REPORT

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System Impact Assessment Report

Cambridge Preston 115/230 kV Autotransformer

CONNECTION ASSESSMENT & APPROVAL PROCESS

Final Draft Report

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Applicant: Hydro One Networks

Transmission Assessments & Performance Department

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System Impact Assessment Report

Cambridge Preston 115/230 kV Autotransformer

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 approval or disapproval of the proposed connection under Chapter 4, section 6 of the Market Rules.

Approval of the proposed connection is based on information provided to the IESO by the connection applicant and the transmitter(s) 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 the transmitter(s) at the request of the IESO. Furthermore, the connection approval is subject to further consideration due to changes to this information, or to additional information that may become available after the approval has been granted. Approval of the proposed connection means that there are no significant reliability issues or concerns that would prevent connection of the proposed facility to the IESO-controlled grid. However, connection approval does not ensure that a project will meet all connection requirements. In addition, further issues or concerns may be identified by the transmitter(s) during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with physical or equipment limitations, or with the Transmission System Code, before connection can be made.

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

HYDRO ONE

Special Notes and Limitations of Study Results

The results reported in this study are based on the information available to Hydro One, at the time of the study, suitable for a preliminary assessment of a new generation or load 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 connection on facilities owned by other load and generation (including OPGI) customers.

In this study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent 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 connection have been identified to the extent permitted by a preliminary 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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CAMBRIDGE PRESTON 115/230 KV AUTOTRANSFORMER IESO SYSTEM IMPACT ASSESSMENT

SIA Findings

This System Impact Assessment has examined the benefits and impact of the new 115/230 kV autotransformer in Cambridge- Preston area and a new 115 kV switchyard at Freeport, on the reliability of the IESO-Controlled grid. The installation of the facilities represent a development project that will relieve current transmission overloads and provide the adequate level of supply to the Kitchener Waterloo area loads. The need for this development was originally identified by Hydro One as part of the 2003 Detweiler Area supply study.

Summary

Hydro One Networks Inc. is proposing to install a new 250 MVA, 230/115 kV autotransformer at Cambridge Preston TS which will provide a connection between the 115 kV circuit D7G and D9G and the 230 kV circuits M20D and M21D. A new 115 kV switching station located around Freeport and consisting of two 115 kV in-line breakers on D7G and D9G is also part of this plan.

The new in-line breakers will split the 115 kV circuit D7G into D7F and F12C, and 115 kV circuit D9G into D9F and F11C. The new transformer will be tapped off the 115 kV lines F11C or F12C and terminated at the 230 kV end at M20D or M21D. The purpose of the new autotransformer is to eliminate the thermal overloads on the 115 kV circuits D9G and D7G which supply the load in Kitchener-Waterloo area. The new arrangement is shown in Figure 1.

A new Special Protection System which would be required to alleviate post-contingency thermal concerns is also proposed for the area.

The normal operating mode will be connecting the new autotransformer to the circuits M20D and F12C. Thus, this System Impact Assessment is limited to examining the impact of having the new autotransformer at that normal operating mode on the IESO-controlled grid with local loads at 2008 and 2012 summer peak levels. The new Special Protection Scheme named ‘M20D/M21D Overload Rejection Scheme’ will alleviate thermal overloads in 230 kV circuits M20D and M21D.

The proposed Cambridge Preston autotransformer connection is a developmental project which is needed to provide reliable power supply to Kitchener-Waterloo area load. The new transmission will eliminate post-contingency thermal concerns related to the 115 kV system.

At the time that this SIA was performed, several other transmission/generation reinforcements and upgrades have been proposed for the Cambridge area. As these projects are yet to be finalised or committed, those were not included in this assessment.

The following conclusions and recommendations were made from the analysis.

Conclusions and Recommendations

Conclusions:

(1) The proposed autotransformer mitigates the overloading of 115 kV circuits D7G and D9G during the period of study (2008 – 2012).

(2) A summary of the loading on M20D and M21D is shown in Table 1. Under 2008 summer extreme weather conditions, the *Cambridge area load* is predicted to be approximately 360 MW. For this level of load, there is no overloading foreseen on M20D/M21D. The *Cambridge area load* constitutes flow in to Gerdau-Courtice Steel, Galt TS, Cambridge MTS #1 and Preston TS.

Thermal overloading of M20D and M21D will begin to appear when the *Cambridge area load* reaches 390 MW. The overload of M20D for the loss of M21D can be alleviated by the use of the new SPS; however M21D will still be overloaded for the loss of M20D because Gerdau-Courtice Steel load is supplied off M21D only.

Table 1 – M20D and M21D Thermal Result Summary

Cambridge Area Load *		Overloaded	Loss of
360 MW (2008 extreme load forecast)	Pre-contingency	No	-
	Post-contingency	No	-
390 MW	Pre-contingency	No	-
	Post-contingency/No SPS	M20D M21D	M21D M20D+Detweiler T3+Preston T1
	Post-contingency/Post-SPS	M21D	M20D+Detweiler T3+Preston T1

* Cambridge Area Load = Gerdau-Courtice Steel + Galt TS + Cambridge MTS #1 + Preston TS

Note: the normal operating mode is the connection of the 230 kV side of the new autotransformer to M20D. Since the Gerdau-Steel load is supplied only by M21D, the connection of the autotransformer to M21D could cause overloads that are not identified in this report. This mode of operation may require load transfer from M21D to M20D.

(3) The post-contingency voltage declines at LT buses at Galt and Kitchener MTS#5 do not meet the Transmission Assessment Criteria under 2008 conditions. In addition to these two stations, the voltage declines at Cedar LT bus also do not meet the requirements under 2012 conditions. These excessive declines are not a result of this new connection.

(4) Short circuit levels as a result of the new connection do not exceed the interrupting capabilities of the existing breakers in the IESO-controlled grid. It should be noted that short circuit levels at Middleport 230 kV may be near breaker interrupting capabilities if 450 MW of proposed new generation is incorporated in the Cambridge area.

Note: the SIA analysis is based on the expectation that the relay settings of D7F/D9F/M20D/M21D circuits will be modified to account for the effect of the additional injection of the new transformer.

Recommendations:

(1) Thermal overloading of M20D and M21D taps to Cambridge Preston must be addressed before Cambridge area load exceeds 390 MW.

(2) Measures must be taken to mitigate existing excessive voltage declines at Galt, Kitchener MTS #5 and Cedar stations.

IESO's Requirements for Connection

The following requirements for the incorporation of Cambridge Preston 115/230 kV autotransformer to F11C, F12C, M20D and M21D circuits and the new 115 kV Freeport SS have been identified.

(1) Measures must be initiated to address future overloading of M20D and M21D taps to Cambridge Preston which will occur when the Cambridge area load exceeds 390 MW. These measures must be evaluated by the IESO.

(2) Hydro One Networks will be required to provide continuous on-line monitoring of the:

- 115 kV and 230 kV voltages of the new autotransformer
- Statuses for the new breakers L9L11, L7L12, T2K and the 230 kV circuit switchers.
- Active and reactive power flow through the new autotransformer
- The status of the Special Protection System arming.

(3) The opening of the autotransformer only at the 115 kV side by the SPS must not cause any unacceptable voltages and/or ferroresonance phenomenon.

(4) The proponent must notify the IESO as soon as it becomes aware of any changes to the assumptions made in the connection assessment. The IESO will determine whether these changes require a re-assessment.

(5) The Special Protection scheme must be fully redundant with a separate communication paths and batteries.

Notification of Conditional Approval

From the information provided, our review concludes that the proposed changes will not result in a material adverse effect on the reliability of the IESO-controlled grid. It is recommended that a Notification of Conditional Approval be issued for Cambridge Preston 115/230 kV autotransformer subject to the IESO receiving written acknowledgement that the requirements listed in this report will be implemented.

1. Project Description

Hydro One Networks Inc. is proposing to install a 250 MVA, 230/115 kV autotransformer at Cambridge Preston TS. This new transformer will be tapped off from the 115 kV lines F11C/F12C and terminate at the 230 kV end at M20D/M21D. The circuits F11C+D9F is existing D9G and F12C+D7F is existing D7G.

Currently, the majority of the Kitchener-Waterloo area load is supplied from D7G and D9G. The purpose of the autotransformer is to increase the load-meeting capability of the area by providing an alternate supply from the 230 kV system.

This project also includes:

- The implementation of a Special Protection Scheme which if armed will trip the autotransformer for the loss of M20D or M21D
- The addition of in-line breakers on D9G and D7G at Freeport JCT
- The renaming and sectionalizing of D9G into D9F and F11C
- The renaming and sectionalizing of D7G into D7F and F12C

The proposed project is expected to be in service in November 30, 2007.

– End of Section –

2. General Requirements

Models & Data

1. The Connection Applicant must complete the IESO Facility Registration process in a timely manner before IESO final approval for connection is granted. Finalized models and data must be provided to the IESO. This information should be submitted to the IESO before first energization of any equipment to allow the IESO to perform any additional reliability studies.

2. During commissioning, the Connection Applicant must provide evidence to the IESO confirming that the equipment installed meets the Market Rules requirements and matches or exceeds the performance predicted in the finalized models and data. Until this evidence is provided, the Connection Applicant must accept any restrictions the IESO may impose upon their participation in IESO-administered market or connection to the IESO-controlled grid.

Connection Equipment (Breakers, Disconnects, Transformers, Buses)

1. High voltage 230 kV equipment connected to terminal stations must be capable of continuously operating in the range between 220 kV and 250 kV.

   High voltage 115 kV equipment connected to terminal stations must be capable of continuously operating in the range between 113 kV and 127 kV.

   Some recognized contingencies such as load shedding, open line end can cause a temporary voltage increase above the maximum continuous limit of 250 kV/127 kV. For these conditions, connection equipment may be exposed to voltages slightly above its maximum continuous rating for the short period of time that it takes the IESO to direct operations to restore a normal voltage profile, and to prepare for the next contingency. This re-preparation period will be as short as possible, but it will not take longer than 30 minutes.

   The IESO requires that the 230 kV/115 kV connection equipment have the following requirements:

   - equipment must be able to interrupt rated fault current for voltages up to the maximum continuous rating
   - equipment must remain in service and not automatically trip for voltages up to 5% above the maximum continuous rating for up to 30 minutes to allow the system to be re-dispatched to return voltages within their normal range.

2. The Transmission System Code states that 230 kV equipment should have a 3-phase symmetrical short circuit capability of 63 kA and a single line to ground short circuit capability of 80 kA (usually limited to 63 kA). The Code also states that 115 kV equipment should have a 3-phase symmetrical short circuit and a single line to ground short circuit capability of 50 kA.

