REPORT

System Impact Assessment Report

CONNECTION ASSESSMENT & APPROVAL PROCESS

Final Report

CAA ID: **2018-633**
Project: **Leamington TS DESN # 2**
Applicant: **Hydro One Networks Inc.**

Engineering Studies Department
Independent Electricity System Operator

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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 project 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 project 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. This report does not in any way constitute an endorsement of the proposed connection for the purposes of obtaining a contract with the IESO for the procurement of supply, generation, demand response, demand management or ancillary services.

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 connection 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.

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Executive Summary

Conditional Approval for Connection

Hydro One Networks Inc. (the "connection applicant" and "transmitter") is planning a one-time 80 MW load increase to the existing Dual Element Spot Network (DESN) switchyard at Leamington Transformer Station (TS), from 100 MW to 180 MW, and planning to add a new DESN switchyard at the existing Leamington TS to provide electric supply to the expected load growth in the Leamington area (the "project"). The project will connect to Hydro One Networks Inc. ("Hydro One") owned 230 kV circuits from Chatham Switching Station (SS) to Keith TS, C21J and C22J near the existing Leamington TS. After the project, Leamington TS will have two DESN switchyards: DESN 1 for the existing switchyard and DESN 2 for the new switchyard.

Figure 1 shows the single-line diagram for the project's connection point on the local transmission system and Figure 2 shows the layout of the proposed project. The project will include two 75/100/125 MVA, 215.5/27.6/27.6 kV transformers each with a 230 kV disconnect switch on the high voltage side of the transformer. There will be two 27.6 kV buses separated by a normally open bus-tie breaker and each 27.6 kV bus will have one shunt capacitor bank rated at 21.6 Mvar at 27.6 kV. The load will be fed from a total of twelve feeders. The planned in-service date is in January 2020.

The connection applicant understands that the project will result in thermal and voltage issues in the Windsor area system and has started working with the IESO to reinforce the transmission system to accommodate the load increase in this area. During the interim period before future transmission reinforcement is in place, to protect circuits C22J and C21J from post-contingency thermal overload following the loss of C21J or C22J, respectively, Hydro One proposes to add a contingency-based load rejection (L/R) scheme, namely, Leamington contingency-based Special Protection System (SPS). The SPS would reject Leamington TS load following the loss of C21J or C22J. To avoid post-contingency high voltages, all capacitors at Leamington TS are proposed to be automatically tripped for system over-voltage conditions.

Studies were performed considering the connection of two additional loads near Leamington TS, Aphria Customer Transformer Station (CTS) (60 MW) and Mastron II CTS (53 MW), which are proposed to connect to circuits C22J and C21J, respectively, within the next two years.

This assessment concludes that the proposed connection of the project is expected to have no material adverse impact on the reliability of the integrated power system, provided that all requirements in this report are implemented. Therefore, the assessment supports the release of the Notification of Conditional Approval for connection of the project.

Assessment Findings

The project, together with Mastron II CTS and Aphria CTS, was assessed for impact on system reliability of the IESO-controlled grid, and based on our study results, we have identified the following assessment findings.

1. With all transmission elements in-service and with Brighton Beach CGS out of service, under peak load conditions and with no transfers on J5D, the incorporation of the project could result in:
    a. thermal overloads and voltage criteria violations following the loss of C21J or C22J. Up to 210 MW of load would need to be rejected by the Leamington contingency-based SPS to prevent Ontario Resources and Transmission Assessment Criteria (ORTAC) thermal and voltage criteria violations. However, under these system conditions, rejecting more than 150 MW of load is a violation of the ORTAC load security criteria. In addition, Mastron II CTS

or Aphria CTS would be interrupted by configuration, for a maximum of 263 MW of load being interrupted.

b. thermal overloads and voltage criteria violations for the following recognized double contingencies: simultaneous loss of C21J and C23Z, simultaneous loss of C22J and C24Z, simultaneous loss of C23Z and C24Z, failure of Chatham DL21 breaker, failure of Chatham L21L47 breaker, failure of Chatham DL44 breaker, and failure of Keith C21J in-line breaker. The worst recognized double contingency is the simultaneous loss of C21J and C23Z, which requires up to 257 MW of load to be rejected by the revised Leamington contingency-based SPS (see section 4.13) to prevent ORTAC thermal and voltage criteria violations. In addition, up to 53 MW of load at Mastron II CTS would be interrupted by configuration, for a total of 310 MW of load being interrupted. However, interrupting 310 MW of load is acceptable under ORTAC load security criteria for these system conditions.

2. During either C21J or C22J outages and with Brighton Beach CGS in-service, under peak load conditions and with no transfers on J5D, the incorporation of the project could result in:

   a. pre-contingency under voltages and voltage stability margin violations at Leamington TS. 25 MW of the load at Leamington TS and Aphria CTS (or Mastron II CTS) would need to be curtailed or transferred to Kingsville TS when system conditions allow to address voltage criteria violations. However, under these system conditions, interrupting any load is a violation of the ORTAC load security criteria;

   b. thermal overloads on C22J following the loss of a single Brighton Beach CGS unit or for the loss of the entire Brighton Beach CGS plant, and excessive low voltages at Leamington TS, Aphria CTS and Mastron II CTS following the loss of the entire Brighton Beach CGS. The issues could be mitigated by rejecting up to 210 MW of load through arming of the revised Leamington contingency-based SPS. However, under these system conditions, rejecting more than 150 MW of load is a violation of the ORTAC load security criteria;

   c. thermal overloads on C22J following the simultaneous loss of C23Z and C24Z. The overloads could be mitigated by rejecting up to 100 MW of load through arming of the revised Leamington contingency-based SPS, which is acceptable under the ORTAC load security criteria for these system condition;

   d. excessive low voltages at Leamington TS, Aphria CTS and Mastron II CTS following simultaneous loss of C23Z and C24Z, or failure of Chatham DL44 breaker. These conditions were found to be the most restrictive of those required to be studied under ORTAC. Although they may impact the local reliability of supply to the Leamington TS, Aphria CTS and Mastron II CTS loads; the impact on the bulk system is acceptable and there is no violation to applicable reliability standards.

3. No thermal or voltage violations were identified under maximum historical J5D export levels (400 MW) if Brighton Beach CGS is in-service after the incorporation of the project.

4. The C22J thermal rating will become limiting during export to Michigan when Brighton Beach CGS is out of service, when the maximum exports on J5D under summer and winter conditions with planning thermal ratings are 220 MW and 100 MW, respectively.

   In addition, post-contingency voltage violations were identified when J5D export exceeds 100 MW with Brighton Beach out of service. To mitigate these violations and allow higher J5D exports when the pre-contingency thermal ratings are not limiting, additional schemes are required for:

   a. any contingency that includes the loss of C21J, C22J, Chatham D bus, and the simultaneous loss of C23Z and C24Z contingency, to prevent excessive low voltage. This could be addressed by adding local under-voltage L/R schemes (see section 4.13). Up to 369 MW of load at Leamington TS, Apria CTS, and Mastron II CTS would need to be rejected to prevent criteria violations;

b. the inadvertent breaker operation of the in-line 230 kV circuit breaker CF on circuit J5D at Michigan Waterman, to prevent excessive high voltages in the Windsor area. This could be addressed by implementing local over-voltage capacitor switching schemes at Lauzon TS and Keith TS (see section 4.13).

5. After the incorporation of the project, up to 567 MW of load along the Chatham to Keith corridor could be interrupted with C21J and C22J out of service. While up to 600 MW of load is allowed to be interrupted by configuration with two transmission elements out of service, the ORTAC requires all load in excess of 250 MW be restored within 30 minutes, the load in excess of 150 MW be restored within 4 hours, and the total load needs to be restored within 8 hours. Hydro One has indicated that these restoration targets cannot be met;

6. Chatham to Longwood and Chatham to Lambton circuits are part of the North East Power Coordinating Council (NPCC) Bulk Power System (BPS) system. Following the loss of one circuit, the system needs to be re-prepared within 30 minutes to be able to withstand next recognized contingency. After a forced outage to L28C, L29C, W44LC, W45LS or S47C circuits under peak load conditions, the system cannot be re-prepared to withstand the simultaneous loss of L28C and L29C, W44LC and W45LS, or W44LC and S47C if local generation is out of service; this is because, with the exception of East Windsor CGS, all local generators are slow starting. Up to 190 MW of load at Leamington TS, Aphria CTS, and Mastron II CTS would need to be curtailed until enough local generation is online and avoid declaring emergency conditions. The SPS identified in section 4.14 with the capability to arm load rejection for the four BPS circuits indicated earlier would avoid the load curtailment.

Requirements for Connection

Specific Requirements: The following *specific* requirements are applicable for the incorporation of project. Specific requirements pertain to the level of reactive compensation needed, operation restrictions, special protection system, upgrading of equipment and any project specific items not covered in the *general requirements*.

1. Since the ORTAC load security criteria cannot be met after project incorporation as identified in findings #1 and #2, Hydro One, is required to obtain an exemption from satisfying the load security criteria, as per section 7.5 of the ORTAC, for the loads supplied by Leamington TS before the in-service date of the project.
2. As identified in finding #5, Hydro One is required to obtain an exemption from satisfying the load restoration criteria, as per section 7.5 of the ORTAC, for the loads connected to circuits C21J and C22J.
3. Hydro One is required to provide a plan for load curtailment/rejection and load restoration along circuits C21J and C22J specifying how the demand will be managed during and following outages.
4. Hydro One is required to install the revised Leamington SPS identified in section 4.13, which is a contingency based L/R scheme, as per the selection matrix shown in Table 18. The SPS must have full redundancy and separation of the communication channels, and must satisfy the requirements of the NPCC Type I SPS criteria in accordance to section 3.4.1 in ORTAC.
5. Hydro One is also required to install the following:
    a. A local under-voltage L/R scheme that will automatically trip Leamington TS load in four equal stages if the voltage at any of the Leamington 230 kV buses is below 207 kV for more than 5 seconds, with a delay of 3 seconds between stages.

b. Coordinated local area over-voltage capacitor protection that will include automatically tripping the capacitors at Leamington TS as per the settings in Table 19 of section 4.13.

c. A local over-voltage capacitor switching scheme at Lauzon TS that will automatically trip the Lauzon TS 115 kV capacitor if the voltage at any of Lauzon 115 kV buses is above 133kV for more than 500 milliseconds.

d. A local over-voltage capacitor switching scheme at Keith TS that will automatically trip the Keith TS 115 kV capacitor if the voltage at Keith 115 kV bus is above 133kV for more than 500 milliseconds.

Hydro One is required to submit a Facility Description Document (FDD) for these schemes to the IESO for approval during the Market Registration process.

6. Hydro One must revise the protection settings for 230 kV circuits C21J and C22J according to the Protection Impact Assessment (PIA) report included in Appendix A of this SIA report. If Hydro One identifies that further changes to the protection settings are required after this SIA is finalized, those changes must be submitted by the transmitter to the IESO at least six (6) months before any modifications are to be implemented on the existing protection systems.

General Requirements: The connection applicant shall satisfy all applicable requirements specified in the Market Rules. The most relevant requirements are presented in section 2 of this report.

Recommendation

To address the finding #6, Hydro One is recommended to install the contingency-based L/R SPS identified in section 4.14. The SPS should have full redundancy and separation of the communication channels, and must satisfy the requirements of the NPCC Type I SPS criteria in accordance to section 3.4.1 in ORTAC.

– End of Section –

1. Project Description

Hydro One Networks Inc. (the "connection applicant" and "transmitter") is planning a one-time 80 MW load increase to the existing Dual Element Spot Network (DESN) switchyard at Leamington Transformer Station (TS), from 100 MW to 180 MW, and planning to add a new DESN switchyard at the existing Leamington TS to provide electric supply to the expected load growth in the Leamington area (the "project"). The project will connect to Hydro One Networks Inc. ("Hydro One") owned 230 kV circuits from Chatham Switching Station (SS) to Keith TS, C21J and C22J, near the existing Leamington TS. After the project, Leamington TS will have two DESN switchyards: DESN 1 for the existing switchyard and DESN 2 for the new switchyard.

Figure 1 shows the single-line diagram for the project's connection point on the local transmission system and Figure 2 shows the layout of the proposed project. The project will include two 75/100/125 MVA, 215.5/27.6/27.6 kV transformers each with a 230 kV disconnect switch on the high voltage side of the transformer. There will be two 27.6 kV buses separated by a normally open bus-tie breaker and each 27.6 kV bus will have one shunt capacitor bank rated at 21.6 Mvar at 27.6 kV. The load will be fed from a total of twelve feeders. The planned in-service date is in January, 2020.

The connection applicant understands that the project will result in thermal and voltage issues in the Windsor area system and has started working with the IESO to reinforce the transmission system to accommodate the load increase in this area. During the interim period before future transmission reinforcement is in place, to protect circuits C22J and C21J from post-contingency thermal overload following the loss of C21J or C22J, respectively, Hydro One proposes to add a contingency-based Load Rejection (L/R) scheme, namely, Leamington contingency-based Special Protection System (SPS). The SPS would reject Leamington TS load following the loss of C21J or C22J. The selection matrix divides the 24 feeders supplying Leamington TS load into 8 groups (L1, L2, L3, L4, L5, L6, L7 and L8) with three feeders per group. The selection matrix for the proposed Leamington contingency-based SPS is shown in Table 1. To avoid post-contingency high voltages, all capacitors at Leamington TS are proposed to be automatically tripped for system over-voltage conditions.

