REPORT

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System Impact Assessment Report

Markham MTS #4

Final Report
CONNECTION ASSESSMENT & APPROVAL PROCESS

CAA ID 2008-320

Applicant: PowerStream Inc.

Transmission Assessments & Performance Department

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System Impact Assessment Report

Markham MTS #4

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.

Table of Contents

MARKHAM MTS #4
IESO SYSTEM IMPACT ASSESSMENT

SIA Findings

Summary

PowerStream Inc. is proposing to build Markham MTS #4, a new 230/27.6 kV DESN station to be located along the Highway 407 corridor, approximately 1 km north of Parkway TS. The station, which will be tapped off from the existing 230 kV circuits P45 and P46, will also include the installation of 2x20 Mvar low voltage capacitors.

The proposed project is expected to be in service as early as December 31, 2009.

The project is under the connection project classification and is needed to facilitate load growth in the Markham and Richmond Hill area to provide loading relief to surrounding stations.

This System Impact Assessment (SIA) examines the impact of Markham MTS #4 transformer station on the IESO-controlled grid under 2010 and 2014 peak summer load scenarios and was performed according to the IESO's Ontario Resource and Transmission Assessment Criteria:

(http://www.ieso.ca/imoweb/pubs/marketAdmin/IMO_REQ_0041_TransmissionAssessmentCriteria.pdf)

The following conclusions and recommendations were made:

Conclusions and Recommendations

The analysis concluded that:

(1) The proposed transformer station does not have a negative adverse impact to the reliability of the IESO-controlled grid.

(2) Post-contingency thermal loadings and voltage declines are within criteria as per the Transmission Assessment Criteria.

Sensitivity studies show that if both 20 Mvar capacitors are unavailable under peak 2014 load conditions, the voltage decline at Markham MTS #4 before tap changer action could be as high as 11%. With the capacitors in-service, the voltage decline was about 8%. Therefore, in addition to power factor correction, the capacitors will help provide post-contingency voltage support at the LV bus. Note, peak 2014 load levels correspond to the station load capability.

(3) PowerStream has indicated the LV power factor at Markham MTS #4 without compensation to be about 0.88 at summer peak. Under this power factor value, the installation 40 Mvar of capacitors should be adequate in providing reactive compensation for loadings up to the station's capacity.

(4) The switching of a 20 Mvar capacitor step or less meets the IESO requirement on voltage change.

(5) Load forecasts indicate that many PowerStream stations in the Markham/Richmond Hill and Vaughan areas will be loaded at capacity during the study period. PowerStream has indicated plans to install Vaughan MTS #4 (2013) and Markham MTS #5 (2015) to facilitate future load growth.

(6) The total load supplied by P45 and P46 is not expected to exceed 312 MW for the study period. This loading level is within the 600 MW threshold as per the IESO Transmission Assessment Criteria.

IESO's Requirements for Connection

(1) PowerStream is required to install 40 Mvar of LV capacitors coincident to the in-service of Markham MTS #4.

PowerStream must commit to regularly reviewing the the Market Rule reactive requirements at Markham MTS #4 and must notify the IESO should it forecast/determine the summer peak power factor to be lower than that assumed in the report. Additional reactive compensation may be required in the future should the actual power factor be lower than what was assumed in this report.

(2) PowerStream must ensure the 28 kV breakers have short circuit capabilities of 17 kA or greater (symmetrical) and 12 kA or greater (single line to ground).
(3) PowerStream is required to provide impedance values of the station line taps to the IESO once the conductor type is known.
(4) PowerStream is required to install UFLS facility at Markham MTS #4 and will need to ensure that UFLS targets with the addition of the new load are valid.
(5) PowerStream is required to confirm that voltage control will be available to provide 3% or 5% reduction within five minutes of receipt of the direction from the IESO.
(6) All equipment must be capable of operating continuously for system voltages between 220 kV and 250 kV
(7) PowerStream is required to provide on-line monitoring quantities as listed in Section 2.5, "Online Monitoring" of this report.
(8) PowerStream must notify the IESO as soon as possible as it becomes aware of any changes to the assumptions made in the connection. The IESO will determine whether these changes require a re-assessment.

It addition to the above requirements, PowerStream will need to initiate the Customer Impact Assessment with the transmitter.

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 the Markham MTS #4 subject to the IESO receiving written acknowledgement that the requirements listed in this report will be implemented.