3. Connection equipment must be designed so that the adverse effects of failure on the

IESO-controlled grid are mitigated. This includes ensuring that all breakers fail in the open position.

Connection equipment must be designed so that it will be fully operational in all reasonably foreseeable ambient temperature conditions.

Protection Systems

1. Hydro One is required to meet the transmitters' requirements with respect to protection systems for the new transformer and coordination with the existing protection systems, as outlined in the Transmission System Code.

2. The Special Protection Scheme must be fully duplicated with a separation of communication channels. It should also meet the requirements of the NPCC “Special Protection System Criteria.”

IESO Monitoring and Telemetry Data

1. The Market Rules list the requirements with respect to the telemetry data that must be provided to the IESO and to the performance standards that must be adhered to.

   Hydro One Networks is required to provide on-line monitor of voltages, isolation device status, transformer ULTC tap positions, active and reactive power flow through the new autotransformer and the SPS status.

   In accordance with the requirements for a *transmitter*, Connection Applicant must ensure that all the equipment needed to provide the telemetry data and meet the performance standards will be installed.

   The IESO will finalize items to be telemetered during the IESO Market Entry Process.

– End of Section –

3. Review of Connection Proposal

3.1 Proposed Connection Arrangement

The new connection arrangement is shown in Figure 1. As a part of this new connection, the 115 kV lines from Detweiler, D7G and D9G will each be split into two circuits with new designations:

1) D7G to be split at Freeport JCT via a 3000 A in-line breaker into circuits D7F and F12C.
2) D9G to be split at Freeport JCT via a 3000 A in-line breaker into circuits D9F and F11C.

The 2 new in-line breakers along with existing and new switches result in a new switching station, Freeport SS. The new 230/115 kV autotransformer will be connected to F11C and F12C at Speedsville JCT via two 1.062 km long 115 kV lines. These lines have a maximum normal summer operating rating of 1070 A. The 115 kV disconnect switches have a continuous rating of 2000 A. Under normal conditions, the disconnect switch to F12C will be kept closed, while the disconnect switch to F11C will be kept normally opened. F11C and F12C both terminate at the K Bus which is isolated from T1 via a 3000 A circuit breaker T2K.

The High voltage side of autotransformer will terminate on M20D and M21D at Preston TS. Its isolation is provided by two 1200 A circuit switchers. Under normal conditions, the circuit switcher to M20D will be kept normally closed while the circuit switcher to M21D will be kept normally opened.

The transformer is rated for 250 MVA and is equipped with a ULTC with a range of ± 27.5 kV achieved in 20 steps. The transformer impedance is 10% on a 250 MVA base.

A special protection scheme named ‘M20/M21D Overload Rejection Scheme’ will be designed as part of this project. The purpose of the SPS is to remove the autotransformer from service if any of M20D or M21D which is not connected to the autotransformer is tripped such that the 230 kV circuit connected to the autotransformer will not be overloaded.

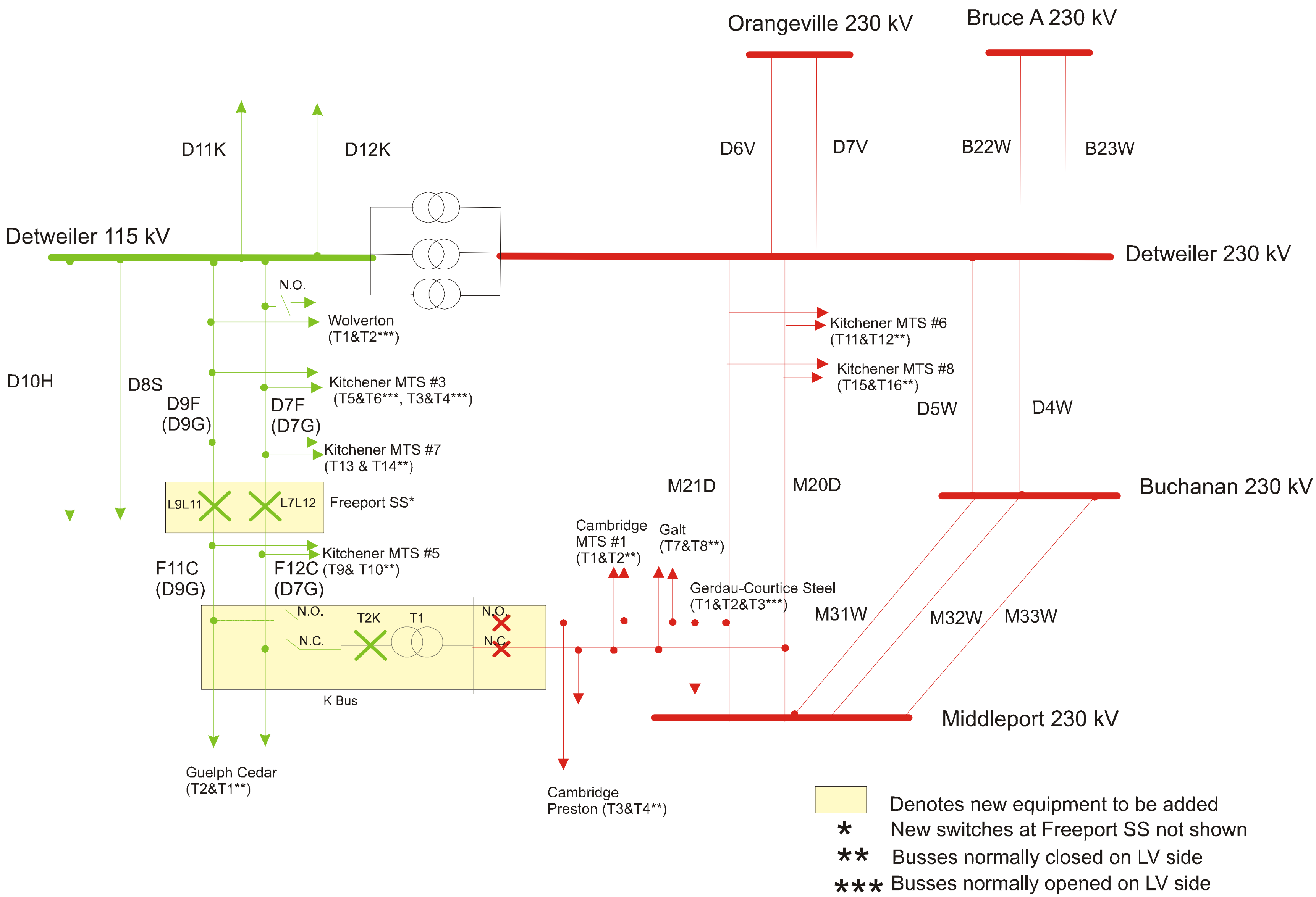

FIGURE 1: PROPOSED CONNECTION

3.2 Existing System

Figures 2A and 2B show the MW flow on D7G and D9G at Detweiler in 1 Hr average samples during the period of Jan 1- Dec 31, 2005. The positive flow is leaving the bus.

Similarly, Figures 2C and 2D show the flows on M20D and M21D at Detweiler respectively and figures 2E and 2F show the flows on M20D and M21D at Middleport respectively in 1 Hr average samples during the period of Jan 1 - Dec 31, 2005. The positive flow is leaving the bus.

These peak flows found in figures 2A – 2F were used to develop suitable study scenarios.