Studies were performed considering the connection of two additional loads near Leamington TS, Aphria Customer Transformer Station (CTS) (60 MW) and Mastron II CTS (53 MW), which are proposed to connect to circuits C22J and C21J, respectively, within the next two years. As the additional loads would contribute to thermal and voltage issues in the Windsor area system, they are also required to participate in the proposed Leamington contingency-based SPS, as shown in Table 1. If capacitor(s) are required to be connected at Aphria CTS and Mastron II CTS, they will need to be automatically tripped for system over-voltage conditions as well.

Table 1: Selection Matrix for Hydro One's Proposed Leamington Contingency-based SPS

Contingency	Load									
	Leamington TS								Aphria CTS	Mastron II CTS
	L1	L2	L3	L4	L5	L6	L7	L8		
C21J	x	x	x	x	x	x	x	x	x	---
C22J	x	x	x	x	x	x	x	x	---	x

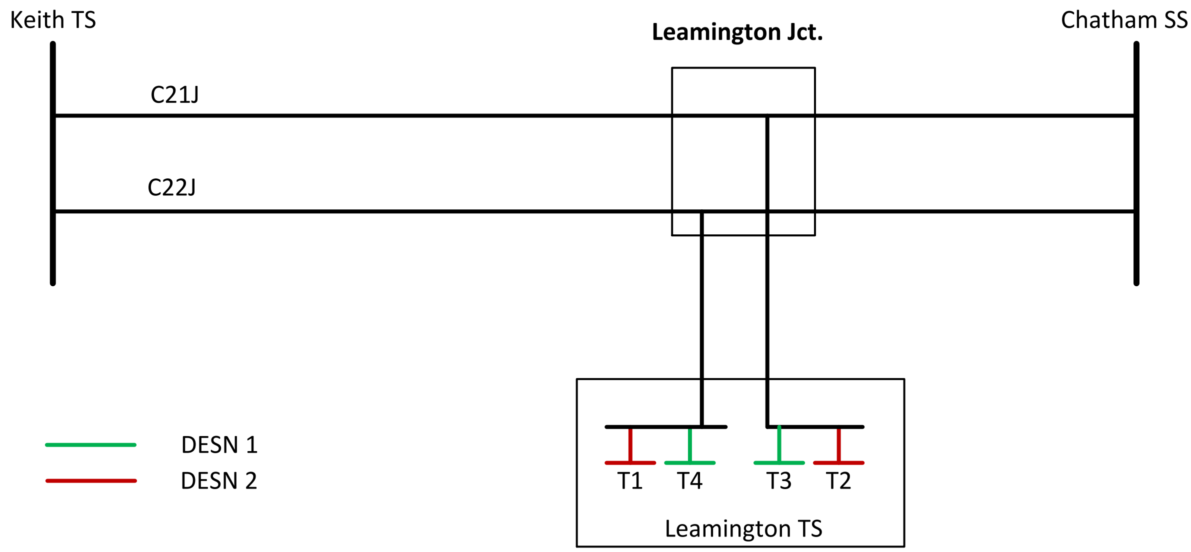

Figure 1: Simplified Single Line Diagram for the Project's Connection Point on Local Transmission System

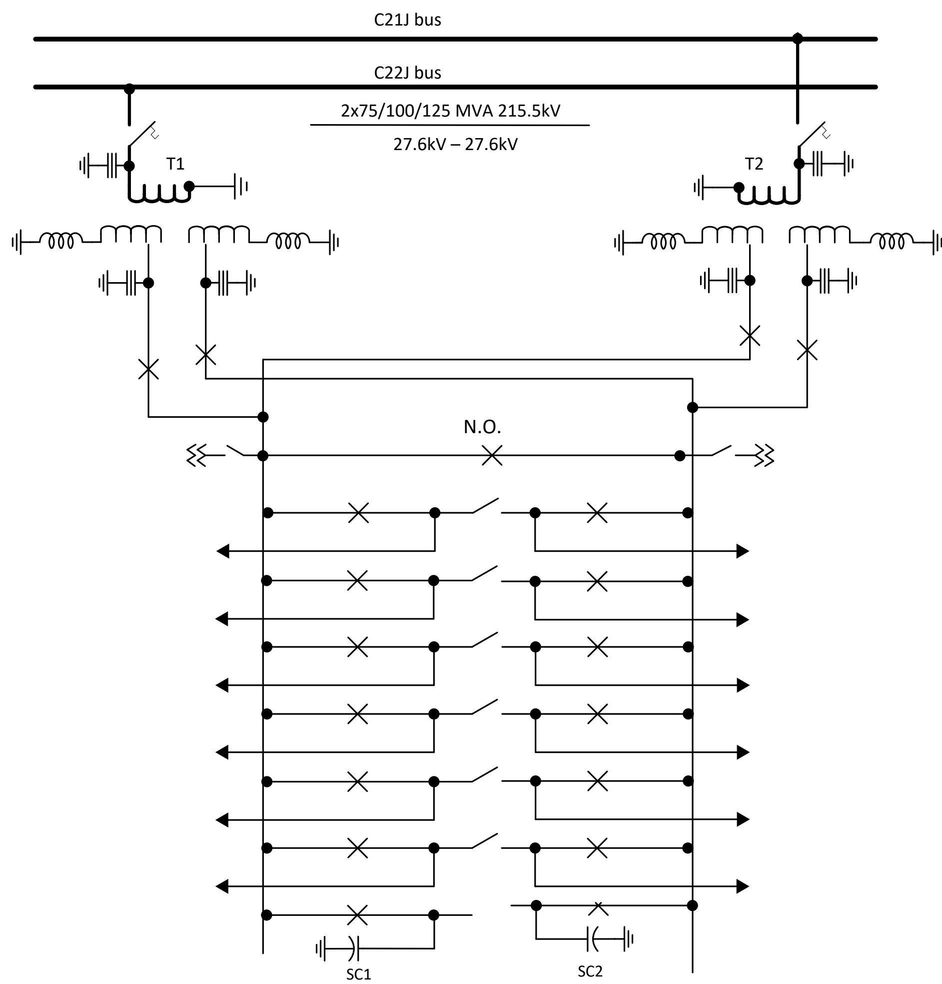

Figure 2: Single Line Diagram of the New DESN Switchyard at Leamington TS

– End of Section –

2. General Requirements

Hydro One shall satisfy all applicable requirements specified in the Market Rules, the Transmission System Code (TSC) and reliability standards. This section highlights some of the general requirements that are applicable to the project.

2.1 Reliability Standards

As currently assessed, the project does not fall within the North American Electric Reliability Corporation's (NERC) definition of the Bulk Electric System (BES) or the Northeast Power Coordinating Council's (NPCC) of the Bulk Power System (BPS). As such, the project does not have to meet NERC or NPCC requirements and is only required to meet obligations and requirements under the Market Rules at this time.

However, like any other system element in Ontario, the BPS and BES classifications of this project will be periodically re-evaluated as the electrical system evolves.

2.2 Project Changes

Hydro One shall notify the IESO at connection.assessments@ieso.ca as soon as they become aware of any changes to the project's scope or data used in this assessment. The IESO will determine whether these changes require a re-assessment.

2.3 Power Factor

As per Appendix 4.3 of the Market Rules, Hydro One shall ensure that the project has the capability to maintain the power factor within the range of 0.9 lagging and 0.9 leading as measured at its defined meter point.

2.4 Voltage Levels

Hydro One shall ensure that the project's equipment meets the voltage requirements specified in section 4.2 and section 4.3 of the Ontario Resource Transmission Assessment Criteria (ORTAC).

2.5 Connection Equipment Design

Hydro One shall ensure that the project's equipment is designed to be fully operational in all reasonably foreseeable ambient temperature conditions. The connection equipment must also be designed so that the adverse effects of its failure on the IESO-controlled grid are mitigated.

2.6 Fault Levels

As per the TSC, Hydro One shall ensure the project's 230 kV connection equipment is designed to withstand the fault levels in the area. If any future system changes result in an increased fault level higher than the project's equipment capability, Hydro One will be required to replace that equipment with higher rated equipment capable of withstanding the increased fault level, up to maximum fault level specified in the TSC. Appendix 2 of the TSC establishes the maximum fault levels for the transmission system. For the 230 kV system, the maximum 3 phase and single line to ground symmetrical fault levels are 63 kA.

2.7 Under Frequency Load Shedding Facilities

Hydro One is required to install UFLS facilities at the proposed project to allow for the detection of under-frequency conditions and the selection and tripping of load via circuit breakers.

Hydro One must select 35 % of aggregate peak load among its owned facilities for under-frequency tripping, based on a date and time specified by the IESO that approximates system peak, according to section 10.4 of Chapter 5 of the Market Rules.

As Hydro One has a peak load of greater than 100 MW at all its owned facilities, the UFLS relay connected loads shall be set to achieve the amounts to be shed stated in Table 2:

Table 2: UFLS Setting

UFLS Stage	Frequency Threshold (Hz)	Total Nominal Operating Time (s)	Load Shed at stage as % of Connection Applicant's Load	Cumulative Load Shed at stage as % of Connection Applicant's Load
1	59.5	0.3	7 – 9	7 – 9
2	59.3	0.3	7 – 9	15 – 17
3	59.1	0.3	7 – 9	23 – 25
4	58.9	0.3	7 - 9	32 - 34
Anti-Stall	59.5	10.0	3 – 4	35 - 37

The proposed two shunt capacitor banks should be shed by the UFLS relay at 59.5 Hz with a time delay of 3 seconds.

The maximum load that can be connected to any single UFLS relay is 150 MW to ensure that the inadvertent operation of a single UFLS relay during the transient period following a system disturbance does not lead to further system instability.

2.8 IESO Telemetry

In accordance with section 7.5 of Chapter 4 of the Market Rules, Hydro One shall provide to the IESO the applicable telemetry data listed in Appendix 4.17 of the Market Rules on a continual basis. The data shall be provided in accordance with the performance standards set forth in Appendix 4.22, subject to section 7.6A of Chapter 4 of the Market Rules. The whole telemetry list will be finalized during the IESO Market Registration process.

Hydro One must install monitoring equipment that meets the requirements set forth in Appendix 2.2 of Chapter 2 of the Market Rules. As part of the IESO Market Registration 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.

2.9 Revenue Metering

Hydro One should be aware that Chapter 6 – Wholesale Metering of the Market Rules must be met. This includes any intermediate project stages such as installation of temporary equipment or the use of mobile transformers. For more details the connection applicant is encouraged to seek advice from their Metering Service Provider (MSP) or from the IESO metering group.

2.10 Protection Systems

The connection applicant shall ensure that the protection systems are designed to satisfy all the requirements of the TSC. New protection systems must be coordinated with existing protection systems. Protection systems within the project shall only trip the appropriate equipment isolating the fault.

BPS elements are deemed by the IESO to be essential to system reliability and security and must be protected by redundant protection systems in accordance with Section 8.2 of the TSC. These redundant protection systems must satisfy all requirements of the TSC, and in particular, they must be physically separated and not use common components, common battery banks, or common instrument transformer secondary windings.

The protection systems for transmission voltage BES elements (whose rated voltage is higher than 100 kV) must be redundant. Redundancy must be present in protective relaying for normal fault clearing and control circuitry associated with protective functions including trip coils of the circuit breakers or other interrupting devices. These redundant protection systems must not use common instrument transformer secondary windings. A single communication system, if used, must be monitored and reported and a single DC supply, if used, must be monitored and reported for both low voltage and open circuit.

As the electrical system evolves, transmission voltage non-BPS or non-BES elements (whose rated voltage is higher than 100 kV) within the project, may be re-classified as BPS elements or BES elements. It is recommended the connection applicant design the protection systems for these elements according to the protection requirements for BPS elements or have adequate provisions for future upgrade to meet those requirements.

2.11 IESO Market Registration Process

Hydro One must initiate and complete the IESO Market Registration process in a timely manner, at least eight months before energization to the IESO-controlled grid and prior to the commencement of any project related outages, in order to obtain IESO final approval.

Hydro One is required to provide “as-built” equipment data for the project during the IESO Market Registration process to allow the IESO to incorporate this project into IESO work systems and to perform any additional reliability studies.

If the submitted equipment data differ materially from the ones used in this assessment, then further analysis of the project may need to be done by the IESO before final approval to connect is granted.

At the sole discretion of the IESO, performance tests may be required at the project. The objectives of these tests are to demonstrate that equipment performance meets the IESO requirements, and to confirm models and data are suitable for IESO purposes. The transmitter may also have its own testing requirements. The IESO and the transmitter will coordinate their tests, share measurements and cooperate on analysis to the extent possible.

2.12 Project Status

As per Market Manual 2.10, Hydro One shall provide a status report of its proposed project with respect to its progress upon request from the IESO. The project status report form can be found on the IESO Web site. Failure to comply with project status requirements listed in Market Manual 2.10 will result in the project being deemed withdrawn by the IESO.

The Hydro One will be required to also provide updates and notifications in order for the IESO to determine if the project is “committed” as per Market Manual 2.10. A committed project is a project that has demonstrated to the IESO a high probability of being placed into service.

A project will be deemed by the IESO to be a committed project if:

(1) the connection applicant provides notification to the IESO specifying a defined and future-dated in-service date for the project, and;

(2) the connection applicant provides notification to the IESO indicating that the project is actively being completed (i.e. not declared to be “on hold”), and;

(3) the connection applicant does one of the following:

- provides a notification to the IESO indicating that the connection applicant will be compensated with respect to the project through a power purchase contract, or rates set by the Ontario Energy Board,

- provides a notification to the IESO indicating that a leave to construct approval has been granted by the Ontario Energy Board,
- provides a notification to the IESO indicating that the project has a connection cost recovery agreement (CCRA) in place with the transmitter,
- provides a joint notification with the transmitter to the IESO indicating the project will come into service,
- provides notification through the IESO Facility Registration process that the project has started construction.
- identifies the project in its Plans for New or Modified Facilities Information Submittal Form for the 18-Month Outlook(IMO_FORM_1484) for the Outlook assessment, or Plans for Retired, New or Modified Facilities Information.