1. Project Description

PowerStream Inc. is proposing to build Markham MTS #4, a new 230/27.6 kV DESN station to be located along the Highway 407 corridor, approximately 1 km north of Parkway TS. The station, which will be tapped off from the existing 230 kV circuits P45 and P46, will also include the installation of 2x20 Mvar low voltage capacitors.

The new station will accommodate new load growth within the Markham and Richmond Hill surrounding areas. PowerStream also plans to transfer some of the existing load from Buttonville TS, Richmond Hill MTS #2 and Markham MTS #1 to Markham MTS #4.

The proposed project is expected to be in service as early as December 31, 2009.

2. General Requirements

2.1 Equipment Rating

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

1. 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).

2. 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.

2.2 Power Factor

The Market Rules require that wholesale customers and distributors connected to the IESO-controlled grid shall operate at a power factor within the range of 90% lagging to 90% leading as measured at the defined meter point.

2.3 Underfrequency Load Shedding Requirements

The market rules (Chapter 5, Section 10.4) require that each distributor and connected wholesale customer, in conjunction with the relevant transmitter, make arrangements to enable the automatic disconnection of up to 35% of its peak demand for conditions of system under-frequency. For the purposes of administrating this, the province is divided up into a number of UFLS areas and the UFLS targets must be met for each of these areas.

A detailed description of the UFLS requirements is given in Market Manual 7: System Operations, Part 7.4, Chapter 4, Section 4.4

PowerStream Inc. is required to install facilities at Markham MTS #4 to allow for the detection of under frequency conditions, and the selection and tripping of feeder circuit breakers for load shedding, for immediate or future deployment.

In the event that the existing UFLS area load is insufficient in meeting the UFLS targets with the addition of the new load and immediate deployment is required, Power Stream, is required to submit during the IESO Market Entry process a revised schedule of feeder selections and their related load amounts for each shedding stage that will ultimately satisfy the above targets.

2.4 Voltage Reduction Facilities Requirements

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

The Connection Applicant is required to confirm that voltage control will be available from local or remote location to provide 3% or 5% reduction to support the operating obligations.

2.5 On-line Monitoring

The Market Rules (Chapter 4 section 7.5) require that each connected distributor shall provide the IESO on a continual basis with on-line monitored quantities as specified in Appendix 4.17. It is required that PowerStream Inc. install all the equipment needed to monitor the information required by the IESO on a continuous basis. The IESO requires that the following quantities at Markham MTS #4 be provided to the IESO on a continual basis via approved communication protocols:

1. The voltage on the 230 kV bus
2. The status of the 230 kV switches
3. The voltage on the 27.6 kV bus
4. The status of the transformer 27.6 kV breakers
5. The real and reactive power flow through both transformers

PowerStream is required to install all the equipment needed to continuously monitor the information that is required by the IESO. The IESO will finalize items to be monitored during the IESO Facility Registration Process.

2.6 Protection Systems

With respect to the protection and telecommunication requirements, the connection applicant will have to follow the Transmission System Code technical requirements for tapped transformer stations supplying load.

The diagram that was provided by the applicant shows each transformer being separated from the transmission system via a motorized disconnection switch. For this particular arrangement the Transmission System Code requires that transfer trip of the Transmitter's breakers at the terminal stations be provided for transformer faults. In the case of Markham MTS #4, which is to be connected to the 230 kV lines P45 and P46 the transfer trip must be sent to Parkway TS of the faulted circuit.

3. Review of Connection Proposal

3.1 Proposed Connection Arrangement

The Claireville 230 kV bus reconfiguration is tentatively scheduled for completion by Q4-2009, prior to Markham MTS #4 coming to service. **Figure 1** shows the transmission system diagram with Markham MTS # 4 in-service with a *post* Claireville 230 kV bus configuration.

The new station is to be equipped with two identical 215.5/28/28 kV transformers T1 and T2. Markham MTS #4 T1 and T2 will be tapped onto P45 and P46 by way of 2 x 300 m line taps. Each transformer is rated for 75/100/125 MVA and is equipped with a ULTC with a range of ± 34.5kV in 32 steps on the HV side.

Low voltage side isolation of each transformer winding is to be provided by a 2500 A, 28 kV circuit breaker. The LV bus-tie breaker is rated for 2500 A and is **operated normally opened**. The station will have 12 feeders and each feeder is to be equipped with a 1250 A breaker. The 20 Mvar capacitor banks will also be equipped with a 1250 A breaker.