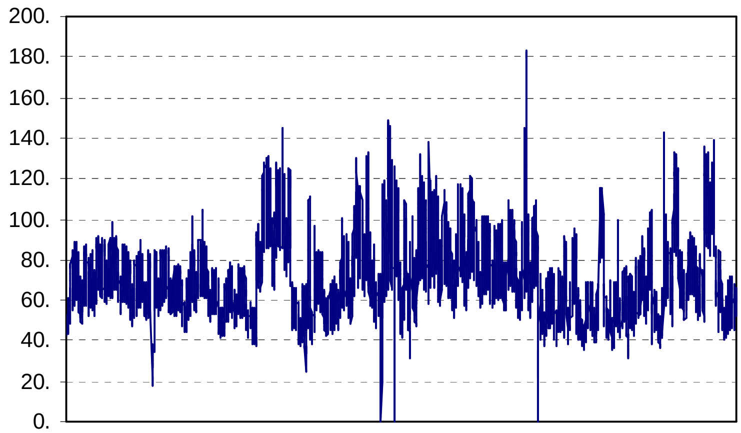

FIGURE 2A – MW FLOW IN D7G @ DETWEILER

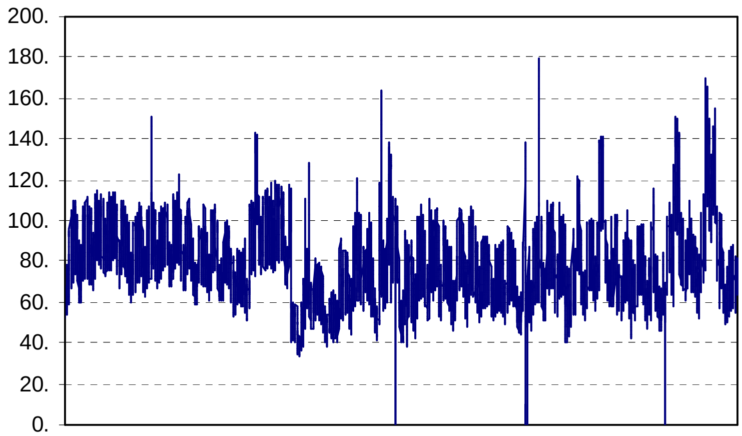

FIGURE 2B – MW FLOW IN D9G @ DETWEILER

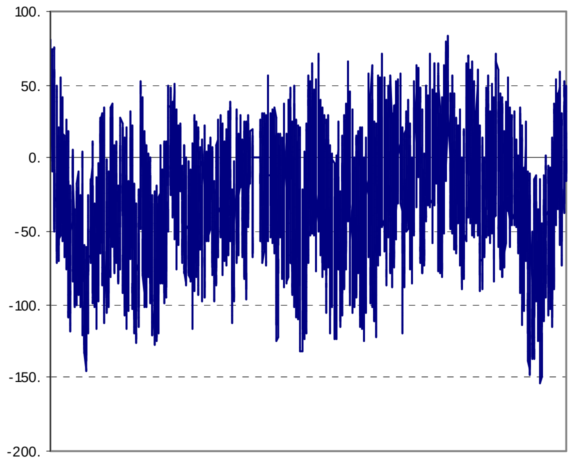

FIGURE 2C – MW FLOW ON M20D @ DETWEILER

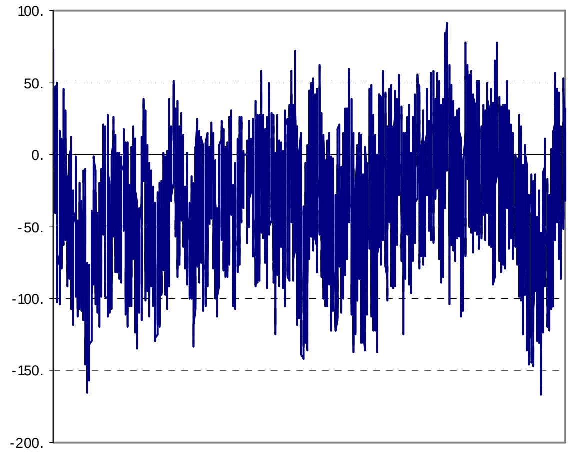

FIGURE 2D – MW FLOW ON M21D @ DETWEILER

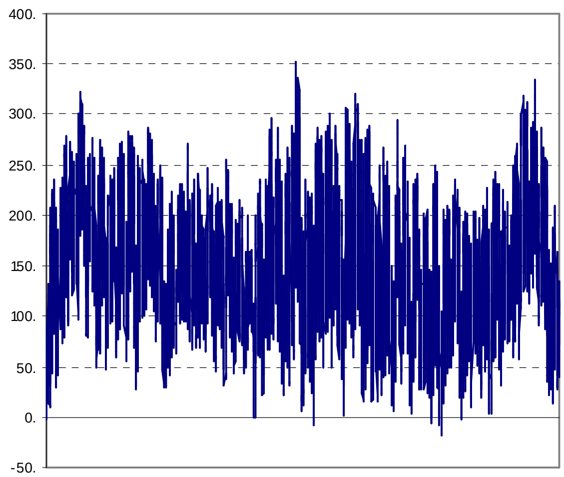

FIGURE 2E- MW FLOW ON M20D @ MIDDLEPORT

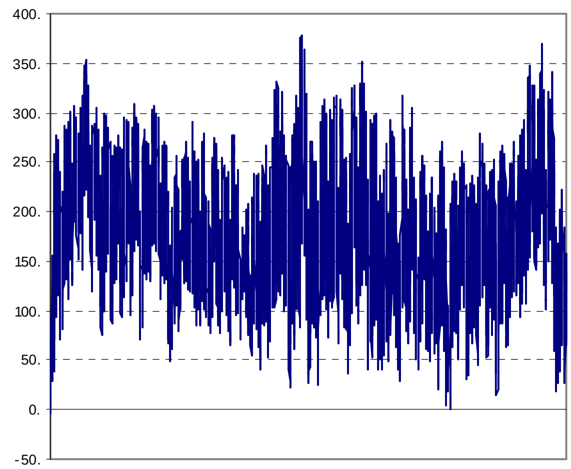

FIGURE 2F– MW FLOW ON M21D @ MIDDLEPORT

– End of Section –

4. Data Verification

4.1 Transformer

Specifications of the 115/230 kV autotransformer provided by the connection applicant are listed below.

Rating (MVA)	250
Voltage (kV)	239/121/13.9
Configuration	3-Phase, 60 cycle
Impedance (pu on 250 MVA base)	0.10
Summer Thermal Ratings (MVA)	250/340/425
Winter Thermal Ratings (MVA)	250/400/500
ULTC (HV)	+27.5 kV to -27.5 kV in 20 steps

4.2 Circuit Breakers and Switches

Specifications of the isolation devices provided by the connection applicant are listed below. The incomplete data must be provided to the IESO.

(1) Breakers L9L12 & L7L12 at Freeport JCT

Rated line-to-line voltage	115 kV
Interrupting time	
Interrupting media	
Rated continuous current	3000 A
Rated short circuit breaking current	40 kA

(2) Breaker T2K

Rated line-to-line voltage	115 kV
Interrupting time	
Interrupting media	
Rated continuous current	3000 A
Rated short circuit breaking current	40 kA

(3) Switches 60L9L11-11 and 60-L7L12-12 at Freeport SS

Rated line-to-line voltage	115 kV
Rated continuous current	

(4) Switches 21-F11C and 21-F12C at LV of T1

Rated line-to-line voltage	115 kV
Rated continuous current	2000 A

(4) Circuit Switches 21T2-M21D and 21T2-M20D at HV of T1

Rated line-to-line voltage	230 kV
Rated continuous current	2000 A

4.3 Overhead Circuits

Specifications of the F11C and F12C line extensions from Speedsville JCT to T1 provided by the connection applicant are listed below.

Max Operating Voltage (kV)	127
Length (km)	1.062
Continuous Rating (Summer)	1070 A
Positive sequence impedance (1)	R = 0.000614 pu, X = 0.00342 pu, B = 0.000548 pu
Max Fault Current	40 kA

(1) RXB are provided on a 100 MVA base and were obtained from the Hydro One Secure Operating website

– End of Section –

5. Fault Level Assessment

A fault level assessment was performed for three different scenarios:

SC1 - Pre-autotransformer connection (existing system)
SC2 - Post-autotransformer connection
SC3 - Post-autotransformer connection + 300 MW (230 kV) and 150 MW (115 kV) of proposed new generation within the Cambridge area

Short circuit levels were measured at the high and low tension side of the busses along the D9F/D7F-F11C/F12C-M21D/M20D path of the new autotransformer connection. All short circuit levels were found to be within the interrupting capability of the existing HV breakers and maximum short circuit levels as specified in the "Transmission System Code." Hydro One should verify LV short circuit levels against breaker capabilities.

(1) SC1: Short Circuit Levels

The following table summarizes the short circuit levels at various busbars for a pre-autotransformer connection. Listed next to each busbar is its breaker interrupting capability. For busbars with more than one breaker, the capability of the most limiting breaker is listed.

Busbar	Breaker Interrupting Capability				Fault Levels (kA)			
	Symmetrical		Asymmetrical		Symmetrical		Asymmetrical	
	3 ph	LG	3 ph	LG	3 ph	LG	3 ph	LG
Detweiler 230 kV[3]	39.40	39.40	46.20	46.20	21.17	18.51	23.23	20.64
Detweiler 115 kV[3]	38.00	38.00	45.50	45.50	21.18	24.65	25.57	28.89
Middleport 230 kV[3]	60.00	60.00	70.60	70.60	57.11	55.29	67.56	62.75
Freeport 115 kV[1,2]	40	-	-	-	9.49	6.74	10.23	6.93
Cambridge Preston 115 kV[2]	40	-	-	-	N/A	N/A	N/A	N/A

Notes:
(1) The greater short circuit levels of the D9F/D7F busses is presented
(2) Only the 3 phase symmetrical rating was provided by the connection applicant.
(3) Breaker Interrupting Capability values were obtained from the 2002 High Voltage Short-Circuit Survey.

(2) SC2: Short Circuit Levels

The following table summarizes the short circuit levels for a post-autotransformer connection. Listed next to each busbar is its breaker interrupting capability rating. For busbars with more than one breaker, the capability of the most limiting breaker is listed.

Busbar	Breaker Interrupting Capability				Fault Levels (kA)			
	Symmetrical		Asymmetrical		Symmetrical		Asymmetrical	
	3 ph	LG	3 ph	LG	3 ph	LG	3 ph	LG
Detweiler 230 kV[3]	39.40	39.40	46.20	46.20	21.49	18.91	23.57	21.08
Detweiler 115 kV[3]	38.00	38.00	45.50	45.50	23.38	26.90	27.82	31.05
Middleport 230 kV[3]	60.00	60.00	70.60	70.60	57.27	55.58	67.75	63.07
Freeport 115 kV[1,2]	40	-	-	-	13.87	11.27	14.95	11.74
Cambridge Preston 115 kV[2]	40	-	-	-	13.15	11.77	14.67	13.14

Notes:
(1) The greater short circuit levels of the D9F/D7F busses is presented
(2) Only the 3 phase symmetrical rating was provided by the connection applicant.
(3) Breaker Interrupting Capability values were obtained from the 2002 High Voltage Short-Circuit Survey.

(3) SC3: Short Circuit Levels

The following table summarizes the short circuit levels for a post-autotransformer connection + 450 MW of proposed new generation in Cambridge area. Listed next to each busbar is its breaker interrupting capability rating. For busbars with more than one breaker, the capability of the most limiting breaker is listed.

Busbar	Breaker Interrupting Capability				Fault Levels (kA)			
	Symmetrical		Asymmetrical		Symmetrical		Asymmetrical	
	3 ph	LG	3 ph	LG	3 ph	LG	3 ph	LG
Detweiler 230 kV[3]	39.40	39.40	46.20	46.20	23.50	20.09	25.78	22.40
Detweiler 115 kV[3]	38.00	38.00	45.50	45.50	25.97	29.32	31.35	33.83
Middleport 230 kV[3]	60.00	60.00	70.60	70.60	59.54	57.06	70.43	64.76
Freeport 115 kV[1,2]	40	-	-	-	17.20	14.15	18.55	14.75
Cambridge Preston 115 kV[2]	40	-	-	-	18.13	18.73	22.93	23.93

Notes:
(1) The greater short circuit levels of the D9F/D7F busses is presented
(2) Only the 3 phase symmetrical rating was provided by the connection applicant.
(3) Breaker Interrupting Capability values were obtained from the 2002 High Voltage Short-Circuit Survey.

From the short circuit values presented in (1),(2) and (3), it can be concluded that the short circuit levels as a result of the new connection do not exceed the interrupting capabilities of the existing breakers in the IESO-controlled grid. Note, however, fault levels at Middleport 230 kV may approach breaker interrupting capability if 450 MW of proposed generation is incorporated in the Cambridge area.

6. System Impact Studies

This connection assessment study concentrated on identifying the effect of the proposed transformer would have on thermal loading and system voltages.

6.1 Assumptions and Background

Following sub-sections summaries the assumptions and background information used in the assessment.

6.1.1 Pre-contingency conditions

- The study was performed for a system with all transmission elements in service.
- The loads used for 2008 study reflect summer coincident peaks under extreme weather conditions. The total Ontario primary demand is 29,772.2 MW and the zonal distribution is :

NW	NE	Essa	Ottawa	East	Toronto	Niagara	SW	Bruce	West
923	1169	1673	1916	1738	10149	1045	5391	57	3439

- The pre-contingency load-flow, prior to the connection of the new transformer had the following interface and import levels. These flow levels are not significantly changed by addition of the new autotransformer.

BLIP	FABC	FETT	FS	Michigan	New York
-1436	4570.3	5586.4	1400	1427.7	1594

- The pre-contingency load-flow had following MW flow levels without new transformer in service.

D9F@D	D9F@D	M21D@M	M20D@M	M21D@D	M20D@D	Detweiler T2	Detweiler T3	Detweiler T4
113.4	132.0	251.7	237.6	-1.6	-7.9	-154.0	-161.9	-154.0

- For voltage decline studies, the active power loads were converted into constant current and constant admittance loads equally. The reactive power loads were converted only into constant admittance loads.
- The larger power stations in the province had following number of units I/S.