– End of Section –

3. Data Verification

3.1 Equipment Data

The connection equipment specifications were assessed based on the information provided by the connection applicant.

3.1.1 230 kV Disconnect Switch

Table 3: Specifications of the 230 kV Disconnect Switches

Number to be installed	Maximum Continuous Voltage Rating (kV)	Continuous Current Rating (A)	Short Circuit Symmetrical Rating (kA)
2	250	550	63

The 230 kV disconnect switch has a maximum continuous voltage rating of 250 kV and a short circuit symmetrical rating of 63 kA which meet the requirements and standards in the Market Rules and TSC.

3.1.2 230 kV Transformer

Table 4: Specifications of the 230 kV Transformers

Unit	Transformation (kV)	Rating (MVA) (ONAN/ONAF/OFAF)	Positive Sequence Impedance (pu) S_B= 62.5 MVA	Winding Configuration			High Voltage ULTC Tap Changer
				H	X	Y	
T1/T2	215.5/27.6/27.6	75/100/125	HX: 0.00487+j0.17867 HY: 0.00489+j0.17750 XY: 0.0199+j0.32559	Yg	Zig-zag Grounded through 1.5 ohm reactor	Zig-zag Grounded through 1.5 ohm reactor	215.5 ± 40 kV in ± 16 steps

3.1.3 Shunt Capacitor

Table 5: Specifications of the 27.6 kV Shunt Capacitors

Number to be installed	Rated Capacitance at Rated Voltage (Mvar)	Rated Voltage (kV)	Nominal System Voltage (kV)
2	21.6	27.6	27.6

– End of Section –

4. Impact on System Reliability

The technical studies focused on identifying the impact of the project on the reliability of the IESO-controlled grid in the vicinity of the project.

4.1 Study Area Description

The project will connect in the Windsor area system of the IESO-controlled grid, as shown in Figure 3. The Windsor area system consists of 230 kV and 115 kV systems.

The Windsor 230 kV system includes the 230 kV circuits C23Z and C24Z from Chatham to Lauzon, circuits C21J and C22J from Chatham to Keith, and circuit J5D between Keith TS and Waterman switching station (Michigan). There are four wind generating stations in the system: Comber West and East on C23Z and C24Z, respectively, Port Alma I and II on C24Z, and Dillon and Belle River on C23Z. Moreover, a new wind farm, namely Romney Wind Energy Centre (CAA 2016-586), is expected to become in-service by December 2019 and connect to C21J. Two gas generation units at Brighton Beach CGS, i.e. G1 and G1B also connect to the system through circuit J20B.

Windsor 115 kV system is bounded by Lauzon 230/115 kV autotransformers, and Keith 230/115 kV autotransformers. There are four gas generating stations in the system: West Windsor CGS, East Windsor CGS, Windsor TransAlta CGS, as well as unit G1A at Brighton Beach CGS. There are also one solar generating station, i.e. Windsor Airport CGS, and two wind generating stations, i.e. Pointe Aux Roches CGS and Gosfield CGS.

Windsor 230 kV system load forecast is winter peaking while Windsor 115 kV system load forecast is summer peaking. The overall Windsor area system is susceptible to a variety of operational problems including pre-contingency voltage instability, post-contingency voltage decline, voltage rise and thermal overload. As a result, a number of special protection schemes, which are all included in the Windsor area special protection schemes (SPS), are employed to facilitate operation of the system.

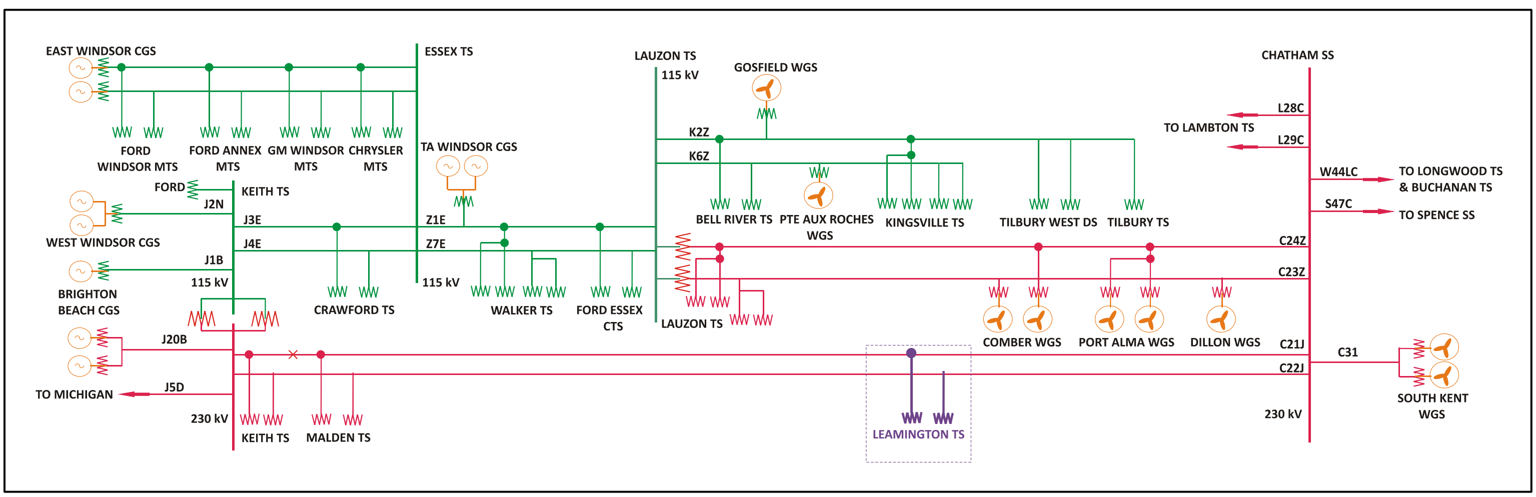

Figure 3: Windsor area System

As the Windsor 230 kV system is interconnected to Michigan system, some contingencies within Michigan system were also assessed in this SIA. Figure 4 shows the single line diagram of nearby Michigan system which primarily includes the elements involved in the studied contingencies.

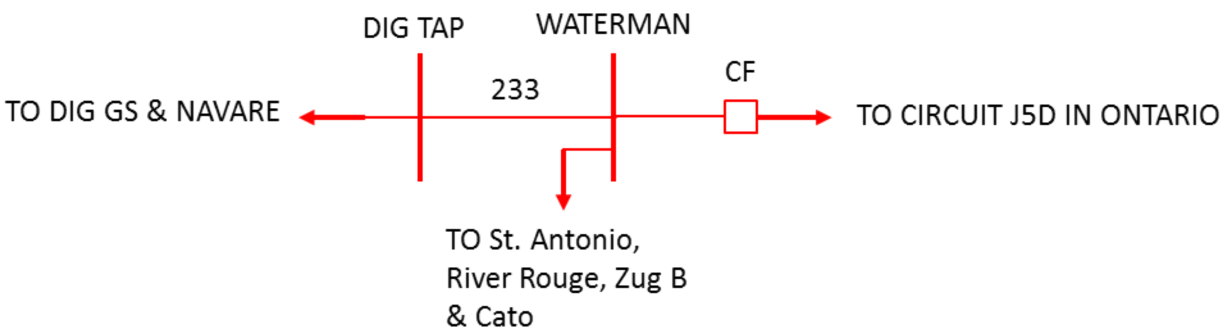

Figure 4: Nearby Michigan System

4.2 Existing Control Actions

Available control actions to currently manage thermal or voltage concerns in the Windsor area system include generation re-dispatch, curtailment of imports or exports on circuit J5D, and arming of the Windsor area special protection schemes. Listed below is a summary of schemes included in the Facility Description Document (FDD) for the Windsor area special protection schemes that are relevant to this project:

(1) **Keith TS G/R and cross tripping scheme** which includes:

- Brighton Beach G/R– It provides selection of units G1, G1A and G1B at Brighton Beach CGS to be tripped for contingencies included in the scheme.
- Keith capacitor switching – It provides selection of capacitor SC11 at Keith TS to be switched out for contingencies included in the scheme.

(2) **Lauzon contingency-based L/R scheme - Lauzon SPS** which includes:

- Kingsville L/R – It provides selection of load to be rejected at Kingsville TS in two stages for contingencies included in the scheme, with each stage consisting of half the Kingsville load.
- Kingsville capacitor switching – It provides selection of capacitors at Kingsville TS to be switched out in two stages for contingencies included in the scheme with each stage consisting of two Kingsville capacitors.
- Belle River L/R – It provides selection of the entire load to be rejected at Belle River TS for contingencies included in the scheme.

(3) **Kingsville under-voltage L/R** – It provides selection of load to be rejected at Kingsville TS when the voltage at any of Kingsville 115 kV buses is below 106 kV for more than 7 seconds.

4.3 Study Assumptions

4.3.1 General Assumptions

In this assessment, the 2018 summer base case was used with the following assumptions:

(1) **Transmission facilities**: All existing transmission facilities and future proposed transmission system upgrades with 2029 in-service dates or earlier were assumed in-service including:

- Transformer Replacement at Keith TS (CAA 2007-265)

(2) **Protection changes:** No adjustments to the existing transmission protection systems were assumed for incorporating the project as per the PIA report (Appendix A).

(3) **Generation facilities:** All existing and committed major generation facilities with 2029 in-service dates or earlier were assumed available including:

- Romney Wind Energy Centre (CAA 2016-586) with December 2019 in-service date.

(4) **Load facilities:** All major load facilities with the in-service dates in 2029 or earlier were assumed in-service including:

- Aphria-Leamington Greenhouse (CAA 2018-638): a 60 MW CTS connected to C22J with Q1, 2020 in-service date;
- Mastron II Greenhouse (CAA 2018-642): a 53 MW CTS connected to C21J with Q4, 2020 in-service date.

(5) **Load forecast:** Hydro One provided the extreme weather coincident winter and summer peak load forecast after conservation in June 2018 for the years from 2019 to 2029 for the project and the existing stations in Windsor area system as displayed in Table 6 and Table 7. The coincidence forecasts were assumed based on historical data during winter and summer peak. The Integrated Regional Resource Plan (IRRP) for Windsor – Essex area is in progress and it is expected to refine the load forecast for Windsor – Essex area.

(6) **Load model:** As per section 2.4 in ORTAC, constant power load models were used for thermal assessment, post-ULTC voltage level and voltage change assessment, and steady state voltage stability assessment. Voltage dependent load models were used for pre-ULTC voltage level and voltage change assessment, and shunt capacitor switching assessment.

(7) **Load power factor:** The power factor was assumed to be 0.9 at the high-voltage buses of the load facilities with low voltage capacitors out of service except for DESN 2 at Leamington TS, Aphria CTS and Mastron II CTS; where the power factor was set to 0.95 at the low-voltage buses.

Table 6: Winter Load Forecast for Windsor area 230 and 115 kV Stations (MW)

Station	Load Forecast (MW)										
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Belle River TS	33	33.6	34.21	34.98	35.69	36.4	37.1	37.88	38.59	39.22	40
Industrial Customer # 1	24	23.9	23.7	23.55	23.41	23.34	23.2	23.05	22.98	22.84	22.7
Crawford TS	65	64.2	63.61	63.16	62.72	62.43	62.06	61.76	61.39	61.02	60.73
Essex TS	51	50.2	49.7	49.4	49.03	48.74	48.44	48.15	47.85	47.56	47.34
Industrial Customer # 2	5.6	5.54	5.459	5.459	5.38	5.38	5.38	5.38	5.301	5.301	5.222
Industrial Customer # 3	2.4	2.39	2.387	2.387	2.387	2.387	2.319	2.319	2.319	2.319	2.319
Industrial Customer # 4	5.5	5.46	5.411	5.411	5.359	5.359	5.308	5.308	5.256	5.205	5.205
Industrial Customer # 5	14.5	14.3	14.18	14.18	14.07	14.07	13.95	13.95	13.84	13.84	13.73
Keith TS T1	8.4	8.3	8.2	8.2	8.2	8.1	8.1	8	8	7.9	7.9
Keith TS T22/T23	47.15	46.7	46.27	46.81	46.54	46.34	46.14	45.93	45.73	45.39	45.19
Lauzon TS T5/T6	68.87	68.3	67.81	67.48	67.15	67.02	66.75	66.48	66.22	65.89	65.55
Lauzon TS T7/T8	57.29	56.8	55.7	55.44	55.17	54.98	54.78	54.58	54.38	54.05	53.85
Malden TS	85.88	85.2	85.32	85.04	84.75	85.25	85.67	86.09	85.88	85.46	85.18
Tilbury TS	0.530	0.53	0.531	0.531	0.531	0.531	0.531	0.531	0.531	0.531	0.531
Tilbury West DS	15.36	15.2	15.77	15.69	15.69	15.69	15.69	15.77	15.77	15.77	15.77
Walker MTS #2	47.07	46.7	46.3	46.07	45.83	45.66	45.48	45.3	45.12	44.83	44.59
Walker TS #1	44.58	44.1	43.82	43.63	43.37	43.24	43.05	42.92	42.73	42.48	42.28
Kingsville TS	128	120	120	120	120	120	120	121	121	121	121
Leamington TS DESN 1	180	168	172	173	173	174	174	175	175	176	176
Leamington TS DESN 2	138	179	193	193	193	193	193	193	193	193	193
Aphria Leamington CTS	0	60	60	60	60	60	60	60	60	60	60
Mastron II CTS	20	53	53	53	53	53	53	53	53	53	53