Figure 2 shows the Markham MTS #4 station diagram.

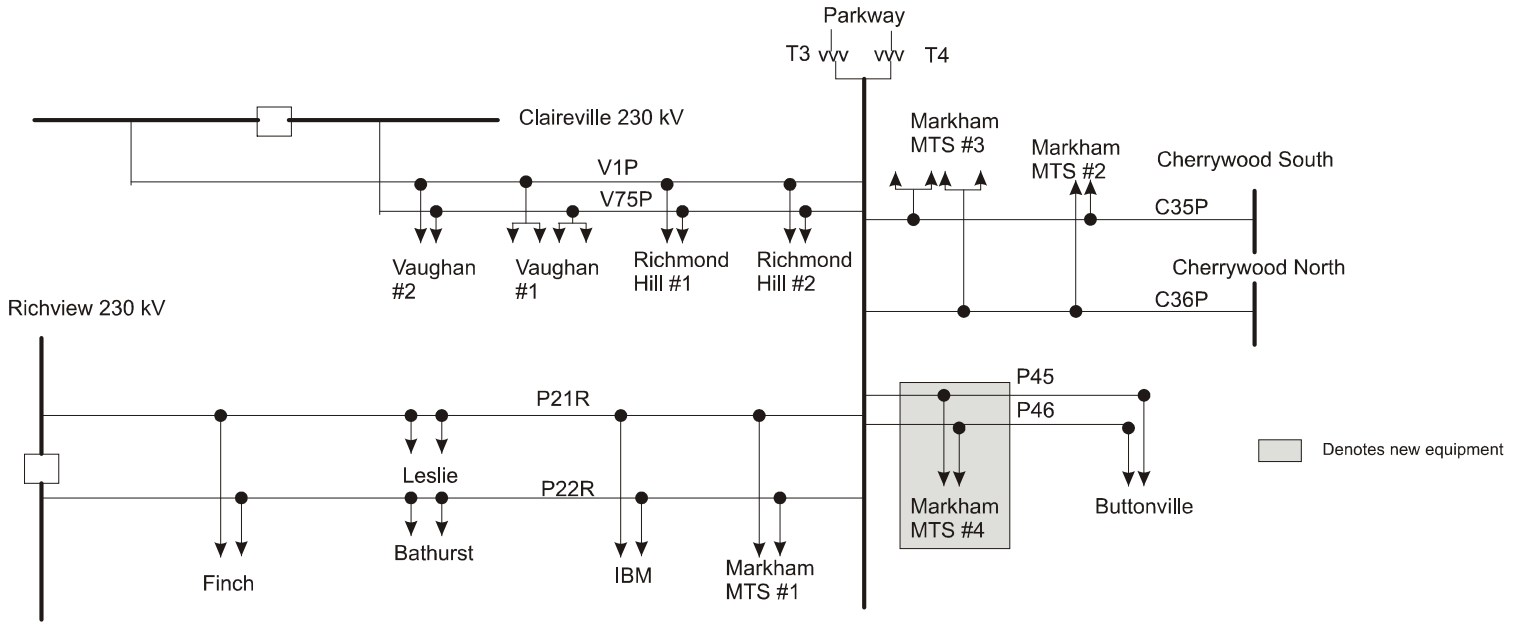


Figure 1: Connection Diagram of Transmission System for Markham MTS #4

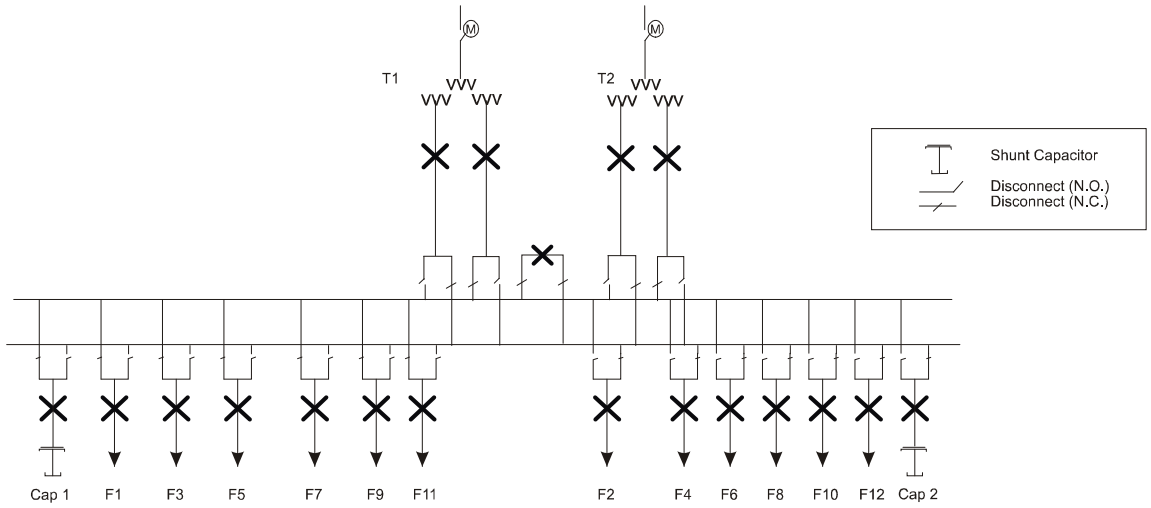


Figure 2: Markham MTS #4 Station Diagram

3.2 Existing System

Figures 3A, 3B, 3C shows the (i) MW and Mvar flows on P45 and P46 at Parkway (ii) MW flows on Parkway T3 and Parkway T4, and (ii) Voltages at Parkway 230 kV taken in hourly average samples for the period of October 1, 2007 to October 1, 2008.