Darlington GS	Bruce GS	Nanticoke GS	Lennox GS	Pickering GS	Lambton GS
4	6	5	1	6	0

- The following assumptions were made for the 2008 scenario.
  (a) The wind projects Ripley, Melancthon I and II, Kingsbridge stage I are in service. At the time of the study, Phase I of Kingsbridge Stage II was also being considered.
  (b) Leader A and B, Erie Shores and Kruger Wind farms are in service.
  (c) QFW upgrade is in service.
  (d) New 230 kV capacitors are added at Essa, Detweiler, Orangeville and Beach (1 each).
  (e) Four new 230 kV capacitors are added at Middleport.

(f) New LV capacitors are added at Halton, Meadowvale, Palmero, Jim Yarrow, Cambridge Preston, Whitby, Otonabee and Oakville.
(g) 40 % of the Cedar TS load is allocated to the load that is fed from F11C and F12C. The remaining 60 % is allocated to the load that is fed from B6G and B5G.
(h) The F11C and F12C extensions from Speedsville JCT to autotransformer T1 are assumed to have following parameters obtained from the Hydro One Secure Operations Web Site: length = 1.062 km, R = 0.000614 pu, X = 0.00342 pu, B = 0.000548 pu.
(i) With the exception of the new extension to the new autotransformer T1, line properties of D9F, D7F, F11C and F12C remain consistent with D9G and D7G. Properties include thermal ratings and line impedances.
(j) The study examines the autotransformer connected to F12C and M20D.
(k) The 230 kV side of the autotransformer terminates on M20D at a length 0.016 km from Preston TS.

- The load distribution in the local area for 2008 summer weather is given below. Each of these loads was modeled with a 0.9 lag power factor.

Station	Forecast 2008 Summer Coincident Peak under Extreme Weather (MW)
Detweiler	33.52
Stratford	107.33
Gerdau Courtice Steel	28.07
Galt	167.5
Cambridge MTS # 1	77.7
Cambridge Preston	90.3
Wolverton	19.9
Kitchener MTS #1	28.7
Kitchener MTS #3	57.3
Kitchener MTS #4	69.7
Kitchener MTS #5	78.5
Kitchener MTS #6	80.6
Kitchener MTS #7	45.5
Kitchener MTS #8	29.1
Guelph Cedar	98.6
Rush MTS	44.1
Waterloo MTS #3	37.1

As a measure of confidence of the 2008 load forecast, the load pocket on D7G, D9G, M21D and M20D was compared against 1 Hr average samples during the period of Jan 1- Dec 31, 2005. The 1 Hr average samples for the load pocket were obtained by the following formula:

Total Load = (D7G+D9G+M21D+M20D) MW out at Detweiler + (M21D+M20D) MW out at Middleport

Station	2008 Forecast Summer Coincident Peak Loads for D7G, D9G, M21D and M20D Load Pocket under Extreme Weather Conditions (MW)
Kitchener MTS #6	80.6
Kitchener MTS #8	29.1
Cambridge MTS # 1	77.7
Cambridge Preston	90.3
Galt	167.5
Gerdau Courtice Steel	28.07
Kitchener MTS #3	57.3
Kitchener MTS #7	45.5
Kitchener MTS #5	78.5
Wolverton	19.9
Guelph Cedar (assumed 40% fed from D9G+D7G)	41.2
Total	**715.67**

Figure 3 shows the total 2005 loads and the 2008 load forecast on D7G, D9G, M21D and M20D circuits. As shown, the 2008 forecast used in the computer simulations conservatively represents a stressed load situation in the area.

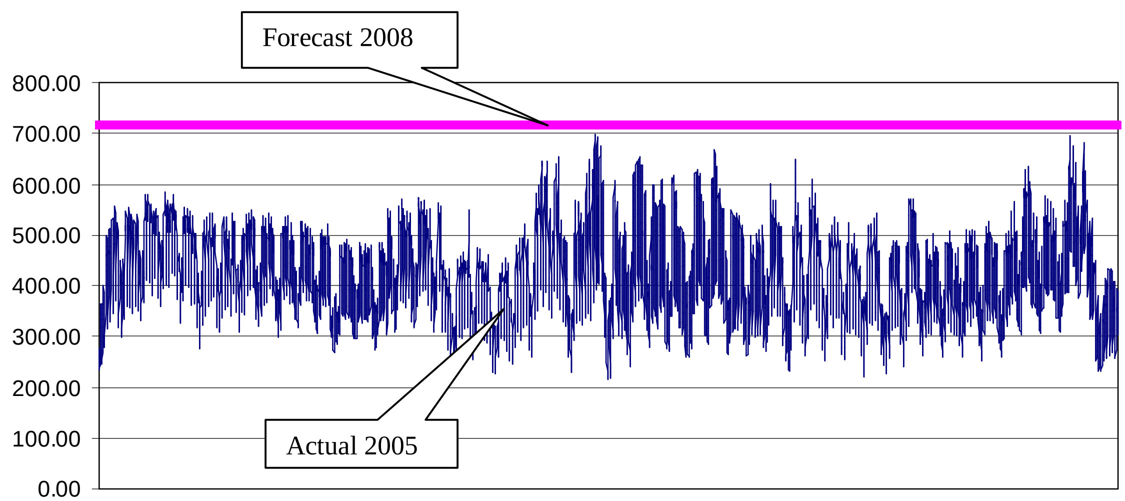

FIGURE 3 – 2005 HISTORIAL LOADS ON D7G+D9G+M21D+M20D VERSUS 2008 LOAD FORECAST IN MW

6.1.2 Study Scenarios

The thermal and voltage analysis were examined under the following two scenarios:

- Scenario $\mathbf{S_{pre}}$: Represents a pre-autotransformer connection system configuration.
- Scenario $\mathbf{S_{post}}$: Represents a post-autotransformer connection system configuration.

Figures of these scenarios can be found in Appendix A.

6.1.3 Contingency and control actions

The following table lists the contingencies used to perform the thermal and voltage analysis for this study. Contingencies denoted by **PRT are applicable to a Pre-autotransformer** connection while contingencies denoted by **POT are applicable to a Post-autotransformer** connection. Certain control actions were initiated to respect voltage and post-contingency thermal loading criteria.

The POT3 contingency has an associated SPS. The results below for the voltage and thermal analysis do not include SPS action. The application of the SPS is investigated separately in Section 6.4.

	Contingency	Control Actions
PRT1/POT1	B560V+B561M	• Bruce Units G6, G7 rejected • Bruce R25, R27, R28 rejected • Longwood R3, R4, R5, R6, R7 rejected
PRT2	Detweiler T3 + M20D	No control actions were initiated
POT2	Detweiler T3 + M20D+ New T1	No control actions were initiated
PRT3/POT3	M21D+Gerdeau Courtice Steel	No control actions were initiated
PRT4	Detweiler T3+M20D+M21D	No control actions were initiated
POT4	Detweiler T3+M20D+M21D+New T1	No control actions were initiated
PRT5/POT5	D4W+D5W	No control actions were initiated
PRT6/POT6	B22D+B23D	No control actions were initiated
PRT7/POT7	D6V+D7V+Detweiler T4+Orangeville T1+T3	No control actions were initiated
PRT8	D9G	No control actions were initiated
POT8	F11C	No control actions were initiated
PRT9	D7G	No control actions were initiated
POT9	D9F	No control actions were initiated
POT10	F12C+ New T1	No control actions were initiated
POT11	D7F	No control actions were initiated
PRT10/POT12	M32W+M33W	No control actions were initiated

6.2 Thermal Analysis

The following describes the criteria used in examining the thermal analysis for this assessment.

(1) Pre-Contingency Ratings:

(a) Transmission Circuits

- Transmission circuits are required to be within *continuous* operating ratings.
- Continuous ratings are calculated under 35ºC, 4 km/hr wind speed and daytime sheltered conditions at the maximum operating conductor temperature.

(b) Transformers

- Transformers are required to be within *continuous* operating ratings.
- Continuous ratings are calculated under 30 ºC conditions

(2) Post-Contingency Ratings:

(a) Transmission Circuits

- Transmission circuits are required to be within *continuous* operating ratings.
- Normally, post-contingency flows are observed under 15 long term ratings (LTR). The 15 min LTR cannot be used in this assessment due to the lack local generation and fast acting control actions available to provide loading relief.

(b) Transformers

- Transformers are required to be within *10-day long term* ratings.

6.2.1 Monitored Equipment

The following tables represent the monitored equipment and ratings used for the thermal analysis. Monitored elements are indicated on the single-line diagrams provided in Appendix A. Rating values were provided by Hydro One.

(a) Transmission Circuits Ratings

Continuous Ratings for Monitored Transmission Circuits (A)			
M21D @ Middleport	M20D @ Middleport	M21D @ Detweiler	M20D @ Detweiler
2070	2070	2070	2070
D9G/D9F @ Detweiler	D7G/D7F @ Detweiler	M20D @ Galt JCT x Preston JCT	M21D @ Ameristee Cambridge JCT x Galt JCT
1210	1210	1130	1130
D7G @ Siebert JCT x Kitchener #6	D9G @ Siebert JCT x Kitchener #6	F12C @ Speedsville x Preston	
1210	1210	1070	

(b) Transformer Ratings

Rating	Detweiler T2	Detweiler T3	Detweiler T4	Preston T1
Continuous (MVA)	250	250	225	250
10 day LTR (MVA)	284	383	295	340

6.2.2 Pre-contingency Analysis

The following are the pre-contingency flows prior to the connection of the autotransformer. In parenthesis is the loading expressed as a percentage of continuous rating. Ratings are in Amperes for circuits and in MVA for transformers. The analysis was completed for both S_{pre} and S_{post} scenarios under 2008 and 2012 conditions. The S_{pre} scenario under 2012 conditions although hypothetical, was used to understand the conditions that would otherwise prevail under the existing configuration.