Table 7: Summer Load Forecast for Windsor area 230 and 115 kV Stations (MW)

Station	Load Forecast (MW)										
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Belle River TS	47.6	48.4	49.5	50.5	51.5	52.5	53.6	54.6	55.5	56.6	57.6
Industrial Customer # 1	33.4	33.1	32.9	32.7	32.6	32.4	32.2	32.1	31.9	31.7	31.5
Crawford TS	87	86.2	85.6	85	84.6	84.1	83.7	83.2	82.7	82.3	81.8
Essex TS	68	67.3	66.9	66.4	66	65.6	65.2	64.8	64.4	64.1	63.7
Industrial Customer # 2	7	6.9	6.9	6.8	6.8	6.8	6.8	6.7	6.7	6.6	6.6
Industrial Customer # 3	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3
Industrial Customer # 4	10.6	10.5	10.5	10.4	10.4	10.3	10.3	10.2	10.1	10.1	10.0
Industrial Customer # 5	12.7	12.6	12.6	12.5	12.5	12.4	12.4	12.3	12.3	12.2	12.1
Keith TS T1	8.3	8.2	8.2	8.2	8.1	8.1	8	8	7.9	7.9	7.8
Keith TS T22/T23	69	68.4	69.2	68.8	68.5	68.2	67.9	67.6	67.1	66.8	66.4
Lauzon TS T5/T6	103	102	101.5	101	100.8	100.4	100	99.6	99.1	98.6	98.2
Lauzon TS T7/T8	85.8	84.2	83.8	83.4	83.1	82.8	82.5	82.2	81.7	81.4	81.0
Malden TS	121	121.1	120.7	120.3	121	121.6	122.2	121.9	121.3	120.9	120.5
Tilbury TS	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Tilbury West DS	18.6	19.3	19.2	19.2	19.2	19.2	19.3	19.3	19.3	19.3	19.3
Walker MTS #2	79.1	78.5	78.1	77.7	77.4	77.1	76.8	76.5	76.0	75.6	75.3
Walker TS #1	69.1	68.6	68.3	67.9	67.7	67.4	67.2	66.9	66.5	66.2	65.8
Kingsville TS	84	75	75	75	75	75	75	76	76	76	76
Leamington TS DESN 1	126	109	114	114	115	116	117	117	117	118	118
Leamington TS DESN 2	49	52	53	53	53	53	53	53	53	53	53
Aphria Leamington CTS	0	60	60	60	60	60	60	60	60	60	60
Mastron II CTS	2	2	2	2	2	2	2	2	2	2	2

4.3.2 Study Scenarios

Two scenarios were used to stress Windsor 230 kV system. The base cases employed the following common assumptions:

- According to section 2.2 in ORTAC, the study period shall run from the planned in-service date of the project up to 10 years into the future depending on the availability of load forecasts. Therefore, load level at individual stations in the vicinity of the project were set to the forecasted winter and summer peak load level for year 2022, which has the highest load forecast in Windsor area within the study period;
- The Windsor 115 kV area was assumed closed in this study which means that there is a continuous 115 kV transmission path between Lauzon TS and Keith TS;
- The existing Windsor area special protection schemes were assumed available;
- Since wind and solar power may not be available during peak load levels, all wind and solar generation facilities in Windsor area were assumed out of service;
- All gas generation facilities in Windsor area except for Brighton Beach CGS were assumed in-service;

- Since the loss of the three units at Brighton Beach CGS is a recognized contingency, all three units at Brighton Beach CGS were assumed out of service with all transmission elements in-service.

Additional assumptions for each scenario are listed below.

S1- No export or import on J5D conditions: This scenario was used to evaluate the impact of the project on system reliability following all contingencies listed in Table 8 and Table 9, under no power transfers on J5D. Study details are presented in sections 4.5 to 4.10.

S2- Export on J5D conditions: This scenario, detailed in section 4.11, was used to evaluate the impact of the project on system reliability under export conditions. Exports on J5D were increased up to the historical maximum flow, i.e. 400 MW, even though the expectation is that the project will reduce the flow to Michigan on J5D due to the natural flow distribution. This scenario strictly evaluated the impact of the project on system reliability following N-1 and N-2 contingencies listed in Table 8 and Table 9, with all transmission elements in-service pre-contingency. Exports to Michigan on J5D were assumed to be controllable to zero during planned outages, therefore those study conditions are captured by scenario S1.

S3- Import on J5D conditions: This scenario, detailed in section 4.12, was used to evaluate the impact of the project on system reliability under import conditions. The load increase at Leamington TS, Aphria CTS and Mastron II CTS is expected to increase the flow from Michigan on J5D by about 180 MW and 60 MW in winter and summer, respectively, due to the natural flow distribution, if all other being equal, e.g., same tap position, same transmission configuration etc. This scenario added the expected increase of flow to the maximum historical level of 140 MW shown in Figure 5. Therefore, the import on J5D was set to 320 MW in the winter and 200 MW in the summer. The scenario was used strictly to evaluate the impact of the project on system reliability following N-1 and N-2 contingencies listed in Table 8 and Table 9, with all transmission elements in-service pre-contingency. Imports from Michigan on J5D were assumed to be controllable to zero during planned outages, therefore those study conditions are captured by scenario S1.

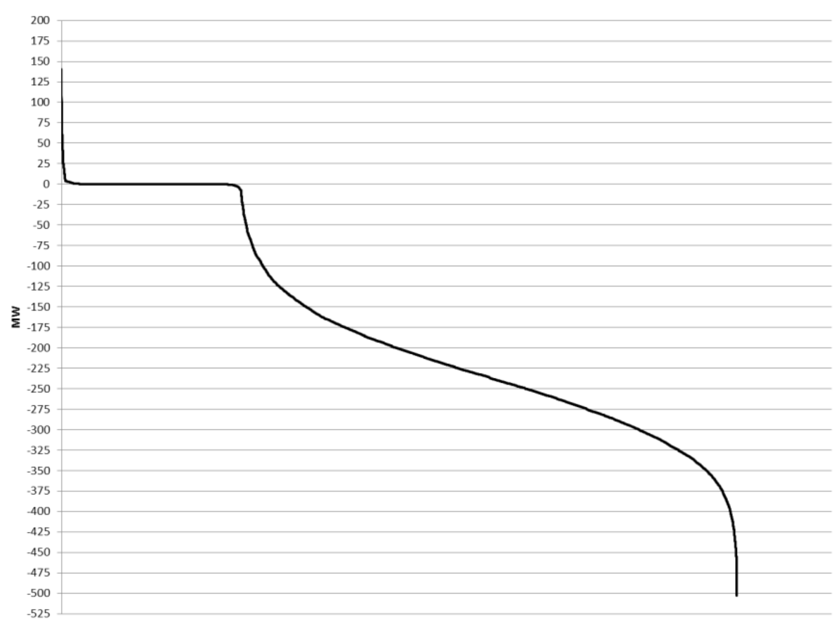

Figure 5: Import on J5D from Michigan in the Period from 2013 to 2018

4.4 Study Contingencies

Contingencies were performed based on the NERC TPL-001-4 planning events for BES elements and NPCC Directory 1 planning events for BPS elements. Table 8 and Table 9 show the list of all simulated contingencies in Ontario and Michigan systems, respectively.

Table 8: List of Simulated Contingencies in Ontario system

N-1 Contingencies (All elements I/S – Single Contingencies)			
C21J / C22J	C23Z / C24Z	J5D	Keith A Bus
Chatham D Bus	Brighton Beach CGS	G1 / G1A / G1B at Brighton Beach CGS	
N-2: Tower Contingencies (All elements I/S – Double Contingencies)			
C21J + C23Z	C21J + C22J	C22J + C24Z	C23Z + C24Z
L29C + L28C	W44LC + S47C	N21W + N22W	
N-2: Breaker Failure (B/F) Contingencies (All elements I/S – Double Contingencies)			
Keith 230 C21J B/F (C21J + Keith A Bus)	Keith 230 HL5 B/F (J5D + C22J)	Keith 230 AL5 B/F (J5D + Keith A Bus)	Keith 230 AL20 B/F (J20B + Keith A Bus)
Keith 230 HL20 B/F (J20B + C22J)	Chatham 230 DL21 B/F (C21J + Chatham D Bus)	Chatham 230 DL23 B/F (C23Z + Chatham D Bus)	Chatham 230 DL44 B/F (W44LC + Chatham D Bus)
Chatham KL22 B/F (C22J + Chatham K Bus)	Lauzon T2K B/F (C24Z + Lauzon cap)		
N-1-1: Contingencies (Outage condition + Contingency)			
J5D + C21J / C22J	J5D + C23Z / C24Z	J5D + Chatham D bus	Chatham K Bus + loss of Chatham D Bus
Brighton Beach GS + C21J / C22J	C22J open ended at Chatham + Keith C21J IBO	C21J open ended at Chatham + Keith C21J IBO	
N-1-2: Contingencies (Outage condition + Double contingency)			
L29C + (W44LC + W45LS)	C21J + (C23Z + C24Z)	L24L + (W44LC + W45LS)	C21J /C22J + Chatham DL44
L28C + (W44LC + W45LS)	L28C + (W44LC + S47C)	L29C + (W44LC + S47C)	W44LC + (L28C + L29C)
W45LS + (L28C + L29C)	S47C + (L28C + L29C)		

Table 9: List of Simulated Contingencies in Michigan system

N-1 Contingencies (All elements I/S – Single Contingencies)	
CF IBO	230 kV circuit 233

4.5 Thermal Assessment

Section 4.7.2 of the ORTAC specifies the following criteria for thermal loading of transmission facilities:

(1) All line and equipment loadings shall be within their continuous ratings with all elements in-service;
(2) All line and equipment loadings shall be within their long-term emergency ratings with any one element out of service; and
(3) Immediately following contingencies, lines may be loaded up to their short-term emergency ratings where control actions such as re-dispatch, switching, etc. are available to reduce the loading to the long-term emergency ratings. It is assumed that for the bulk power system, loading conditions and control actions are available to reduce the loading to the long-term emergency rating or less within 15 minutes.

Table 10 and Table 11 list the thermal ratings of the monitored circuits in Amperes and the monitored transformers in MVA, respectively, as provided by Hydro One. The circuit's conductor ratings were calculated for summer and winter weather conditions with ambient temperatures of 35ºC and 10ºC, respectively, and with wind speed of 4 km/h. The continuous ratings for the conductors were calculated at the lower of the sag temperature or 93ºC operating temperature. The LTE ratings for the conductors were calculated at the lower of the sag temperature or 127ºC operating temperature. The STE ratings were calculated at the sag temperature with 100% continuous pre-load.

Table 10: Circuit Section Summer and Winter Thermal Ratings

Circuit/ Transformer	Circuit Section		Continuous		LTE		STE	
			Summer	Winter	Summer	Winter	Summer	Winter
	From	To	A		A		A	
C21J	Keith TS	Malden TS	840	1020	1020	1170	1100	1240
C21J	Malden TS	Sandwich JCT	840	1020	1020	1170	1100	1240
C21J	Sandwich JCT	Leamington JCT	1060	1300	1370	1550	1570	1730
C21J	Leamington JCT	Mastron II CTS	1160	1420	1530	1720	1830	2000
C21J	Mastron II CTS	Leamington TS	1160	1420	1530	1720	1830	2000
C21J	Leamington JCT	Chatham SS	1060	1300	1370	1550	1570	1730
C22J	Keith TS	Malden TS	840	1020	1020	1170	1100	1240
C22J	Malden TS	Sandwich JCT	840	1020	1050	1190	1150	1290
C22J	Sandwich JCT	Leamington JCT	840	1020	1020	1170	1100	1240
C22J	Leamington JCT	Aphria CTS	1160	1420	1530	1720	1830	2000
C22J	Aphria CTS	Leamington TS	1160	1420	1530	1720	1830	2000
C22J	Leamington JCT	Chatham SS	840	1020	1020	1170	1100	1240
C23Z	Lauzon TS	Sandwich JCT	1060	1300	1400	1580	1900	2030
C23Z	Sandwich JCT	Comber WF JCT	1060	1300	1400	1580	1840	1980
C23Z	Comber WF JCT	KEPA WF JCT	1060	1300	1400	1580	1840	1980
C23Z	KEPA WF JCT	Dillon RWEC JCT	1060	1300	1400	1580	1690	1840
C23Z	Dillon RWEC JCT	Chatham SS	1060	1300	1400	1580	1690	1840
C24Z	Lauzon TS	Sandwich JCT	1060	1300	1400	1580	1900	2030
C24Z	Sandwich JCT	Comber WF JCT	840	1020	1040	1180	1130	1270
C24Z	Comber WF JCT	KEPA WF JCT	840	1020	1040	1180	1130	1270
C24Z	KEPA WF JCT	Chatham SS	840	1020	1020	1170	1100	1240
J5D	Keith TS	McKee JCT	1230	1230	-	-	7164	7164
J5D	McKee JCT	Waterman	730	900	960	1080	1210	1300
J3E	Keith TS	Crawford JCT	810	1000	1070	1200	1390	1490
J3E	Crawford JCT	Essex TS	810	1000	1070	1200	1390	1490
J4E	Keith TS	Crawford JCT	810	1000	1000	1140	1090	1220
J4E	Crawford JCT	Essex TS	810	1000	1000	1140	1090	1220
Z1E	Essex TS	Windsor Transalta JCT	970	1190	1260	1420	1430	1570
Z1E	Windsor Transalta JCT	Walker JCT	970	1190	1260	1420	1430	1570
Z1E	Walker JCT	Jefferson JCT	870	1070	1140	1280	1390	1490
Z1E	Jefferson JCT	Lauzon TS	910	1110	1190	1340	1370	1500
Z7E	Essex TS	Walker JCT	970	1190	1260	1420	1430	1570
Z7E	Walker JCT	Jefferson JCT	870	1070	1140	1280	1390	1490
Z7E	Jefferson JCT	Lauzon TS	910	1110	1190	1340	1370	1500

Table 11: Transformer Summer and Winter Thermal Ratings

Transformer	Continuous		LTE		STE	
	Summer	Winter	Summer	Winter	Summer	Winter
	MVA		MVA		MVA	
Lauzon T1	250	250	296.8	321.8	364.2	393.6
Lauzon T2	250	250	296.8	321.8	364.2	393.6
Keith T11	115	115	180.3	191.7	224.5	234.9
Keith T12	115	115	160.3	174.5	187.5	203.5
Keith PSR5	500	500	703	764	998	998

S1-All elements in-service: Pre-contingency

The pre-contingency flows on all monitored elements are within their continuous ratings under both summer and winter conditions.