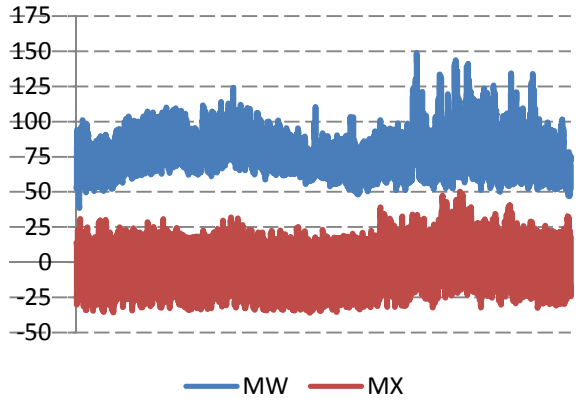


FIGURE 3A: P45 AND P46 MW AND MVAR FLOWS @ PARKWAY TS

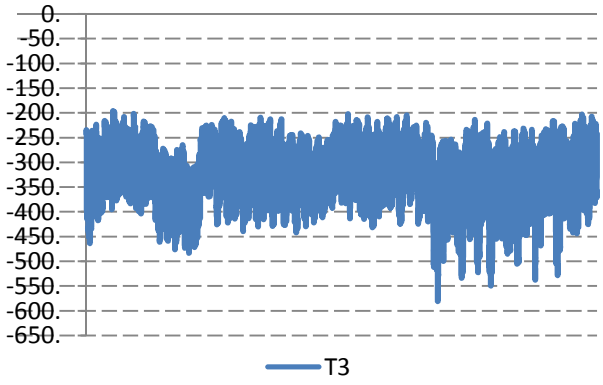


FIGURE 3B: PARKWAY T3 MW FLOWS @ 230 KV BUS

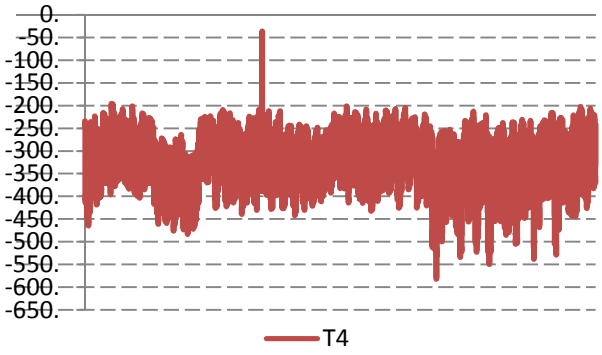


FIGURE 3C: PARKWAY T4 MW FLOWS @ 230 KV BUS

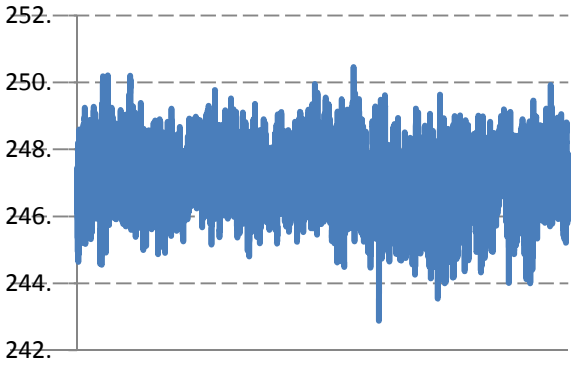


FIGURE 3D: PARKWAY 230 KV VOLTAGES

4. Data Verification

4.1 Transformers

Specifications from the connection applicant are listed below:

Rating (MVA)	75/100/125 MVA
Voltage (kV)	215.5/28/28
Positive Impedance	HX = 10.7% (37.5 MVA base) HY = 10.6% (37.5 MVA base) XY = 11.18% (75 MVA base)
Continuous Rating (MVA)	75 MVA
10 Day Limited Time Rating Summer (MVA)	170 MVA
10 Day Limited Time Rating Winter (MVA)	190 MVA
ULTC (HV side)	± 34.5 kV in 32 steps

4.2 Circuit Breakers

Specifications of the connection applicant are listed below. PowerStream will need to ensure that the 28 kV breakers have a symmetrical short circuit interrupting capability of 17 kA or greater as specified in the Transmission System Code.

	Transformer Breakers	Bus Tie Breaker	Feeder Breakers
Nominal Voltage (kV)	28	28	28
SC Circuit Interrupting Capability (kA)	-	-	-
Continuous Rating (A)	2500	2500	1250
Normal Operation	Closed	Opened	Closed

4.3 Overhead Circuit

Double circuit 230 kV line taps from P45 and P46 will be connected to Markham MTS #4. The length of these taps will be about 300 m each. At the time of this report, PowerStream had yet to determine the conductor type. For the purposes of the study, it is assumed that the impedance of these line taps are negligible. It is expected that PowerStream provides impedance values of this line tap to the IESO once the conductor type is known.

5. System Impact Studies

This connection assessment study focused on identifying the effect of Markham MTS #4 on thermal loading and system voltages under pre- and post-contingency situation with 2010 and 2014 peak loads.

5.1 Study Assumptions and Background