(1) 2008 - Scenario S_{pre}: Pre-Autotransformer

<table>
<tr><td colspan="8">2008 Scenario S_{pre}: Pre-contingency flow/Continuous Rating</td></tr>
<tr><td>M21D@M</td><td colspan="2">M20D@M</td><td>M21D@D</td><td>M20D@D</td><td colspan="2">Detweiler T2</td><td>Detweiler T3</td></tr>
<tr><td>624.2 (30.2%)</td><td colspan="2">586.0 (28.3%)</td><td>31.4 (1.5%)</td><td>29.6 (1.4%)</td><td colspan="2">154.8 (61.9%)</td><td>162.7 (65.1%)</td></tr>
<tr><td>Detweiler T4</td><td>D9G@D</td><td>D7G@D</td><td colspan="2">M20D@
Galt JCT x Preston JCT</td><td colspan="3">M21D@ Ameristee
Cambridge Jct x Galt JCT</td></tr>
<tr><td>154.8 (68.8%)</td><td>644.0 (53.2%)</td><td>601.8 (49.7%)</td><td colspan="2">435.9 (38.6%)</td><td colspan="3">493.7 (43.7%)</td></tr>
<tr><td colspan="3">D7G @ Siebert JCT x Kitchener #6</td><td colspan="3">D9G @ Siebert JCT x Kitchener #6</td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="3">602.3 (49.8%)</td><td colspan="3">540.5 (44.7%)</td></tr>
</table>

(2) 2012 - Scenario S_{pre}: Pre-Autotransformer

<table>
<tr><td colspan="8">2012 Scenario S_{pre}: Pre-contingency flow/Continuous Rating</td></tr>
<tr><td>M21D@M</td><td colspan="2">M20D@M</td><td>M21D@D</td><td>M20D @D</td><td colspan="2">Detweiler T2</td><td>Detweiler T3</td></tr>
<tr><td>757.7 (36.6%)</td><td colspan="2">726.1 (35.1%)</td><td>15.2 (0.7%)</td><td>24.4 (1.2%)</td><td colspan="2">176.2 (70.5%)</td><td>185.2 (74.1%)</td></tr>
<tr><td>Detweiler T4</td><td>D9G@D</td><td>D7G@D</td><td colspan="2">M20D@
Galt JCT x Preston JCT</td><td colspan="3">M21D@ Ameristee
Cambridge Jct x Galt JCT</td></tr>
<tr><td>176.2 (78.3%)</td><td>754.2 (62.4%)</td><td>710.3 (58.7%)</td><td colspan="2">540.1 (47.8%)</td><td colspan="3">596.7 (52.8%)</td></tr>
<tr><td colspan="3">D7G @ Siebert JCT x Kitchener #6</td><td colspan="3">D9G @ Siebert JCT x Kitchener #6</td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="3">710.8 (58.7%)</td><td colspan="3">647.0 (53.5%)</td></tr>
</table>

(3) 2008 - Scenario S_{post}: Post-Autotransformer

2008 Scenario S_{post}: Pre-contingency flow/Continuous Rating					
M21D@M	M20D@M	M21D@D	M20D@D	Detweiler T2	Detweiler T3
617.6 (29.8%)	635.3 (30.7%)	48.2 (2.3%)	72.1 (3.5%)	132.2 (52.9%)	138.8 (55.5%)
Detweiler T4	D9F@D	D7F@D	M20D@ Galt JCT -Preston JCT	M21D@ Ameristee Cambridge Jct x Galt JCT	
132.2 (58.8%)	574.2 (47.5%)	394.5 (32.6%)	568.3 (50.3%)	520.6 (46.1%)	
D7F @ Siebert JCT x Kitchener #6	D9F @ Siebert JCT x Kitchener #6	F12C@ Speedsville x Preston	Preston 230/115 kV T1		
395.3 (32.7%)	470.8 (38.9%)	324.2 (30.3%)	68.5 (27.4%)		

(4) 2012 - Scenario S_{post}: Post-Autotransformer

2012 Scenario S_{post}: Pre-contingency flow/Continuous Rating					
M21D@M	M20D@M	M21D@D	M20D@D	Detweiler T2	Detweiler T3
752.1 (36.3%)	786.1 (38.0%)	45.9 (2.2%)	87.6 (4.2%)	148.3 (59.3%)	155.8 (62.3%)
Detweiler T4	D9F@D	D7F@D	M20D@ Galt JCT x Preston JCT	M21D@ Ameristee Cambridge Jct x Galt JCT	
148.4 (66.0%)	656.5 (54.3%)	397.8 (32.9%)	712.1 (63.0%)	635.3 (56.2%)	
D7F @ Siebert JCT x Kitchener #6	D9F @ Siebert JCT x Kitchener #6	F12C@ Speedsville x Preston	Preston 230/115 kV T1		
398.5 (32.9%)	551.0 (45.5%)	394.8 (36.9%)	83.4 (33.4%)		

(5) Comments:

- Pre-contingency results indicate that all loadings are within continuous ratings
- The new autotransformer results in a decrease in pre-contingency loading on D7G/D7F and D9G/D9F at Detweiler as well as reduced flows on the Detweiler T2, T3 and T4. The reduction in the loading on the 115 kV lines D7G/D7F and D9G/D9F is accompanied by an increase in loading on the 230 kV system.

6.2.3 Post-contingency Analysis

The following are the post-contingency loadings of the monitored equipment expressed as a percentage of post-contingency ratings.

(1) 2008 - Scenario S_{pre}: Pre-Autotransformer

Contingency		Scenario S_{pre}: Projected Current Flow/Post-Contingency Rating (%)												
		M21D@ M	M20D@ M	M21D@ D	M20D@ D	Detweiler T2	Detweiler T3	Detweiler T4	D9G@ D	D7G@ D	M20D@ (G-P)	M21D@ (C-G)	D7G@ (S-K#6)	D9G@ (S-K#6)
PRT1	B560V + B561M	20.6	19.4	16.0	16.1	52.8	41.1	50.8	56.8	52.6	41.7	46.8	52.6	47.2
PRT2	Detweiler T3 + M20D	49.1	0.0	13.0	0.0	80.6	0.0	77.5	53.2	49.4	0.0	88.3	49.4	44.5
PRT3	M21D + Gerdeau Cambridge	0.0	45.7	0.0	11.3	53.4	41.5	51.3	53.2	49.6	79.3	0.0	49.7	44.7
PRT4	Detweiler T3 + M20D + M21D	0.0	0.0	0.0	0.0	83.0	0.0	79.7	53.5	50.0	0.0	0.0	50.0	44.9
PRT5	D4W + D5W	47.9	45.8	19.3	19.6	54.6	42.4	52.4	53.6	50.1	38.5	43.8	50.1	45.0
PRT6	B22D + B23D	33.7	31.6	3.3	3.8	58.9	45.8	56.6	53.3	49.8	38.6	43.8	49.8	44.8
PRT7	D6V+D7V+Detweiler T4+ Orangeville T1+ T3	22.1	19.7	9.3	8.6	83.7	65.1	0.0	53.5	50.2	38.2	43.7	50.2	45.0
PRT8	D9G	30.6	28.9	0.1	1.2	53.6	41.7	51.5	0.0	104.1	38.7	43.7	95.4	0.0
PRT9	D7G	30.5	28.8	0.1	1.1	53.3	41.4	51.2	102.7	0.0	38.7	43.7	0.0	94.0
PRT10	M32W + M33W	28.3	25.8	4.2	4.9	54.8	42.6	52.6	53.6	50.1	38.6	44.1	50.1	45.0

(2) 2012 - Scenario S_{pre}: Pre-Autotransformer

The 2012 post-contingency analysis for S_{pre} was performed for those contingencies which resulted in significant loading for the 2008 analysis.

Contingency		Scenario S_{pre}: Projected Current Flow/Post-Contingency Rating (%)												
		M21D@ M	M20D@ M	M21D@ D	M20D@ D	Detweiler T2	Detweiler T3	Detweiler T4	D9G@D	D7G@D	M20D@ (G-P)	M21D@ (C-G)	D7G@ (S-K#6)	D9G@ (S-K#6)
PRT2	Detweiler T3 + M20D	63.7	0.0	15.8	0.0	93.3	0.0	89.7	64.7	60.9	0.0	113.9	60.9	55.4
PRT3	M21D + Gerdeau Courtice Steel	0.0	59.7	0.0	14.8	60.6	47.2	58.3	63.3	59.5	105.0	0.0	59.5	54.3
PRT4	Detweiler T3 + M20D + M21D	0.0	0.0	0.0	0.0	93.9	0.0	90.2	62.5	58.8	0.0	0.0	58.8	53.6
PRT8	D9G	37.4	35.8	1.5	2.4	61.4	47.8	59.0	0.0	125.1	47.8	52.9	116.2	0.0
PRT9	D7G	37.4	35.8	1.5	2.4	61.4	47.8	59.0	125.1	0.0	47.8	52.9	0.0	116.2

(3) 2008 - Scenario S_{post}: Post-Autotransformer

Contingency		Scenario S_{post}: Projected Current Flow/Post-Contingency Rating (%)														
		M21D@ M	M20D@ M	M21D@ D	M20D@ D	Detweiler T2	Detweiler T3	Detweiler T4	D9F@ D	D7F@ D	M20D@ (G-P)	M21D@ (C-G)	D7F@ (S-K#6)	D9F@ (S-K#6)	F12C@ (SP-P)	Preston T1
POT1	B560V+ B561M	20.3	23.8	17.3	19.0	47.2	36.7	45.3	49.4	31.7	60.3	51.4	31.7	40.6	50.4	33.8
POT2	Detweiler T3 + M20D + New T1	49.0	0.0	13.1	0.0	80.1	0.0	76.9	52.7	49.0	0.0	88.5	49.0	44.1	0.0	0.0
POT3	M21D + Gerdeau Courtice Steel	0.0	48.0	0.0	14.9	49.0	38.1	47.1	49.5	36.1	90.2	0.0	36.1	41.1	19.1	12.7
POT4	Detweiler T3 + M20D + M21D + New T1	0.0	0.0	0.0	0.0	82.5	0.0	79.2	53.0	49.5	0.0	0.0	49.5	44.5	0.0	0.0
POT5	D4W+D5W	47.0	49.0	16.8	13.3	42.8	33.3	41.1	45.2	28.7	56.0	47.3	28.8	36.6	45.3	30.0
POT6	B22D+B23D	33.3	34.4	1.7	0.9	49.8	38.8	47.9	46.5	28.4	52.4	46.6	28.5	38.0	34.8	23.0
POT7	D6V + D7V + Detweiler T4 + Orangeville T1 + T3	21.4	21.8	11.1	12.6	70.4	54.7	0.0	47.3	34.3	50.2	46.1	34.4	38.8	31.9	21.7
POT8	F11C	30.3	31.8	1.9	3.8	44.5	34.6	42.8	22.3	50.5	52.9	46.6	42.0	22.3	35.9	23.8
POT9	D9F	30.2	32.5	2.3	4.9	42.8	33.3	41.1	0.0	64.3	56.1	47.2	55.6	0.0	43.1	28.7
POT10	F12C+ New T1	30.6	28.9	0.3	1.0	53.6	41.7	51.6	69.7	33.6	38.8	43.8	33.6	61.1	0.0	0.0
POT11	D7F	30.2	31.5	1.8	3.4	45.3	35.2	43.5	72.0	0.0	51.5	46.3	0.0	63.3	32.0	21.1
POT12	M32W + M33W	28.0	27.8	5.3	7.7	47.7	37.0	45.8	48.3	32.8	49.4	46.3	32.9	39.7	27.1	18.1

(4) 2012 - Scenario S_{post}: Post- Autotransformer

The post-contingency analysis was only performed for those contingencies which resulted in significant loading for the 2008 analysis.