S1-All elements in-service: Post-contingency

After the project incorporation under S1 winter conditions, post-contingency thermal violations were identified as shown in Table 12. The post-contingency flow on the 49.3 km section from Chatham SS to Leamington Jct. on both C21J and C22J exceeds both LTE and STE ratings following some studied contingencies.

Table 12: Summary of Post-Contingency Thermal Violations for S1-All Elements In-service

No.	Contingency	Overloading Circuit/Section	Comments
1	C21J, C21J + C23Z, Chatham DL21 B/F, Chatham L21L47 B/F and Keith C21J B/F	C22J/Section: Chatham SS to Leamington Jct.	127 % LTE or 120 % STE (winter)
2	C22J + C24Z	C21J/Section: Chatham SS to Leamington Jct.	117 % LTE or 105 % STE (winter)

The existing control actions in Windsor area special protection schemes such as Kingsville and Belle River load rejection schemes are not sufficient to prevent the post-contingency thermal overloads. As all contingencies in Table 12 result in the loss of either C21J or C22J, further studies were performed confirming that using the proposed Leamington contingency-based SPS, which rejects up to all loads at Leamington TS, Aphria CTS, and Mastron II CTS following the loss of either C21J or C22J, was sufficient to overcome the post-contingency thermal overloads. Up to 210 MW of load would need to be rejected for the worst-case single contingency of loss of C21J, and up to 257 MW of load would need to be rejected for the worst-case double contingency of simultaneous loss of C21J and C23Z.

The post-contingency flows on the monitored circuits for Scenario S1 following the remaining contingencies listed in Table 8 remain within LTE limits under both winter and summer conditions with the utilization of the existing control actions.

S1- Forced outage to one of the BPS circuits L28C, L29C, W44LC, W45LS, and S47C

The Chatham to Longwood and Chatham to Lambton circuits listed in the title above are part of the NPCC BPS system. Following the loss of one of these circuits, the system needs to be re-prepared within 30 minutes to be able to withstand next recognized contingency. After a forced outage to L28C, L29C, W44LC, W45LS or S47C under peak load conditions, until enough local generation comes on line, the simultaneous loss of L28C and L29C, W44LC and W45LS, or W44LC and S47C will result in thermal overloads and cascade tripping of BPS elements; because West Windsor CGS, TransAlta Windsor CGS, and Brighton Beach need at least 4 hours to ramp to their minimum loading point, the system cannot be re-prepared for four hours after the first contingency. The post-contingency thermal violations identified are shown in Table 13.

Table 13: Summary of Post-Contingency Thermal Violations for S1-L28C, L29C, W44LC, W45LS, or S47C Forced Outage Condition

No.	Outage	Next Contingency	Overloading Circuit	Comments
1	L28C or L29C	W44LC + W45LS or W44LC + S47C	L29C or L28C	170 % LTE or 150 % STE (summer)
2	W44LC	L28C + L29C	W45LS and S47C	160 % LTE or 112 % STE (summer)
3	W45LS or S47C	L28C + L29C	W44LC	160 % LTE or 112 % STE (summer)

The existing control actions in Windsor area special protection schemes such as Kingsville and Belle River load rejection schemes are not sufficient to re-prepare the system. With one BPS circuit out of service, up to 190 MW of load at Leamington TS, Aphria CTS, and Mastron II CTS would need to be interrupted until enough local generation comes online. To avoid the load curtailment under the forced outage, up to 190 MW of load at Leamington TS, Aphria CTS, and Mastron II CTS should be armed for rejection for the subsequent simultaneous loss of W44LC and W45LS, of W44LC and S47C or of L28C and L29C.

The post-contingency flows on the monitored circuits for Scenario S1 following the remaining contingencies listed in Table 8 remain within LTE limits under both winter and summer conditions with the utilization of the existing control actions.

<u>S1-C21J or C22J out of service: Pre-contingency</u>

The most the outages of C21J and C22J. To prevent the pre-contingency flows on the monitored elements from exceeding their LTE ratings, Brighton Beach GS needs to be fully dispatched during those outages, under both summer and winter conditions with the project.

<u>S1- C21J or C22J out of service: Post-contingency</u>

With C21J out of service under S1 winter conditions, post-contingency thermal violations were identified as shown in Table 14. The existing control actions in the Windsor area special protection schemes such as Kingsville and Belle River load rejection schemes are not sufficient to prevent the post-contingency thermal overloads. Load at Leamington TS and Aphria CTS needs to be rejected following those contingencies to overcome the post-contingency thermal overload. Load rejection is required following the loss of a single unit at Brighton Beach CGS as well as the loss of the entire plant. Up to 210 MW of load would need to be rejected for the loss of the entire Brighton Beach CGS. Additionally, up to 100 MW of load would need to be rejected for the simultaneous loss of C23Z and C24Z.

Therefore, Hydro One is required to add the contingencies of loss of single unit at Brighton Beach CGS, loss of the entire Brighton Beach CGS, and the simultaneous loss of C23Z and C24Z to the proposed Leamington contingency-based SPS and allow rejection of up to all load at Leamington TS, Aphria CTS, and Mastron II CTS.

Table 14: Summary of Post-Contingency Thermal Violations for S1-C21J Outage

No.	Contingency	Overloading Circuit/Section	Comments
1	Loss of unit G1 at Brighton Beach CGS	C22J/Section: Chatham SS to Leamington Jct.	108 % LTE or 102 % STE (winter)
2	Loss of unit G1A at Brighton Beach CGS	C22J/Section: Chatham SS to Leamington Jct.	104 % LTE (winter)

3	Loss of unit G1B at Brighton Beach CGS	C22J/Section: Chatham SS to Leamington Jct.	114 % LTE or 108 % STE (winter)
4	Loss of Brighton Beach CGS	C22J/Section: Chatham SS to Leamington Jct.	137 % LTE or 127 % STE (winter)
5	C23Z + C24Z	C22J/Section: Chatham SS to Leamington Jct.	114 % LTE or 107 % STE (winter)

The post-contingency flows for the monitored circuits for Scenario S1 following the remaining contingencies listed in Table 8 remain within LTE and STE limits under both summer and winter conditions with arming of the Windsor area special protection schemes.

4.6 Voltage Level and Voltage Change Assessment

Sections 4.2 and 4.3 of ORTAC state that the following steady state voltage level and voltage change criteria shall be satisfied:

(1) The pre-contingency voltage levels on 230 kV buses must be between 220 kV and 250 kV, and voltage levels on 115 kV buses must be between 113 kV and 127 kV;
(2) The post-contingency voltage levels on 230 kV buses must be between 207 kV and 250 kV, and voltage levels on 115 kV buses must be between 108 kV and 127 kV; and
(3) Voltage change following a contingency must not exceed 10 % pre-Under Load Tap Changer (ULTC) action and 10 % post-ULTC action.

All 230 kV and 115 kV buses in the Windsor area system and the 230 kV buses at Waterman and Dig Tap in Michigan system were monitored during the voltage assessment.

<u>S1-All elements in-service: Pre-contingency</u>

The pre-contingency voltage levels on all monitored buses are within ORTAC criteria except the 230 kV buses at Aphria CTS, Mastron II CTS and Leamington TS, where voltage level reaches 218 kV, 218 kV and 219 kV respectively due to the addition of the project. To address this pre-contingency voltage violation, two capacitor banks rated at 20 Mvar at 13.8 kV are required at Aphria CTS and Mastron II CTS. After adding the capacitor banks, the voltage levels at Aphria CTS, Mastron II CTS and Leamington TS 230 kV buses reach 223 kV, 223 kV and 221 kV, respectively, meeting the ORTAC requirement.

<u>S1-All elements in-service: Post-contingency</u>

The post-contingency voltage levels on all monitored buses are within ORTAC criteria with the utilization of existing control actions and the proposed Leamington contingency-based SPS. Up to 48 MW of the load at Leamington TS and Aphria CTS would need to be rejected for the worst-case single contingency of loss of C21J, and up to 140 MW of the load at Leamington TS and Aphria CTS would need to be rejected for the worst-case double contingency of simultaneous loss of C21J and C23Z.

<u>S1-One element out of service: Pre-contingency</u>

During the most critical outages, either C21J or C22J outage, with Brighton Beach GS fully dispatched, the pre-contingency voltage levels on all monitored buses are within ORTAC criteria except the 230 kV buses at Leamington TS and Aphria CTS (or Mastron II CTS) where the voltage level reaches 210 kV due to the addition of the project. To address this pre-contingency voltage violation, 25 MW of the load at Leamington TS and Aphria CTS (or Mastron II CTS) is required to be curtailed or transferred to Kingsville TS when system conditions allow.

<u>S1-One element out of service: Post-contingency</u>

The incorporation of the project causes the post-contingency voltage at Leamington TS to reach 201 kV following the loss of Brighton Beach CGS when either C21J or C22J is out of service. The additional function of the Leamington contingency-based SPS proposed in section 4.5, i.e. rejecting load following the loss of Brighton Beach GS, is sufficient to overcome this issue. Up to 100 MW of load would need to be rejected to prevent criteria violations.

Additionally, the incorporation of the project causes the post-contingency voltage at Leamington TS to reach 203 kV following simultaneous loss of C23Z and C24Z when either C21J or C22J is out of service. The additional function of the Leamington contingency-based SPS proposed in section 4.5, i.e. rejecting load following simultaneous loss of C23Z and C24Z, is sufficient to overcome this issue; where up to 40 MW of load would need to be rejected. Moreover, the incorporation of the project causes the post-contingency voltage at Leamington TS to reach 201 kV following the failure of Chatham DL44 breaker when either C21J or C22J is out of service. The local under-voltage L/R schemes required in section 4.13 are sufficient to overcome this issue; where up to 40 MW of the load at Leamington TS and Aphria CTS (or Mastron II CTS) would need to be rejected. These N-1-2 conditions are not expected to violate any NPCC performance requirement under Directory # 1 which stipulates that following an N-1-2 the loss of small or radial portions of the system is acceptable provided the performance requirements are not violated for the remaining bulk power system.

All other post-contingency voltage levels are within ORTAC criteria with the utilization of existing control actions.

4.7 Steady-State Voltage Stability Margin Assessment

Section 5.4.1 of the ORTAC states that there must be sufficient margin from the steady-state voltage instability point, such that the maximum pre-contingency transfer is the lesser of:

(1) a pre-contingency power transfer that is 10% lower than the voltage instability point of the pre-contingency Power-Voltage (P-V) curve; and

(2) a pre-contingency power transfer that results in a post-contingency power flow that is 5% lower than the voltage instability point of the post-contingency P-V curve.

To assess the project’s impact on the steady state voltage stability, the transfer from the generation east of Chatham SS to the load at Leamington TS was used for all subsequent scenarios. The loads at Aphria CTS and Mastron II CTS were assumed at their maximum level.

The Leamington contingency-based SPS required in section 4.5, can be armed for rejection following all contingencies that include the loss of C21J or C22J, the loss of a unit at Brighton Beach CGS, the loss of the entire Brighton Beach CGS, and the simultaneous loss of C23Z and C24Z. Arming this scheme for the aforementioned contingencies ensures that the project has no adverse impact on the post-contingency voltage stability of the system. Therefore, in the assessment of criterion (2) above, the impact of the project on post-contingency voltage stability at Leamington TS was not studied for these contingencies.

<u>S1-All elements in-service</u>

Figure 6 shows that pre-contingency voltage instability occurs at Leamington TS when its load has exceeded 510 MW. Since Leamington TS load after the project is not expected to be more than 369 MW based on available load forecast, the pre-contingency voltage stability margin is greater than 10 %, meeting the ORTAC requirement.

Figure 6 also shows post-contingency PV curves at Leamington TS following Chatham DL44 breaker failure contingency, which was identified as the worst-case contingency. According to these curves, the post-contingency voltage instability would occur when Leamington TS load has exceeded 440 MW. Since Leamington TS load after the project is not expected to be more than 369 MW based on available load forecast, the post-contingency voltage stability margin is greater than 5 %, meeting the ORTAC requirement.