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

5.1.1 Pre-contingency Conditions

- The study was performed for a system with all transmission elements in service.
- The loads used were 2010 summer coincident peaks under extreme weather conditions. The total Ontario primary demand is 28,116 MW and the zonal distribution is :

NW	NE	Essa	Ottawa	East	Toronto	Niagara	SW	Bruce	West
666	1341	1602	1984	1629	10888	1056	5482	65	3403

- The pre-contingency load flow representing existing conditions (without Markham MTS #4 in-service) had the following interface levels :

FETT	CLAN	FS
4743 MW	145 MW	1313 MW

- The following were assumed to be in service for the 2009 scenario:

  (a) Halton Hills GS (CAA ID 2006-232)
  (b) Claireville 230 kV Busbar reconfiguration (CAA ID 2006-220)
  (c) Sithe-Goreway Project (CAA ID 2000-008)
  (d) Hurontario SS to Jim Yarrow MTS 230 kV Transmission (CAA ID 2006-248)
  (e) Churchill Meadows TS (CAA ID 2006-230)

- The following buses were split: (i) Claireville 230 kV, (ii) Richview 230 kV, (iii) Cherrywood North 230 kV, (iv) Cherrywood South 230 kV, (v) Leaside 115 kV, (vi) Leaside 230 kV, (vii) Hearn 115 kV, and (viii) Sithe Goreway 230 kV

- For pre tap changer action, 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.

  For post tap changer action, a constant MVA load model was assumed.

- The pre-contingency load flow representing existing conditions (without Markham MTS #4 in-service) had the following flows on P45, P46, Buttonville TS and Parkway T3 and T4:

P45@P	P46@P	Buttonville TS	Parkway T3 @ 230 kV	Parkway T4 @ 230 kV
80 MW	77.7 MW	157 MW	-571 MW	-570 MW

Note: positive values represent flows out of the bus

- The 2014 scenario was obtained from the 2010 scenario by scaling the Toronto zone. Furthermore, loads within the vicinity of Markham MTS #4 were set to their 2014 forecast.
- The 2x20 Mvar capacitors were assumed to be in-service for the thermal and voltage analysis (Sections 5.2 and 5.3).