Contingency		Scenario S_{post}: Projected Current Flow/Post-Contingency Rating (%)														
		M21D@ M	M20D@ M	M21D@ D	M20D@ D	Detweiler T2	Detweiler T3	Detweiler T4	D9F@ D	D7F@ D	M20D@ (G-P)	M21D@ (C-G)	D7F@ (S-K#6)	D9F@ (S-K#6)	F12C@ (SP-P)	Preston T1
POT2	Detweiler T3 + M20D+ New T1	62.1	0.0	17.2	0.0	89.8	0.0	86.3	61.2	57.3	0.0	114.3	57.4	52.2	0.0	0.0
POT3	M21D + Gerdeau Courtice Steel	0.0	62.2	0.0	21.8	54.6	42.4	52.4	55.9	37.8	123.1	0.0	37.9	47.4	34.0	61.1
POT4	Detweiler T3+M20D +M21D+New T1	0.0	0.0	0.0	0.0	91.8	0.0	88.2	60.1	56.6	0.0	0.0	56.6	51.5	0.0	0.0
POT8	F11C	36.5	39.5	2.5	5.5	49.5	38.5	47.6	24.8	51.0	68.2	57.2	42.1	24.9	48.8	81.6
POT9	D9F	36.4	40.0	2.9	6.5	47.6	37.0	45.7	0.0	68.8	70.9	57.8	60.0	0.0	55.4	92.5
POT10	F12C+ New T1	36.8	35.2	0.7	1.4	60.3	46.9	58.0	83.0	37.4	48.3	53.3	37.5	74.3	0.0	0.0
POT11	D7F	36.4	38.6	2.2	4.6	50.4	39.2	48.5	80.6	0.0	64.9	56.7	0.0	71.9	40.2	67.2

(5) Comments

- The autotransformer connection reduces the loading on the D7F and D9F.
- Under 2012 conditions, Detweiler T2 would be near its 10-day limited time rating for the loss of POT2 and POT4. Preston T1 would be near its 10-day limited time rating for the loss of POT9.
- Interpolation of results suggests the M21D/M20D taps @ Galt JCT will likely be adequate for 2009. The circuit upgrades should be completed before the summer of 2010.
- Under 2012 conditions, the M20D/M21D line tap @ Galt JCT will be overloaded for the loss of the companion circuit under 2012 conditions. A SPS scheme exists to provide post-contingency thermal relief. However, at best, it will only reduce the post-contingency levels to those seen in scenario S_{pre}. The S_{pre} results indicate the need to replace the M20D and M21D line segments is independent of the autotransformer connection.
- The following table summarizes the 2008 to 2015 load forecast for Cambridge Area loads on the Galt line taps on M20D and M21D, i.e. the sum of loads at (i) Gerdau-Courtice Steel, (ii) Galt TS, (iii) Cambridge MTS #1 and (iv) Preston TS.

Load Forecast for Cambridge Area Loads	
Year	Total Load (MW)
2008	363.65
2009	379.18
2010	397.80
2011	411.11
2012	426.00
2013	442.64
2014	461.27
2015	482.10

Note:

- The values presented above are for an extreme weather coincident peak forecast based on the historical local area peak demand which occurred on June 5, 2005.

6.3 Voltage Analysis

6.3.1 Pre-Contingency Analysis

The unbalanced flows due to the connection of the autotransformer may be of concern to the voltages on the system.

The following table lists the pre-contingency voltages for S_{pre} and S_{post} scenarios on the high side of several load transformers as well as the active and reactive flow changes as a result of the autotransformer connection under 2008 conditions. A positive flow change represents a flow increase while a negative flow change represents a flow decrease between S_{pre} and S_{post}.

DESN	Transformer	Voltages (kV)		ΔFlow	
		S_{pre}	S_{post}	ΔP (MW)	ΔQ (VArs)
Kitchener #3	T3	121.1	121.7	1.8	0.1
	T4	122.3	122.8	-1.8	-0.1
Kitchener #3	T6	121.1	121.7	3.2	0.4
	T5	122.3	122.8	-3.3	-0.4
Kitchener #7	T13	121	121.6	1.9	0.3
	T14	121.9	122.4	-1.8	-0.3
Kitchener #5	T9	120.4	121.0	3.1	0.3
	T10	121.2	121.8	-3.1	-0.4
Guelph Cedar [2]	T2	121.4	122.2	4.2	0.2
	T1	122.1	122.8	-4.2	-0.6
Cambridge Preston	T3	240.8	240.7	4.6	0.8
	T4	241.4	241.0	-4.6	-0.7
Cambridge MTS #1	T1	240.8	240.7	2.7	0.5
	T2	241.5	241.0	-2.7	-0.5
Galt	T7	241.8	241.5	-3.8	-0.8
	T8	241.1	241.1	3.8	0.9
Kitchener MTS #8	T16	243.5	243.7	-0.2	0
	T15	243.4	243.7	0.2	0.1
Kitchener MTS #6	T11	243.1	243.4	0.1	0
	T12	243.1	243.4	0	0

Despite the slight imbalance in active power caused by the autotransformer, the voltages at the high side of each DESN transformer remain approximately equal.

6.3.2 Post-Contingency Analysis

The ΔV given in the analysis represent the worst of pre-ULTC and post-ULTC values. For pre-ULTC and post-ULTC, the voltage declines are calculated after loads have been converted into voltage dependant functions.

The load at Wolverton can be supplied from either D9F(D9G) or D7F(D7G), despite the connection to latter is normally opened. To obtain the worst possible case, the Wolverton load was placed on the companion line for any contingencies involving the loss of D9F(D9G) or D7F(D7G) such that this load remains connected post-contingency. For contingencies that do not involve the loss of D7F(D7G) or D9F(D9G), the load was supplied by D9F(D9G).

The following tables summarize the computer results obtained from voltage analysis for scenarios S_{pre} and S_{post} under 2008 and 2012 conditions.

(1) 2008 - Scenario S_{pre}: Pre-Autotransformer

Contingency		Scenario S_{pre}: Projected voltage decline percentages $\|\Delta V\|$										
		Detweiler 230 kV	Detweiler 115 kV	Middleport 230 kV (North split)	Middleport 230 kV (South split)	Kitchener MTS #5 115 kV	Cedar 13.8 kV	Kitchener MTS #5 13.8 kV	Preston 27.6 kV	Galt 27.6 kV	Preston 230 kV	Orangeville 230 KV
PRT1	B560V+B561M	10.6	11.1	9.4	9.0	11.5	4.6*	6.1	4.2*	4.2*	10.2	10.2
PRT2	Detweiler T3 + M20D	2.4	2.8	0.6	-0.5	2.9	2.5*	2.9	5.4*	9.8*	4.9	1.4
PRT3	M21D + Gerdeau Cambridge	1.8	1.9	-0.6	0.2	1.9	1.7*	2.0	4.9*	8.6*	4.1	1.2
PRT4	Detweiler T3 + M20D+M21D	0.0	0.4*	-1.5*	-1.5*	0.4	0.4	0.5	-	-	-	0.3*
PRT5	D4W+D5W	0.2*	0.2*	0.4*	0.2*	0.3*	0.3	0.3*	0.4*	0.5*	0.5*	0.8*
PRT6	B22D+B23D	0.6	1.4	0.0	-0.2	1.5	1.5	1.5	0.2	0.3	0.3	0.8
PRT7	D6V+D7V+ Detweiler T4+ Orangeville T1+T3	-3.2*	-2.9*	-1.1*	-1.1*	-2.9*	-0.4	-2.1	-0.1	-1.1	-2.0*	-2.1*
PRT8	D9G	0.7	1.0	0.0	-0.1	4.0	1.4*	9.1*	0.3	0.3	0.3	0.7
PRT9	D7G	0.6	0.8	0.0	-0.1	4.3	1.5	8.8*	0.2	0.2	0.2	0.7
PRT10	M32W+M33W	0.1*	0.2*	-1.0*	-1.2*	0.2*	0.3*	0.3*	-0.6*	-0.5*	-0.5*	0.4*

Notes:

- * indicates that the pre-ULTC action exhibited a larger voltage decline.

(2) 2012 - Scenario S_{pre}: Pre-Autotransformer

The post-contingency analysis was only performed for those local contingencies that resulted in significant voltage declines for the 2008 analysis

Contingency		Scenario S_{pre}: Projected voltage decline percentages $\lvert\Delta V\rvert$										
		Detweiler 230 kV	Detweiler 115 kV	Middleport 230 kV (North split)	Middleport 230 kV (South split)	Kitchener MTS #5 115 kV	Cedar 13.8 kV	Kitchener MTS #5 13.8 kV	Preston 27.6 kV	Galt 27.6 kV	Preston 230 kV	Orangeville 230 KV
PRT2	Detweiler T3 + M20D	4.1	5.4	1.0	-0.3	5.7	3.5*	3.6	7.1*	11.2*	7.9	2.4
PRT3	M21D + Gerdeau Cambridge	3.1	3.2	-0.7	0.6	3.4	2.2*	2.3	6.5*	9.9*	0.2	1.8
PRT8	D9G	0.9	1.4	0.0	0.1	5.6	3.8	11.2*	0.4	0.5	0.4	0.8
PRT9	D7G	0.9	1.4	0.0	0.1	6.3	3.2	10.9*	0.4	0.5	0.4	0.8

Notes:

- * indicates that the pre-ULTC action exhibited a larger voltage decline.
- The results for S_{pre} and S_{post} were obtained by scaling the local load pocket within the vicinity of the new connection to 2012 levels. An analysis of the worst contingency POT2 was also completed with the Southwest zone scaled to 5810 MW to reflect a 2012 forecast. The results were similar to those documented above.