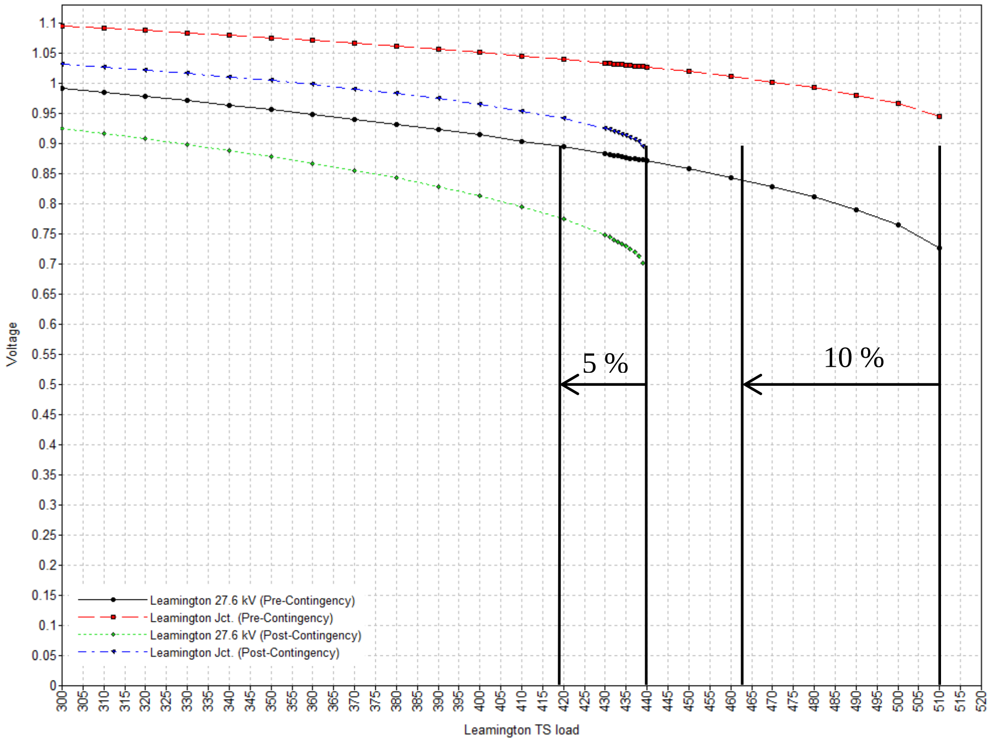

Figure 6: P-V Curves at Leamington Jct. and Leamington TS Buses under S1 Conditions

<u>S1-One element out of service</u>

During either C21J or C22J outage with Brighton Beach GS fully dispatched, the P-V curve in Figure 7 shows that pre-contingency voltage instability occurs at Leamington TS when its load has exceeded 378 MW. Since Leamington TS load after the project is expected to be 369 MW based on available load forecast, the voltage stability margin is less than 10 %. To meet this ORTAC requirement, 25 MW of the load at Leamington TS and Aphria CTS (or Mastron II CTS) needs to be curtailed under these outage conditions or transferred to Kingsville TS (only for Leamington TS load) when system conditions allow. This is consistent with the low voltage assessment findings in section 4.6.

Figure 7 also shows post-contingency PV curves at Leamington TS following Chatham DL44 breaker failure contingency. According to these curves, the post-contingency voltage instability would occur when Leamington TS load has exceeded 354 MW. Since Leamington TS load after the project is expected to be 369 MW based on available load forecast, the post-contingency voltage stability margin is less than 5 %. To meet the ORTAC requirement, an additional 7 MW of the load at Leamington TS and Aphria CTS (or Mastron II CTS) needs to be rejected in post-contingency by the proposed under-voltage L/R schemes that will be discussed in section 4.13.

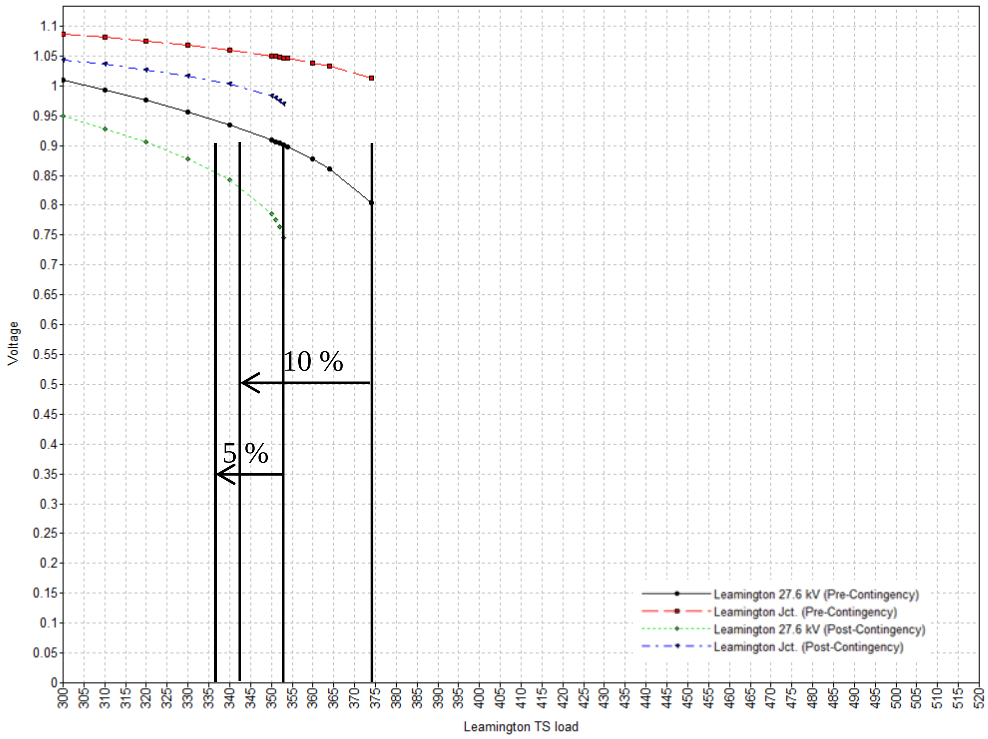

Figure 7: P-V Curves at Leamington Jct. and Leamington TS Buses when One Element is Out of Service under S1 Conditions

4.8 Transient Voltage Performance Assessment

Section 4.4 of the ORTAC states that the minimum post-contingency voltage sag must remain above 70 % of the nominal voltage, and must not remain below 80 % of the nominal voltage for more than 250 milliseconds within 10 seconds following a fault.

The transient post-contingency voltages in the Windsor area system were examined following a LG fault on W44LC close to Chatham SS and a Chatham DL44 breaker failure under S1 winter conditions, which were identified as the worst-case scenarios. Figure 8 shows that the minimum transient post-contingency voltage is 204 kV, 88 % based on a nominal voltage of 230 kV. This meets the ORTAC criteria. Therefore, the ORTAC transient voltage performance criteria are met after the incorporation of the project.

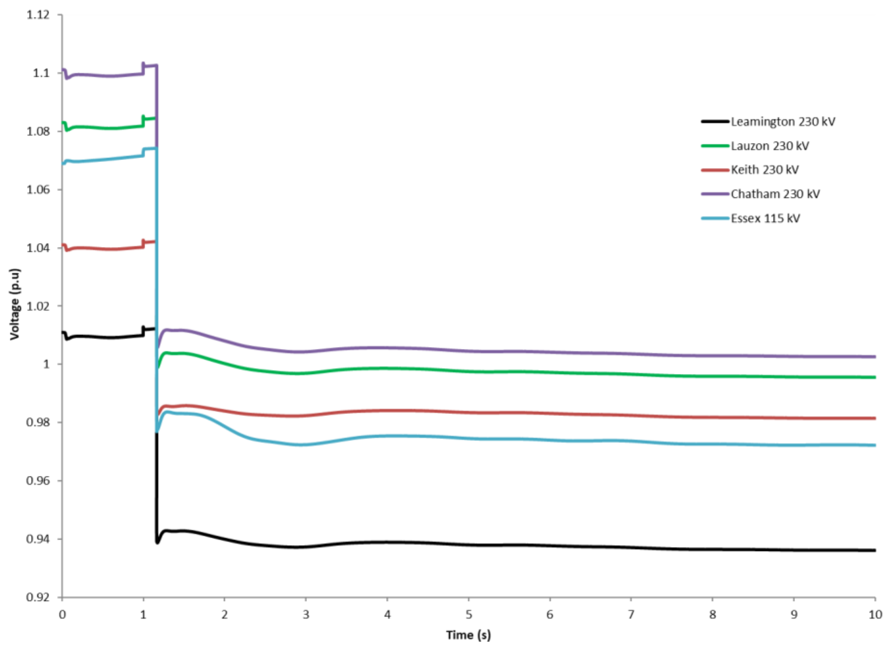

Figure 8: Voltage Responses following a LG Fault on W44LC close to Chatham SS and Chatham DL44 Breaker Failure

4.9 Shunt Capacitor Switching Assessment

The ORTAC states that reactive devices should be sized to ensure that voltage declines or rises for switching operations will not exceed 4% of steady-state rms voltage at delivery point buses before tap changer action using a voltage dependent load model.

The switching of the capacitor banks proposed at Leamington TS of 21.6 Mvar @ 28.8 kV was tested under various outage conditions at 2022 load levels. Table 15 shows the capacitor switching results for the project's 230 kV buses. In all studied scenarios, the voltage change following the capacitor switching is within the prescribed 4% permissible voltage change limit.

Table 15: Capacitor Switching Study for the Project

230 kV Bus	Leamington C21J			Leamington C22J		
Outage Condition	Cap O/S	Cap I/S	Change	Cap O/S	Cap I/S	Change
	kV	kV	%	kV	kV	%
None	236.7	238.2	0.66 %	236.6	238.1	0.66 %
C22J Chatham end open	232.2	233.9	0.72 %	230.2	232.4	0.96 %
C22J Keith end open	235.2	236.7	0.66 %	235.1	237.0	0.82 %
J5D	235.5	237.7	0.92 %	235.4	237.6	0.93 %
C21J				227.3	229.7	1.06 %
C22J	227.6	230.0	1.06 %			

4.10 Load Security and Restoration Assessment

Sections 7.1 and 7.2 of the ORTAC specify the following criteria for load security and restoration:

(1) With one element out of service, not more than 150 MW of load may be interrupted by configuration and by planned load curtailment or load rejection, excluding voluntary demand management. Planned load curtailment or load rejection, excluding voluntary demand management is permissible only to account for local generation outages

(2) With two elements out of service, planned load curtailment or load rejection exceeding 150 MW is permissible only to account for local generation outages. Not more than 600 MW of load may be interrupted by configuration and by planned load curtailment or load rejection, excluding voluntary demand management.

(3) All loads must be restored within approximately a target of 8 hours. When the amount of load interrupted is greater than 150 MW, the amount of load in excess of 150 MW must be restored within approximately a target of 4 hours. When the amount of load interrupted is greater than 250 MW, the amount of load in excess of 250 MW must be restored within a target of 30 minutes.

The loss of C21J or C22J will interrupt Mastron II CTS load (53 MW) or Aphria CTS load (60 MW) by configuration, respectively. Furthermore, the loss of C21J in section 4.5 requires load rejection of up to 210 MW via the Leamington contingency-based SPS when Brighton Beach CGS is out of service. Therefore, a maximum of 263 MW of load will be interrupted following the loss of C21J. This load interruption violates the load security criteria in section 7.1 in ORTAC, where with one element out of service, a maximum of only 150 MW of load can be interrupted by configuration and planned load rejection.

The simultaneous loss of tower sharing circuits C21J and C23Z when Brighton Beach CGS is out of service requires planned load rejection of up to 257 MW via the Leamington contingency-based SPS, as detailed in section 4.5. In addition, up to 53 MW of load at Mastron II CTS would be interrupted by configuration, for a total of 310 MW of load being interrupted. This does not violate the load security criteria in section 7.1 in ORTAC, where a maximum of 150 MW plus Brighton Beach CGS capacity, i.e. 490 MW, but not more than 600 MW of load can be interrupted by configuration and by planned load curtailment or load rejection, excluding voluntary demand management with two elements out of service.

The simultaneous loss of tower sharing circuits C21J and C22J will interrupt load by configuration at Malden TS, Leamington TS, Aphria CTS, and Mastron II CTS of up to 567 MW. This does not violate the load security criteria in section 7.1 in ORTAC, where up to 600 MW of load can be interrupted by configuration with two elements out of service.

Following the simultaneous loss of C21J and C22J, up to 317 MW of load will need to be restored within approximately 30 minutes, up to 417 MW of load will need to be restored within approximately 4 hours, and the total load will need to be restored within approximately 8 hours according to the load restoration criteria in section 7.2 in ORTAC.

4.11 Export Conditions on J5D

This assessment assumed the arming requirements for the Leamington contingency-based SPS identified in sections 4.5 and 4.6 of this report are met in order to mitigate all violations identified with zero exports. From this point, the flow on J5D was gradually increased by dispatching generation outside the Windsor area until the flow on J5D reached its typical maximum pre-contingency flow, i.e. 400 MW. Pre- and post-contingency thermal and voltage analysis were performed to identify if there are additional thermal overloads or voltage limit violations restricting export capability.

S2-Maximum export on J5D based on pre-contingency conditions

During export conditions, a pre-contingency thermal overload was identified prior to encountering a voltage limit violation when Brighton Beach CGS is out of service. Thermal overload caused by exceeding the summer or winter planning continuous ratings on circuit C22J limits exports to Michigan on J5D to 220 MW or 100 MW, respectively. If Brighton Beach CGS is in-service, then the exports on J5D can reach 400 MW without any thermal or voltage violations.