5.1.2 Load Forecast and Growth

- The load distribution in the local area for extreme summer weather, provided by PowerStream, is given below for the study period, 2010 to 2014. Each of these loads were modeled in the load flow analysis with a 0.9 lag power factor at the LV side of the transformer.

  The table below shows the station loads and their respective 10 day LTRs. Highlighted are the years in which the station capability is exceeded.

Station	DESN	10 Day LTR		2008 Peak Summer Load (MW)[3]	Load Forecast (MW)				
		(MVA)	@ 0.9 pf (MW)		2010	2011	2012	2013	2014
Buttonville	P45/P46	177[2]	159	146	157	157	157	157	159
Vaughan #1	T1/T2	170[2]	153	99	153	153	153	153	153
	T3/T4	170[2]	153	89	120	149	153	153	153
Vaughan #2	T1/T2	170[2]	153	145	153	153	153	153	153
Richmond Hill #1	T1/T2	170[2]	153	147	146	146	146	153	153
Richmond Hill #2	T3/T4	112[2]	101	96	101	101	101	101	101
Markham MTS #1	T1/T2	90[2]	81	82	81	81	81	81	81
Markham MTS #2	T1/T2	112[2]	101	95	101	101	101	101	101
Markham MTS #3	T1/T2	112[2]	101	74	101	101	101	101	101
	T3/T4	112[2]	101	79	101	101	101	101	101
Markham MTS #4	T1/T2	170[2]	153	N/A	86	112	122	141	153

Notes: (1) Rating obtained from Hydro One Secure Website
(2) Rating provided by Power Stream Inc.
(3) Hourly Average Peak load from the period of October 1 2007 to October 1, 2008

As shown, all loads will be loaded at capacity by 2014. PowerStream has indicated plans to install Vaughan MTS #4 for 2013 and Markham MTS #5 for 2015, to accommodate the load growth in the Vaughan, Markham and Richmond Hill areas. It should be noted that in 2008, records show that the actual peak summer load at Markham MTS #1 exceeded the 10 day LTR of one of its transformers.

5.1.3 Load Supply Deliverability

The load security and restoration criteria for IESO-controlled grid are defined in the Ontario Resource and Transmission Assessment Criteria document as follows:

"With any one element out of service, equipment loading must be within applicable long-term emergency ratings, voltages must be within applicable emergency ranges, and transfers must be within applicable normal condition stability limits. Not more than 150MW of load may be interrupted by configuration. Planned load curtailment or load rejection, excluding voluntary demand management, is not permissible.

With any two elements out of service voltages must be within applicable emergency ranges. Equipment may be loaded up to applicable short-term emergency ratings immediately following a contingency, but must be reduced to the long-term emergency ratings in the time afforded by the short-term ratings. Not more than 600MW of load may be interrupted as a result of the contingency, and this may include up to 150MW of planned load curtailment or load rejection, excluding voluntary demand management.

Where local generation exist, additional planned load curtailment or load rejection is permissible up to the capacity of the largest local generating unit, or 600 MW, whichever is less. The additional load curtailment is permitted only for generating unit outages with all transmission facilities in service or with any one or two elements out of service. Generating unit outages must consider any common failure modes between units of a multi-unit or combined-cycle plant.

The transmission system must be planned such that, following design criteria contingencies on the transmission system, affected loads can be restored within the restoration times listed below:

- *All load must be restored within approximately 8 hours.*
- *When the amount of load interrupted is greater than 150MW, the amount of load in excess of 150MW must be restored within approximately 4 hours.*
- *When the amount of load interrupted is greater than 250MW, the amount of load in excess of 250MW must be restored within 30 minutes."*

The load supplied by the 230 kV double circuit line P45 and P46 (Markham MTS #4 + Buttonville) is not expected to exceed 312 MW for the study period.

The IESO criteria are met for the study period since (i) for one element out of service the load continues to be supplied via the remaining circuit and (ii) for two elements out of service not more than 600 MW of load would be interrupted.

5.1.4 Contingencies

The following are the contingencies that were performed for the thermal and voltage analysis.

