bank connected to the 44 kV Barwick TS bus. Section 4.3.2 of the ORTAC requires that capacitive devices be sized to ensure that voltage declines or rises at delivery point buses do not exceed 4% of steady state rms voltage for line switching operations.

The proposed 5 Mvar capacitor bank was tested for compliance with Section 4.3.2 of the ORTAC by using a voltage dependent load model. Loads in the Northwest were reduced to 70% of the loads given in Section 4.3, to simulate the switching of the capacitor in preparation for the daily peak load (between 6 and 9 am). A 2.4% voltage change was observed at the 44 kV Barwick TS bus following the switching in of the capacitor, which is in accordance with Section 4.3.2 of the ORTAC. The results of the capacitor switching study are presented in Appendix F.

– End of Section –

Appendix A: Equipment Thermal Ratings

Table A1: Thermal Ratings for 115 kV Circuit K6F

From	To	Cont		LTE	
		A	MVA	A	MVA
Rabbit Lake SS	Margach JCT	530	108	530	108
Margach JCT	Sioux Narrows JCT	430	88	430	88
Sioux Narrows JCT	Nestor Falls JCT	470	96	470	96
Nestor Falls JCT	Ainsworth JCT	470	96	470	96
Ainsworth JCT	Fort Frances JCT	470	96	470	96
Fort Frances JCT	Fort Frances TS	470	96	470	96

Appendix B: Rabbit Lake - Fort Frances Area Loads

Table B1: Coincident Data for Loads Connected to K6F, Rabbit Lake and Fort Frances TS

Supplied From	Station	Load (MW) at 0.9 P.F.
Rabbit Lake 115 kV	Kenora DS	5.5
	Clearwater	2.4
	Minaki	0.6
	Kenora MS	17.5
	Weyerhauser	9.3
115 kV Circuit K6F	Margach	4.7
	Sioux Narrows	2.2
	Nestor Falls	1.9
	Ainsworth	6.1
Fort Frances 115 kV	Fort Frances AB	73.0
	Fort Frances MS	13.3
	Burleigh	1.9

Appendix C: Thermal Loading Assessment Results

Table C1: Thermal Loading Analysis for 115 kV Circuit K6F

Section		All elements in service		Loss of K24F		Loss of Kenora TS		Loss of K23D		Loss of K3D	
From	To	Flow (MVA)	Ldg (%)	Flow (MVA)	Ldg (%)	Flow (MVA)	Ldg (%)	Flow (MVA)	Ldg (%)	Flow (MVA)	Ldg (%)
Rabbit Lake SS	Margach JCT	60	56	97	90	75	69	62	57	64	59
Margach JCT	Sioux Narrows JCT	53	60	88	100	68	77	56	64	58	66
Sioux Narrows JCT	Nestor Falls JCT	50	52	83	86	64	67	52	54	54	56
Nestor Falls JCT	Ainsworth JCT	47	49	78	81	61	64	50	52	51	53
Ainsworth JCT	Fort Frances JCT	20	21	52	54	34	35	23	24	25	26
Fort Frances JCT	Fort Frances TS	20	21	50	52	33	34	22	23	24	25

Appendix D: Power Transfer Capability Assessment

Table D1: Effect of Proposed Barwick TS on Power Transfer Capability of Interfaces

Interface	Circuit	Before Addition of Barwick TS (MW)	After Addition of Barwick TS (MW)	Transfer Change (%)
Ontario Manitoba Transfer East (OMTE)	K21W	71.6	70.8	1.1
	K22W	71.6	70.8	1.1
Minnesota Power Flow South (MPFS)	F3M	72.6	71.3	1.8
East West Transfer East (EWTE)	W21M	103.9	103.7	-
	W22M	103.9	103.7	-

Appendix E: System Voltage Assessment Results

Table E1: Pre and Post-Contingency Voltage Analysis for Proposed Barwick TS

Monitored Bus		All elements in service	Loss of K24F			
			Pre-ULTC		Post-ULTC	
Bus Name	Base voltage (kV)	Voltage (kV)	Voltage (kV)	V_{ch} (%)	Voltage (kV)	V_{ch} (%)
Fort Frances TS	220	238.7	230.4	3.5	230.8	3.3
Dryden TS	220	244.2	240.1	1.7	239.6	1.9
Kenora TS	220	243.8	241.4	1.0	241.7	0.9
Marathon TS	220	248.2	248.8	-0.2	248.8	-0.2
Mackenzie TS	220	244.0	240.8	1.3	240.8	1.3
Rabbit Lake	118	123.1	121.6	1.2	122.6	0.4
Fort Frances TS	118	121.5	117.7	3.1	118.0	2.9
Kenora TS	118	122.6	121.7	0.7	123.0	-0.3
Barwick TS	118	116.0	110.9	4.4	111.4	4.0
Ainsworth Junction	118	119.9	115.1	4.0	115.6	3.6
Ainsworth 4J	118	116.0	110.9	4.4	111.4	4.0

Appendix F: Switching Study Results

Table F1: Switching Study for Proposed 44 kV 5 Mvar Capacitor Bank

Monitored Bus		Before Switching in 5 Mvar Capacitor	After Switching in 5 Mvar Capacitor	
Bus Name	Base voltage (kV)	Voltage (kV)	Voltage (kV)	Change (%)
Fort Frances	220	233.2	234.0	0.3
Dryden	220	241.4	241.5	0.0
Kenora TS	220	237.3	237.7	0.2
Marathon TS	220	248.4	248.5	0.0
Mackenzie TS	220	238.8	239.2	0.2
Rabbit Lake	118	126.8	127.1	0.2
Fort Frances	118	119.1	119.6	0.4
Kenora TS	118	127.8	128.0	0.2
Barwick TS	118	115.5	117.2	1.5
Ainsworth Junction	118	118.8	119.8	0.8
Ainsworth 4J	118	115.5	117.2	1.5
Barwick TS	44	45.1	46.2	2.4