(3) 2008 - Scenario S_{post}: Post-Autotransformer

Contingency		Scenario S_{post}: Projected voltage decline percentages $\|\Delta V\|$												
		Detweiler 230 kV	Detweiler 115 kV	Middleport 230 kV (North split)	Middleport 230 kV (South split)	Kitchener MTS #5 115 kV	Cedar 13.8 kV	Kitchener MTS #5 13.8 kV	Cambridge Preston 27.6 kV	Galt 27.6 kV	Preston 230 kV	Orangeville 230 KV	New T1 115 kV	New T1 230 kV
POT1	B560V+B561M	10.1	9.2	9.6	9.3	8.7	4.5*	5.8	4.2*	4.3*	12.3	10.0	5.4	12.8
POT2	Detweiler T3 + M20D+ NewT1	2.5	3.0	0.6	-0.5	3.2	3.0*	3.3	5.4*	9.8*	4.9*	1.5	3.5	-
POT3	M21D+Gerdeau Cambridge	1.8	1.9*	-0.5	0.3	2.1*	2.4*	2.3*	4.7*	8.4*	4.7	1.2	2.7*	5.0
POT4	Detweiler T3 + M20D+M21D+ New T1	0.1*	0.6*	-1.4*	-1.4*	0.8*	0.9*	0.8*	-	-	-	0.3*	1.1*	-
POT5	D4W+D5W	0.1*	0.1	0.4*	0.2	0.2*	0.2*	0.2	0.4	0.5*	0.4	0.8*	0.2	0.4
POT6	B22D+B23D	0.5	1.2	0.0	-0.1	1.2	1.0	1.1	0.4	0.4	0.4	0.8	0.8	0.5
POT7	D6V+D7V Detweiler T4+ Orangeville T1+T3	-3.2*	-2.9*	-1.1*	-1.1*	-2.6*	1.2*	-2.0	-0.2	-1.2	-2.2*	-2.1*	-2.5*	-2.2*
POT8	F11C	0.4	0.4	0.0	-0.1	1.6	1.0	7.1*	0.4	0.4	0.4	0.6	0.8	0.4
POT9	D9F@D	0.4*	0.4*	0.0	-0.1	5.6*	3.9*	4.0*	0.6	0.6	0.8	0.6*	1.4*	0.9
POT10	F12C+ New T1	0.7	0.9	0.0	-0.1	2.3	0.5	7.3*	0.1	0.2	0.0	0.7	-	0.0
POT11	D7F@D	0.4	0.3	0.0	-0.1	1.8	1.5	1.6	0.4	0.4	0.4	0.6	1.1	0.5
POT12	M32W+M33W	0.1*	0.1*	-0.9*	-1.1*	0.1*	0.0*	0.1*	-0.4*	-0.4*	-0.5*	0.5*	-0.1*	-0.4*

Notes:

- * indicates that the pre-ULTC action exhibited a larger voltage decline.

(4) 2012 - Scenario S_{post}: Post-Autotransformer

The post-contingency analysis was only performed for those local contingencies that resulted in significant voltage declines for the 2008 analysis

Contingency		Scenario S_{post}: Projected voltage decline percentages $\|\Delta V\|$												
		Detweiler 230 kV	Detweiler 115 kV	Middleport 230 kV (North split)	Middleport 230 kV (South split)	Kitchener MTS #5 115 kV	Cedar 13.8 kV	Kitchener MTS #5 13.8 kV	Cambridge Preston 27.6 kV	Galt 27.6 kV	Preston 230 kV	Orangeville 230 KV	New T1 115 kV	New T1 230 kV
POT2	Detweiler T3 + M20D+ New T1	3.8	5.1	1.0	-0.6	6.1	5.8	4.2*	4.0*	10.7*	7.5	2.1	6.7	-
POT3	M21D+Gerdeau Cambridge	2.4	2.0	-0.6	0.6	2.1*	3.4*	1.9*	4.2*	10.2*	7.9	1.4	2.2	8.6*
POT8	D9G (at Cedar)	0.2	0.0	0.0	-0.1	0.9	1.0	6.7*	-1.7	0.6	0.8	0.5	-0.3	0.9
POT9	D9G@D	0.2	-0.1	0.0	0.0	1.0	4.9*	3.6	-1.6	0.7	1.0	0.5	0.3	1.2
POT10	D7G@Cedar + New T1	0.7	1.4	0.0	-0.2	3.8	2.8*	9.0*	-2.7	-0.2	0.3	0.7	-	-0.7
POT11	D7G@D	0.3	0.2	0.0	-0.1	1.7	1.5	0.0	-2.1	0.3	0.5	0.5	-1.7	0.4

Notes:

- * indicates that the pre-ULTC action exhibited a larger voltage decline.
- The results for S_{pre} and S_{post} were obtained by scaling the local load pocket within the vicinity of the new connection to 2012 levels. An analysis of the worst contingency POT2 was also completed with the Southwest zone scaled to 5810 MW to reflect a 2012 forecast. The results were similar to those documented above.

(5) Comments:

- With the exception of the loss of B560V+B561M contingency, voltage declines on the IESO controlled grid are within IESO criteria. $S1_{pre}$ results indicate these excessive declines for the loss of B560V+B561M are not the direct result of the new connection. For the loss of B560V+B561M, voltage declines are reduced on the 115 kV level while declines are increased on the 230 kV level under post-autotransformer connection. The current 10 year Outlook proposes a possible 500 kV/230 kV connection to Cambridge-Preston TS to address this problem.

- Under 2008 conditions, voltage declines at Galt 27.6 kV and Kitchener MTS #5 13.8 kV transformer stations exceed the maximum allowable voltage change percentages under pre-tap changer and post-tap changer action respectively. Under 2012 post-autotransformer configuration, in addition to the above mentioned stations, the Cedar 13.8 kV transformer station exceeds post-contingency voltage declines post-tap changer action. $S1_{pre}$ results indicate the excessive declines at these transformer stations are an existing problem and should be addressed.

6.4 Special Protection System - M20/M21D Overload Rejection Scheme

A contingency-based Special Protection System has been proposed for the new connection. The purpose of the SPS is to remove the autotransformer from service if any of M20D/M21D which is not connected to the autotransformer is tripped such that the remaining 230 kV circuit connected to the autotransformer would not become overloaded. The SPS scheme comprises of an A and B scheme which are redundant. The SPS logic diagram is illustrated in Figure 4.

The loss of M21D, POT3 performed for the voltage and thermal analysis in Section 6.2.3 was not armed for the Special Protection System mentioned above. This section revisits this contingency comparing the results with SPS and without SPS action under 2008 and 2012 conditions.

(1) 2008 conditions

Loss of M21D	Projected Current Flow/Post-Contingency Rating (%)														
	M21D@ M	M20D@ M	M21D@ D	M20D@ D	Detweiler T2	Detweiler T3	Detweiler T4	D9F@D	D7F@D	M20D@ (G-P)	M21D@ (C-G)	D7F@ (S-K#6)	D9F@ (S-K#6)	F12C@ (SP-P)	Preston T1
Without SPS	0.0	48.0	0.0	14.9	49.0	38.1	47.1	49.5	36.1	90.2	0.0	36.1	41.1	19.1	12.7
With SPS	0.0	45.6	0.0	11.5	53.1	41.3	50.9	52.7	49.2	79.5	0.0	49.2	44.2	0.0	0.0

- The loading on the M20D section from Galt JCT to Preston JCT is improved with the use of Special Protection System.

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Loss of M21D	Projected voltage decline percentages |ΔV|												
	Detweiler 230 kV	Detweiler 115 kV	Middleport 230 kV (North split)	Middleport 230 kV (South split)	Kitchener MTS #5 115 kV	Cedar 13.8 kV	Kitchener MTS #5 13.8 kV	Cambridge Preston 27.6 kV	Galt 27.6 kV	Preston 230 kV	Orangeville 230 KV	New T1 115 kV	New T1 230 kV
Without SPS	1.8	1.9*	-0.5	0.3	2.1*	2.4*	2.3*	4.7*	8.4*	4.7	1.2	2.7*	5.0
With SPS	2.0	2.1	-0.5	0.2	2.4	2.2	2.4	4.8*	8.6*	4.0	1.3	2.6	4.2

- From the analysis above, voltage declines on the IESO controlled grid are still within criteria under SPS action.

(2) 2012 Conditions

Loss of M21D	Projected Current Flow/Post-Contingency Rating (%)														
	M21D@ M	M20D@ M	M21D@ D	M20D@ D	Detweiler T2	Detweiler T3	Detweiler T4	D9F@D	D7F@D	M20D@ (G-P)	M21D@ (C-G)	D7F@ (S-K#6)	D9F@ (S-K#6)	F12C@ (SP-P)	Preston T1
Without SPS	0.0	62.2	0.0	21.8	54.6	42.4	52.4	55.9	37.8	123.1	0.0	37.9	47.4	34.0	61.1
With SPS	0.0	58.1	0.0	15.9	58.8	45.7	56.5	60.1	56.2	104.7	0.0	56.3	51.3	0.0	0.0

- By 2012, results show that for the loss of M21D, the loading on M20D at Galt JCT to Preston JCT will be overloaded regardless of SPS action. As mentioned in the thermal analysis, the M20D/M21D line taps at Galt will need to be upgraded by 2009.

Loss of M21D	Projected voltage decline percentages |ΔV|												
	Detweiler 230 kV	Detweiler 115 kV	Middleport 230 kV (North split)	Middleport 230 kV (South split)	Kitchener MTS #5 115 kV	Cedar 13.8 kV	Kitchener MTS #5 13.8 kV	Cambridge Preston 27.6 kV	Galt 27.6 kV	Preston 230 kV	Orangeville 230 KV	New T1 115 kV	New T1 230 kV
Without SPS	2.4	2.0	-0.6	0.6	2.1*	3.4*	1.9*	4.2*	10.2*	7.9	1.4	2.2	8.6*
With SPS	2.9	3.3	-0.7	0.4	4.2	3.3*	3.9	3.4*	9.5*	5.8	1.6	4.8	6.1

- From the analysis above, voltage declines on the IESO controlled grid are still within criteria under SPS action.

Requirement:

- Opened breaker disconnect switches will result in the associated breaker unable to see the line fault. The IESO will require that a breaker associated with the Special Protection scheme must be placed out of service if the breaker disconnect switch is opened.