S2-Maximum export capability on J5D based on post-contingency conditions

With Brighton Beach fully dispatched in-service, there were no thermal or voltage violations observed for export levels up to 400 MW.

With Brighton Beach out of service, since the C22J planning rating limits pre-contingency J5D export to 100 MW, post-contingency thermal analysis was not performed. However, operational thermal ratings may be less restrictive than the planning rating; therefore, post-contingency voltage analysis was performed for export levels up to 400 MW under peak winter conditions.

S2-Post-contingency voltage analysis

Table 16 shows that at 100 MW pre-contingency J5D export levels, the post-contingency voltage levels at the 230 kV buses at Leamington TS, Aphria CTS and Mastron II CTS are below 207 kV and the voltage levels at the Kingsville K2Z 115 kV bus are below 108 kV following the Chatham DL44 breaker failure contingency. This violates the post-contingency voltage level criteria in section 4.3 of ORTAC.

At pre-contingency J5D export levels more than 100 MW and up to 400 MW, post-contingency voltage instability was identified at Leamington TS following any contingency that includes the loss of C21J, C22J, Chatham D bus or the simultaneous loss of C23Z and C24Z. This violates the voltage stability margin criteria in section 5.4.1 of ORTAC.

To address the voltage levels and instability issues, local under-voltage L/R schemes at Leamington TS, Aphria CTS, and Mastron II CTS are proposed, as detailed in section 4.13. Up to 369 MW of the load at Leamington TS, Aphria CTS, and Mastron II CTS would need to be rejected to prevent voltage levels and stability margin criteria violations. Table 16 shows the under voltage issues are addressed for the worst-case contingency of Chatham DL44 breaker failure at 400 MW export on J5D.

At 100 MW pre-contingency J5D export levels, post-contingency over-voltage was identified as shown in Table 17. The voltage levels following the inadvertent breaker operation (IBO) of the in-line 230 kV circuit breaker, CF, on J5D at Michigan Waterman violates the maximum voltage level and maximum voltage change criteria in section 4.3 of ORTAC at all monitored buses; except at Longwood TS. The post-contingency over-voltage issues become worse as the export on J5D increases.

To address the over-voltage issue, switching schemes are required for Lauzon and Keith capacitors. The new Lauzon scheme is to automatically trip Lauzon 115 kV capacitor SC12 when any of Lauzon 115 kV bus voltages exceed 133kV for more than 500 milliseconds. The new Keith scheme is to automatically trip Keith 115 kV capacitor SC11 when Keith 115 kV bus voltage exceeds 133kV for more than 500 milliseconds. Table 17 shows that the post-contingency over-voltage issues are addressed at 400 MW export on J5D.

Table 16: Post-Contingency Voltage Results for Chatham 230 kV DL44 Breaker Failure

Bus Name	Pre-cont.	Chatham 230kV DL44 BF (Export at 100 MW on J5D)				Chatham 230kV DL44 BF with Proposed Leamington Under-voltage L/R Scheme (Export at 400 MW on J5D)			
		Pre-ULTC		Post-ULTC		Pre-ULTC		Post-ULTC	
	kV	kV	ΔV (%)	kV	ΔV (%)	kV	ΔV (%)	kV	ΔV (%)
Keith 230 kV	229	211	-8	211	-8	224	-3	224	-3
Leamington JCT C21J 230 kV	228	207	-10	205	-11	225	-2	223	-3
Leamington JCT C22J 230 kV	226	205	-10	203	-11	223	-2	221	-3
Leamington TS C21J 230 kV	225	204	-10	202	-11	226	1	222	-2
Leamington TS C22J 230 kV	222	201	-10	199	-11	221	-1	219	-2
Aphria TS 230 kV	224	203	-10	201	-11	222	-1	220	-2
Mastron II TS 230 kV	226	205	-10	203	-11	224	-1	222	-2
Lauzon C23Z 230 kV	238	210	-12	211	-12	228	-5	226	-6
Lauzon C24Z 230 kV	236	208	-12	209	-12	226	-5	224	-6
Chatham 230 kV	242	217	-11	216	-11	230	-5	228	-6
Longwood 230 kV	248	244	-2	244	-2	248	0	246	-1
Keith 115 kV	127	114	-11	112	-12	129	-3	122	-4
Essex 115 kV	127	113	-12	114	-11	124	-3	122	-4
Lauzon 115 kV	127	113	-12	114	-11	124	-3	122	-4
Kingsville K2Z 115 kV	122	106	-14	103	-16	116	-5	114	-7

Table 17: Post-Contingency Voltage Results for Michigan Waterman CF IBO

Bus Name	Pre-cont.	Michigan Waterman CF IBO (Export at 100 MW)				Michigan Waterman CF IBO with Proposed Lauzon and Keith Capacitor Switching Scheme (Export at 400 MW)			
		Pre-ULTC		Post-ULTC		Pre-ULTC		Post-ULTC	
	kV	kV	ΔV (%)	kV	ΔV (%)	kV	ΔV (%)	kV	ΔV (%)
Keith 230 kV	229	262	15	237	4	221	-4	226	-2
Leamington JCT C21J 230 kV	228	256	13	234	3	221	-4	226	-1
Leamington JCT C22J 230 kV	226	254	13	232	3	219	-4	223	-2
Leamington TS C21J 230 kV	225	255	14	231	3	216	-4	223	-1
Leamington TS C22J 230 kV	222	255	15	229	4	218	-2	220	-1
Aphria TS 230 kV	224	255	14	231	4	218	-3	222	-1
Mastron II TS 230 kV	226	253	12	232	3	219	-4	223	-2
Lauzon C23Z 230 kV	238	268	13	244	3	227	-5	232	-3
Lauzon C24Z 230 kV	236	266	13	243	3	225	-5	230	-3
Chatham 230 kV	242	260	8	245	2	237	-3	240	-1
Longwood 230 kV	248	247	-1	244	-2	244	-2	245	-2
Keith 115 kV	127	145	15	131	4	121	-5	124	-3
Essex 115 kV	127	146	15	131	4	120	-6	123	-4
Lauzon 115 kV	127	146	15	132	4	120	-6	123	-4
Kingsville K2Z 115 kV	122	143	18	127	5	113	-8	116	-5
Kingsville K6Z 115 kV	122	147	21	129	6	117	-5	122	0

4.12 Import Conditions on J5D

This assessment assumed the arming requirements for the Leamington contingency-based SPS identified in sections 4.5 and 4.6 of this report are met in order to mitigate all violations identified with zero imports. The flow on J5D was set to its typical maximum pre-contingency import flow assuming the new projects in-service, i.e. 320 MW in the winter and 200 MW in the summer. Pre- and Post-contingency thermal and voltage analysis were performed to identify if there are additional thermal overloads or voltage limit violations restricting import capability.

<u>S3-Maximum import capability on J5D based on pre-contingency conditions</u>

The import capability is currently limited by the thermal rating of J5D. As such, it was assumed that the Michigan system could accommodate the maximum flow on circuit J5D up to its rating. As there are no thermal overloads on J5D following the contingencies listed in Table 8, the project is expected to have no adverse impact on the Michigan system with J5D imports condition.

<u>S3-Post-contingency analysis</u>

The post-contingency monitored circuit flows and monitored bus voltage levels, including Waterman and Dig Tap in Michigan system, following the N-1 and N-2 contingencies listed in Table 8 and Table 9, with all elements in-service in pre-contingency remain within ORTAC criteria with the utilization of the existing control actions and the proposed Leamington contingency-based SPS and under-voltage L/R schemes.

4.13 Summary of Required Schemes and Protection Coordination

Based on the aforementioned thermal and voltage assessments performed, the following are required:

(1) **Revised Leamington contingency-based SPS:**

Arming for the simultaneous loss of C21J and C23Z, simultaneous loss of C22J and C24Z, failure of Chatham DL21 breaker, failure of Chatham L21L47 breaker, and failure of Keith C21J breaker contingences can done by over arming for the loss of C21J and C22J. The loss of a single unit at Brighton Beach CGS and the simultaneous loss of C23Z and C24Z contingencies need to be added into the scheme. Moreover, it is required to arm for the single loss of C23Z and C24Z for operation flexibility during outage conditions. Arming for the loss of the entire Brighton Beach CGS can be done by selecting different groups for arming for the loss of each Brighton Beach unit contingency to guarantee enough load is rejected for the loss of the entire Brighton beach CGS. The Leamington contingency based SPS must provide the ability to reject Leamington TS load in 8 groups as well as the load at Aphria CTS and Mastron II CTS following any contingency that includes the loss of C21J, C22J, C23Z, C24Z, Brighton Beach CGS unit(s), or the simultaneous loss of C23Z and C24Z. Table 17 shows the selection matrix for these proposed actions in the revised Leamington contingency-based SPS.

Table 18: Revised Selection Matrix for Leamington Contingency-based SPS

Contingency	Load									
	Leamington TS								Aphria CTS	Mastron II CTS
	L1	L2	L3	L4	L5	L6	L7	L8		
C21J	x	x	x	x	x	x	x	x	x	---
C22J	x	x	x	x	x	x	x	x	---	x
C23Z	x	x	x	x	x	x	x	x	x	x
C24Z	x	x	x	x	x	x	x	x	x	x
C23Z + C24Z	x	x	x	x	x	x	x	x	x	x

Contingency	Load									
	Leamington TS								Aphria CTS	Mastron II CTS
	L1	L2	L3	L4	L5	L6	L7	L8		
G1 at Brighton Beach	x	x	x	x	x	x	x	x	x	x
G1A at Brighton Beach	x	x	x	x	x	x	x	x	x	x
G1B at Brighton Beach	x	x	x	x	x	x	x	x	x	x

(2) Local over-voltage protection coordination:

Local over-voltage protection must be coordinated to provide tripping of capacitors at Leamington TS, Aphria CTS, and Mastron II CTS for system over-voltage conditions to avoid post-contingency high voltages following load rejection by the above Leamington contingency-based SPS. Table 19 shows the preliminary tripping settings for each capacitor at Leamington TS, Aphria CTS, and Mastron II CTS.

Table 19: Leamington Area Over-Voltage Capacitor Tripping Settings

Station	Capacitor	Mvar	Tripping Settings		Monitoring Bus kV
			kV	seconds	
Leamington DESN #1	SC3	20	250	4	230
	SC4	20	250	4	230
Leamington DESN #2	SC1	20	250	8	230
	SC2	20	250	8	230
Aphria	SC1	20	250	6	230
Mastron II	SC1	20	250	6	230

(3) Local voltage-based schemes:

- Local under-voltage L/R scheme at Leamington: The scheme must provide selection of load to be rejected at Leamington TS in four equal stages for a sustained voltage below 207 kV for more than 5 seconds at any of Leamington 230 kV buses. There will be a delay of 3 seconds between stages.
- Local under-voltage L/R scheme at Aphria CTS: The scheme must provide selection of load to be rejected at Aphria CTS for a sustained voltage below 207 kV for more than 6 seconds at Aphria 230 kV bus.
- Local under-voltage L/R scheme at Mastron II CTS: The scheme must provide selection of load to be rejected at Mastron II CTS for a sustained voltage below 207 kV for more than 6 seconds at Mastron II 230 kV bus.
- Local capacitor switching scheme at Lauzon: The scheme must provide tripping for the Lauzon TS 115 kV capacitor SC12 as a result of a voltage at any of Lauzon 115 kV buses above 133kV being attained for more than 500 milliseconds.
- Local capacitor switching scheme at Keith: The scheme must provide tripping for the Keith TS 115 kV capacitor SC11 as a result of a voltage at any of Keith 115 kV buses above 133 kV being attained for more than 500 milliseconds.

4.14 Summary of Recommended Scheme

As identified in section 4.5, to avoid the load curtailment under the forced outage condition to one of the circuits L28C, L29C, W44LC, W45LS, and S47C, Hydro One is recommended to install a contingency based SPS and add the double contingencies, i.e. the simultaneous loss of L28C and L29C, W44LC and W45LS, and W44LC and S47C, into this SPS to reject the loads post-contingency at Leamington TS, Aphria CTS and Mastron III CTS. Moreover, it is recommended to include the subset of single contingencies as well, i.e. L28C, L29C, W44LC, W45LS, and S47C for operation flexibility during outage conditions. Table 20 shows the selection matrix for the recommended contingency based SPS.

Table 20: Selection Matrix for the Recommended Contingency Based SPS

Contingency	Load									
	Leamington TS								Aphria CTS	Mastron II CTS
	L1	L2	L3	L4	L5	L6	L7	L8		
L28C	x	x	x	x	x	x	x	x	x	x
L29C	x	x	x	x	x	x	x	x	x	x
W44LC	x	x	x	x	x	x	x	x	x	x
W45LS	x	x	x	x	x	x	x	x	x	x
S47C	x	x	x	x	x	x	x	x	x	x
L28C + L29C	x	x	x	x	x	x	x	x	x	x
W44LC + W45LS	x	x	x	x	x	x	x	x	x	x
W44LC + S47C	x	x	x	x	x	x	x	x	x	x

4.15 Motor Starting Assessment

The connection applicant has confirmed that there is no major induction motor load to be supplied; thus, motor starting studies were not conducted.

4.16 Short Circuit Assessment

As the low voltage windings of the transformers are configured in Zigzag and Hydro One has confirmed that there is no major synchronous motor load to be supplied, the project will not change the fault levels in its surrounding area for both 3-phase and L-G faults. Thus, short circuits studies were not conducted.