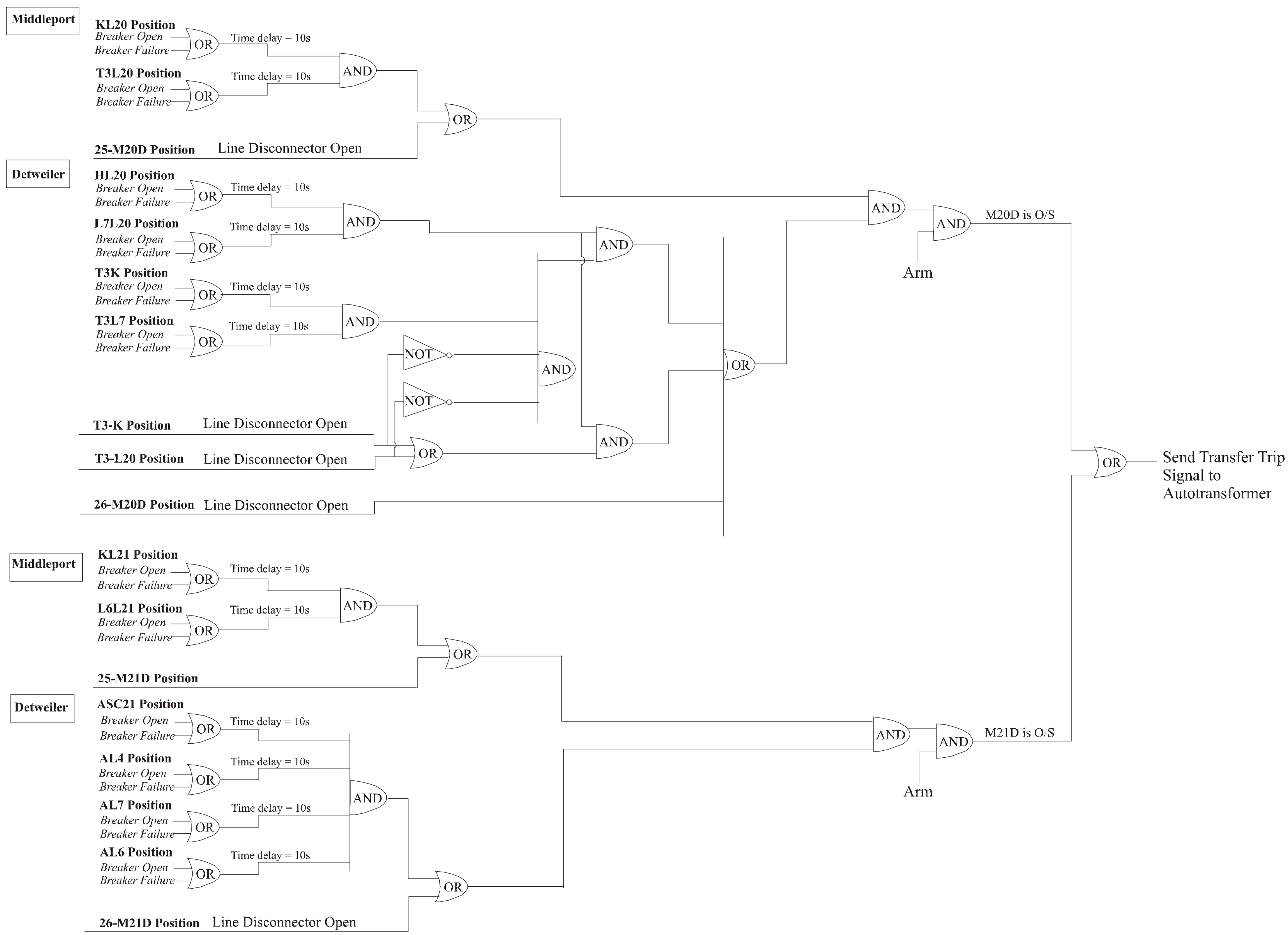

FIGURE 4 – SPS LOGIC DIAGRAM

APPENDIX A

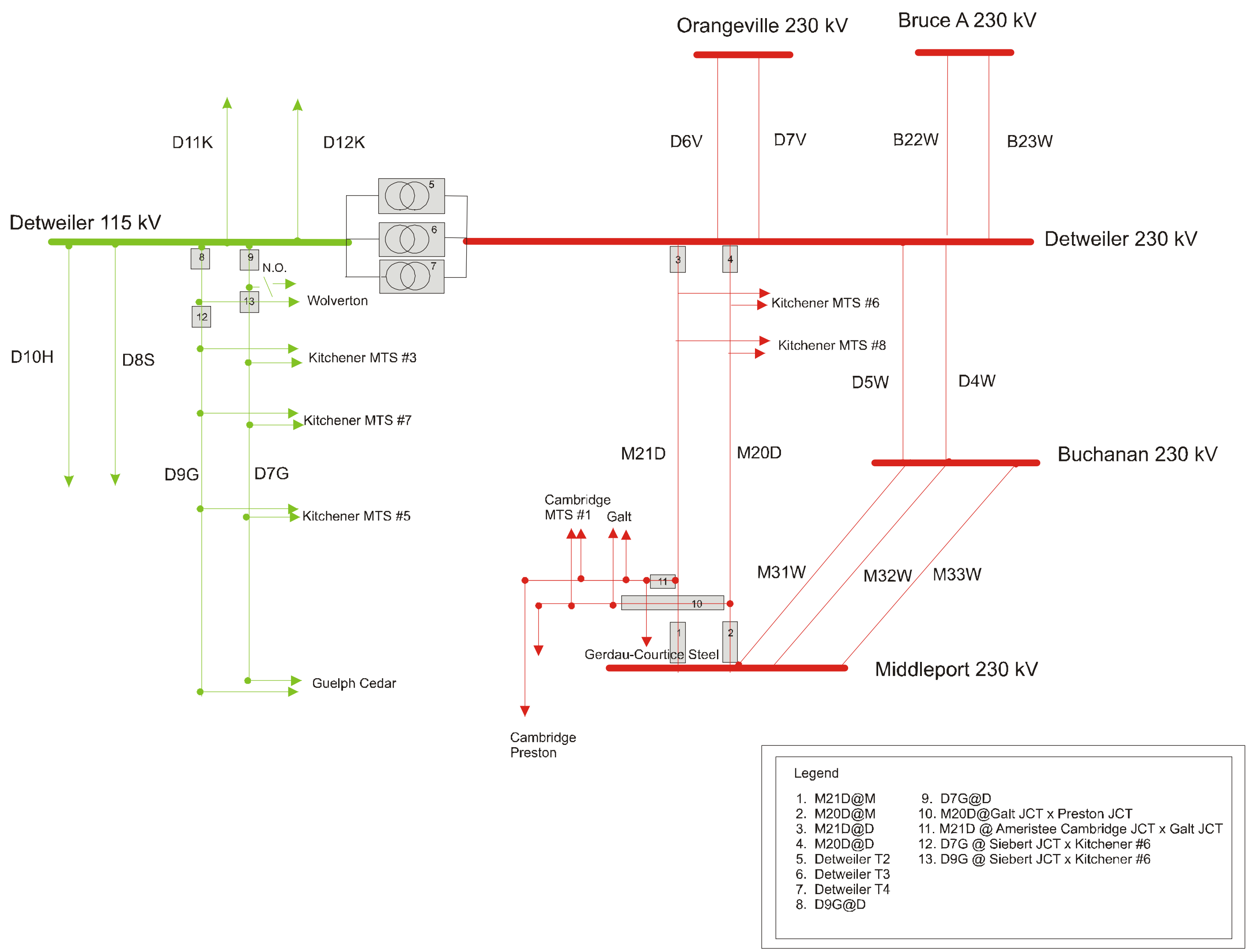

FIGURE A1 – SCENARIO S_{PRE} CONFIGURATION

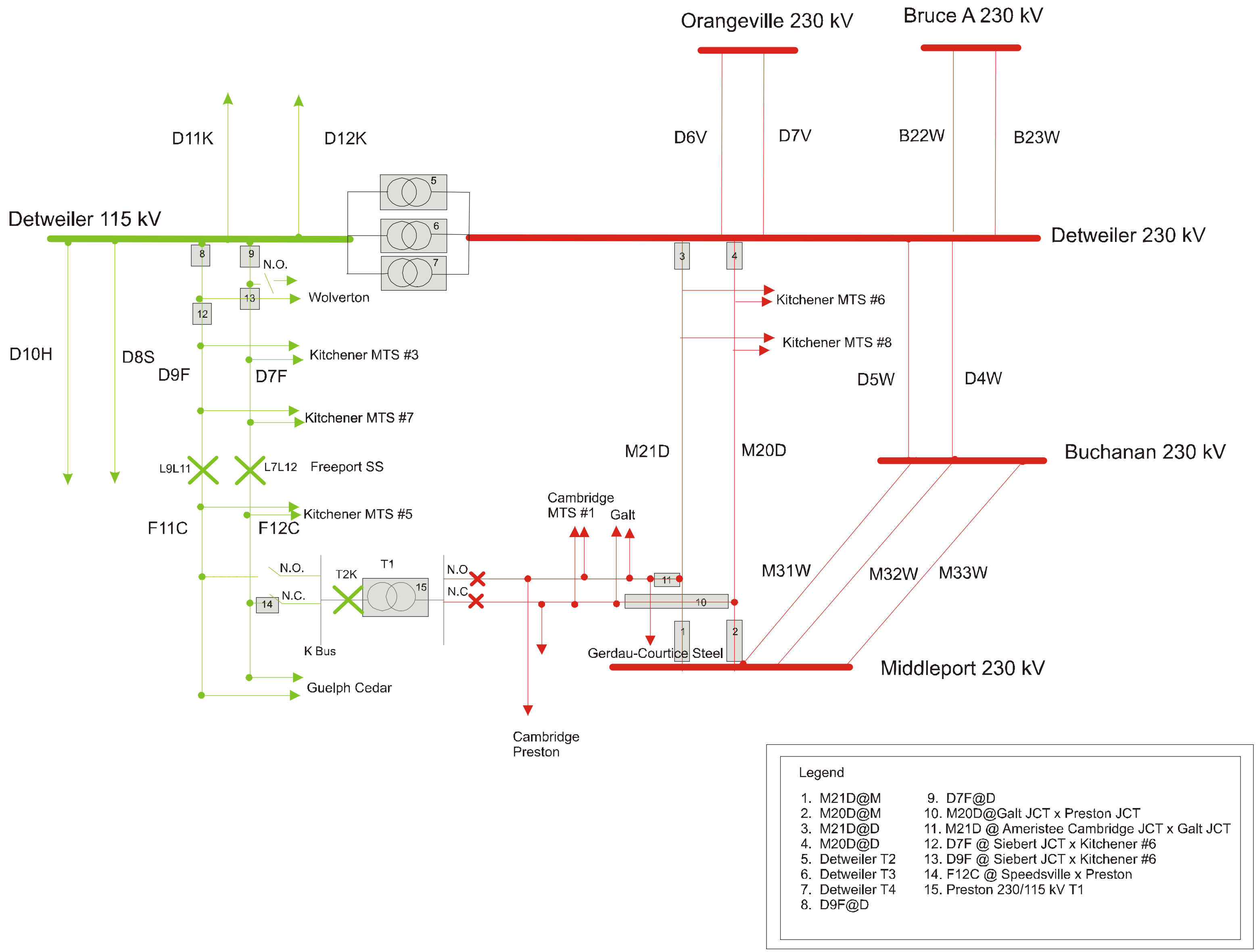

FIGURE A2 – SCENARIO S_{POST} CONFIGURATION

– End of Section –