– End of Section –

5. Appx A: Protection Impact Assessment

Hydro One Networks Inc.
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Toronto, Ontario
M5G 2P5

Protection System Description

HYDRO ONE PROJECT

LEAMINGTON TS #2: BUILD NEW TRANSFORMER STATION

PCT – 936

Rev. 0.1

Date: September 5, 2018

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Disclaimer

This Protection System Description (PSD) has been prepared solely for the IESO for the purpose of assisting the IESO in preparing the System Impact Assessment for connection of the proposed transmission facilities to the IESO-controlled grid. This report has not been prepared for any other purpose and should not be used or relied upon by any person for any other purpose.

This PSD was prepared based on information available to Hydro One at the time the assessment was carried out. It is intended to highlight significant impacts, if any, to affected transmission protections early in the project development process. The results of this PSD are also subject to change to accommodate the requirements of the IESO and other regulatory or legal requirements. In addition, further issues or concerns may be identified by Hydro One during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with the Transmission System Code legal requirements, and any applicable reliability standards, or to accommodate any changes to the IESO-controlled grid that may have occurred in the meantime.

Hydro One shall not be liable to any third party, which uses the results of the PSD under any circumstances, whether any of the said liability, loss or damages arises in contract, tort or otherwise.

Revision History

Revision	Date	Change
R0	July 20, 2018	Initial Release
R0.1	September 5, 2018	Clarification of Cross-tripping

1 INTRODUCTION

GENERAL

This Protection System Description is prepared for the IESO to assess the potential impact of new HONI's Leamington TS #2 project. The primary focus of this study is to assess the impact on Hydro One protection system equipment while meeting IESO's System Reliability Criteria.

DESCRIPTION OF PROJECT DESCRIPTION

The first stage development at Leamington TS involved the development of a 2 x 75/125 MVA, 230/27.6-27.6 kV Bermondsey type DESN station to be brought into service in the in the second quarter of 2018. The load growth which has been due to greenhouse expansion and the uptake of grow light in greenhouses has so far enormously exceeded expectations to the point that the current load forecast shows that the capacity of the first DESN will be exceeded shortly after it comes into service. Hence the development of the second DESN in the Municipality of Leamington is required (Figure 1). The existing Leamington property on Mersea Road 6 is laid out for two DESN stations. Hence the new DESN will be constructed on this property. The proposed in-service date is Q4 2019.

In order to manage thermal limitations on the main supply circuits (C21J and C22J) between Chatham TS and Keith TS, a Special Protection System (SPS) will be required to enable load rejection at the new Leamington DESN for the loss of C21J or C22J. It is expected to be classified as type III system.

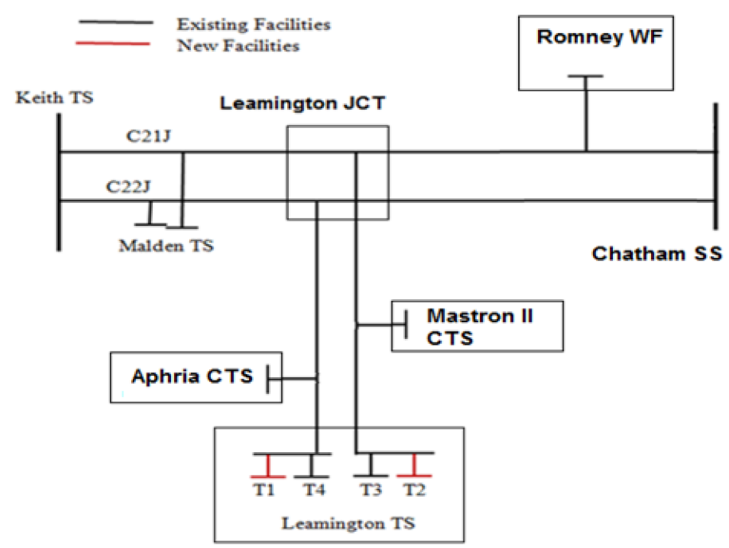

Figure 1 Leamington Station #2 Connection

The new T1/T2 DESN and the LV yard arrangement are shown in Figure #2.

The new 75/100/125MVA, 215.5/28-28 kV Bermondsey type outdoor DESN includes:

- 2x 75/100/125 MVA, 215.5/28-28kV transformers. Each LV Zigzag winding is grounded through a 1.5 ohm neutral reactor
- 4x transformer LV breakers and 1x bus tie breaker
- 12x feeder breakers
- 2x capacitor bank breakers
- Associated disconnect and ground switches

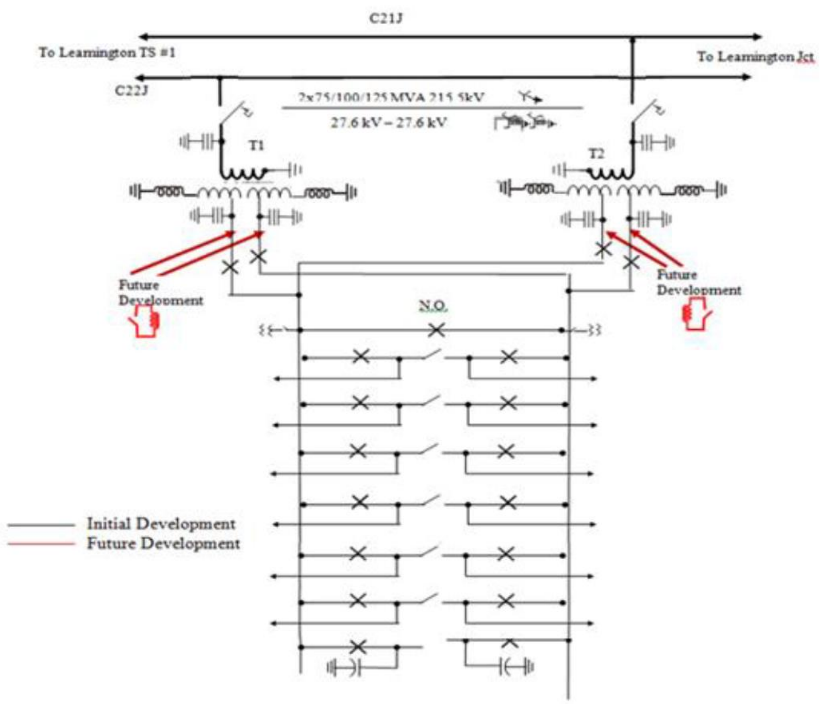

Figure 2 New Added Leamington T1/T2 DESN Transformers and LV Yard Arrangement

Scope of protection-related work in this project includes:

- Design protection and automation in new DESN in the existing Leamington TS.
- Build load rejection SPS.

2 DESCRIPTION OF PROTECTION INSTALLATIONS AND MODIFICATIONS

When this document is prepared, Romney WF generation connection on C21J, Mastron II CTS load connection on C22J and Aphria CTS load connection on C21J are in assessment or construction station respectively. These connections have been assessed in separated documents without significant impact. In this document, these connections are considered as existing connection.

2.1 Leamington TS

2.1.1 Transformer Protections in T1/T2 Yard

- New ‘A’ and ‘B’ protections shall be installed with HONI standard transformer protection IEDs. HV line backup protection shall be implemented in transformer protection IEDs. Provide new line back up protections as per latest PC&T standard. Phase and ground back up protections shall follow the latest PC&T standard philosophy. Typical Bermondsey DESN trip matrix shall be implemented with the associated ZATMs.
- Operation of transformer protection will trip two transformer LV breakers and send a cross-trip signal to remove the existing T3 orT4. The cross-trip signal shall be cascaded to Keith TS to trip the with the fault transformer.
- Receipt of a cross-trip signal from T3 or T4 transformer protection will result in tripping two LV transformer breakers.

Notes: Cross-tripping in this document stands for tripping signal between two DESN Yards. There are two separate cross-tripping signals between two DESN yards: one is for between T1 and T4 transformers. Another one is for between T2 and T3 transformers.

1) When T1 transformer protection sends a cross-tripping signal to T3/T4 Yard, only T4 transformer will be tripped. The cross-tripping also is sent to Keith TS to trip C22J.

2) When T2 transformer protection sends a cross-tripping signal to T3/T4 Yard, only T3 transformer will be tripped. The cross-tripping also is sent to Keith TS to trip C21J.

3) When T3 transformer protection sends a cross-tripping signal to T1/T2 Yard, only T2 transformer will be tripped. The cross-tripping also is sent to Keith TS to trip C21J.

4) When T4 transformer protection sends a cross-tripping signal to T1/T2 Yard, only T1 transformer will be tripped. The cross-tripping also is sent to Keith TS to trip C22J.

2.1.2 27.6kV Breaker Protections

- New breaker failure, reclose and trip protection on the new 27.6 kV transformer breaker shall be provided with HONI standard breaker IEDs. The receipt of cross-trip signal from T3/T4 transformer protection shall trip two transformer LV breakers and initiate the BF protection.

- In the event of LV transformer breaker failure, it shall trip LV breaker on another LV winding of transformer connected with failed LV breaker, other direct-connected LV breakers and send a cross trip signal to T3/T4 transformer protection.

2.1.3 27.6kV Bus Protections

- New 'A' and 'B' group bus protections are to be installed with HONI standard LV bus blocking scheme.
- UFLS: Implement UFLS as per the latest PC&T standard requirements. The breakers selected for UFLS scheme shall be pre-determined and pre-set in the relay configuration settings.

2.1.4 27.6kV Feeder Protections

- New protections on the twelve 27.6 kV feeders shall be installed with HONI standard relay modules. Breaker failure protection will be included as an integral part of the feeder protection.

2.1.5 27.6kV Capacitor Bank Protections

- New protections on two 27.6 kV capacitor banks shall be installed with HONI standard relay module. Breaker failure protection will be included as an integral part of the capacitor bank protections.

2.1.6 Existing Transformer Protections in T3/T4 Yard

- Transformer protection logic shall be modified for bi-directional cross-tripping between new T1/T2 yard and existing T3/T4 yard. Receipt of a cross-trip signal from T1/T2 yard will trip LV breaker and send TT to Keith TS. Receipt of TT signal from Keith TS will send a cross-trip signal to T1/T2. Operation of transformer protection and LV breaker failure will send a cross-trip signal to T1/T2.
- Line backup protection setting shall be reviewed by considering existence of new Leamington DESN transformers.

2.1.7 Cross Tripping Between Two Yards

- Optical fiber-based cross-trip path shall be built between the existing PCT box for T3/T4 and new PCT box for T1/T2. One path will be between T1 and T4 transformers. Another path will be between T2 and T3 transformers. 'Main' and 'Alter' paths shall use different fiber to avoid loss of communication in case of single fiber to be broken.

2.2 Keith TS

- No changes to existing protection IEDs or settings

- Implement SPS for Leamington TS L/R in new DESN.

2.3 Teleprotections

- Existing communication schemes for C21J and C22J teleprotection are shown in Table #1 and #2 below.

A Group							
Keith TS	Malden TS	Chatham SS	Path	Medium	Channel	Relationships	Notes
			DTC0991	Fibre	MAIN	DTC0992	CHATHAM SS X KEITH TS [A MAIN]
			DTC0992	Fibre	ALTERNATE	DTC0991	CHATHAM SS X KEITH TS [A ALT]
			DTC7061	Fibre	MAIN		KEITH TS X MALDEN TS [A]
B Group							
Keith TS	Malden TS	Chatham SS	Path	Medium	Channel	Relationships	Notes
			DTC0993	Fibre	MAIN	DTC0994	CHATHAM SS X KEITH TS [B MAIN]
			DTC0994	Fibre	ALTERNATE	DTC0993	CHATHAM SS X KEITH TS [B ALT]
			DTC7062	Fibre	ALTERNATE		KEITH TS X MALDEN TS [B]

Table #1 – Communication Matrix for Circuit C21J [230kV]

A Group							
Keith TS	Malden TS	Chatham SS	Path	Medium	Channel	Relationships	Notes
			DTC0995	Fibre	MAIN	DTC0996	CHATHAM SS X KEITH TS [A MAIN]
			DTC0996	Fibre	ALTERNATE	DTC0995	CHATHAM SS X KEITH TS [A ALT]
			DTC7065	Fibre	MAIN	DTC7066	KEITH TS X MALDEN TS [A]
B Group							
Keith TS	Malden TS	Chatham SS	Path	Medium	Channel	Relationships	Notes
			DTC0997	Fibre	MAIN	DTC0998	CHATHAM SS X KEITH TS [B MAIN]
			DTC0998	Fibre	ALTERNATE	DTC0997	CHATHAM SS X KEITH TS [B ALT]
			DTC7066	Fibre	ALTERNATE	DTC7065	KEITH TS X MALDEN TS [B]

Table #2 – Communication Matrix for Circuit C22J [230kV]

- When the Leamington DESN project (another project for Leamington TS #1 DESN) – Leamington TS: Build New 75/125 MVA, 230/27.6-27.6 kV DESN" is commissioned, new main and alternate teleprotection channels between Keith TS and Leamington TS would be required for C21J and C22J transfer trip. The new teleprotection channels information will be updated in the communication matrix for these two power circuits.
- Existing C21J and C22J teleprotection scheme can be retained including the new transfer trip channels between Keith TS and Leamington TS.
- Bi-directional cross-tripping between T1/T2 and T3/T4 shall be implemented in the transformer protection logic. The transfer trip signals for T1/T2 shall be cascaded to Keith TS via the main and alternate teleprotection channels for T3/T4.

3 FAULT CLEARING TIMES

Normal and backup fault clearing times for subjected lines will remain same as both line protection and transfer trip protection schemes/settings will not be changed in this project.