Contingencies			
C1	Loss of C550VP + Parkway T4+ Claireville T14	C5	P45+C35P
C2	Loss of P45	C6	V71P
C3	Loss of C35P	C7	V75P+Claireville T16
C4	Loss of C36P	C8	P46+C36P

5.2 Thermal Analysis

5.2.1 Monitored Equipment

The following continuous, long term emergency (LTE) and short-term emergency (STE) ratings were obtained from the Hydro One Secure Website for 35º C, 4 km/h wind speed daytime conditions.

	From	To	Continuous (A)[1]	Long Term Emergency (A)[2]	Short-Term Emergency (A)[3]
P45	Parkway TS	Markham #4 MTS JCT	840	1090	1410
	Markham #4 MTS JCT	Buttonville	840	1090	1410
P46	Parkway TS	Markham #4 MTS JCT	840	1090	1410
	Markham #4 MTS JCT	Buttonville	840	1090	1410
V1P	Richmond Hill JCT	Parkway TS	1290	1700	2110
	Richmond Hill JCT	Richmond Hill 2 JCT	1370	1820	2310
	Richmond Hill # 2 JCT	Richmond Hill MTS #2	840	1090	1220
	Richmond Hill JCT	Richmond Hill MTS #1	840	1090	1410
	Vaughan #1 JCT	Richmond Hill JCT	1370	1820	2310
	Vaughan #1 JCT	Vaughan #1 PH JCT	840	1090	1410
	Vaughan #1 PH JCT	Vaughan #1	840	1090	1410
	Toronto Star JCT	Vaughan #1 JCT	1370	1820	2480
	Toronto Star JCT	Vaughan MTS #2	840	1090	1410
	Claireville TS	Toronto Star JCT	1370	1820	2750
V75P	Richmond Hill #2 JCT	Parkway TS	1290	1700	2110
	Richmond Hill JCT	Richmond Hill #2 JCT	1370	1820	2310
	Richmond Hill #2 JCT	Richmond Hill MTS #2	840	1090	1220
	Vaughan #1 JCT	Richmond Hill JCT	1370	1820	2610
	Richmond Hill JCT	Richmond Hill MTS #1	840	1090	1410
	Vaughan #1 JCT	Vaughan #1 PH JCT	840	1090	1410
	Vaughan #1 PH JCT	Vaughan MTS #1	840	1090	1410
	Toronto Star JCT	Vaughan #1 JCT	1370	1820	2750
	Toronto Star JCT	Vaughan MTS #2	840	1090	1410
	Claireville TS	Toronto Star JCT	1350	1800	2170
C35P	Parkway	Markham #3 JCT	1370	1820	2310
	Markham #2 JCT	Cherrywood 230 TS	1370	1820	2310
C36P	Parkway	Markham #3 JCT	1370	1820	2310
	Markham #2 JCT	Cherrywood 230 TS	1370	1820	2310
P21R	Parkway	Markham #1 JCT	1290	1700	2110
	Leaside JCT	IBM JCT	840	1090	1410
	Richview	Finch JCT	1060	1300	1520
P22R	Parkway	Markham #1 JCT	1290	1700	2110
	Leaside JCT	IBM JCT	840	1090	1410
	Finch JCT	Richview	1060	1300	1520
T3	Parkway 500 kV	Parkway 230 kV	960	1178	1499
T4	Parkway 500 kV	Parkway 230 kV	960	1178	1499
T13	Claireville 500 kV	Claireville 230 kV	810	988	1306
T14	Claireville 500 kV	Claireville 230 kV	808	992	1402
T15	Claireville 500 kV	Claireville 230 kV	808	992	1402
T16	Claireville 500 kV	Claireville 230 kV	936	1147	1472

Notes: (1) For conductors, rating obtained at the lesser conductor temperature of 93ºC or sag temperature

(2) For conductors, rating obtained at the lesser conductor temperature of 127 ºC or sag temperature
For transformers, values presented are equivalent to the 10 day Limited Time Rating

(3) For conductors, rating obtained at the sag temperature with a pre-contingency loading of 75% of the LTE Rating. For Transformers, values presented are equivalent to the 15 minute Limited Time Rating.

5.2.2 Pre-contingency Analysis

The following are the pre-contingency flows represented as a percentage of the continuous ratings. All elements are within continuous ratings for 2010 and 2014 scenarios. It should be noted that Claireville T13 is near its continuous rating.

	From	To	% of Continuous Rating	
			2010	2014
P45	Parkway TS	Markham #4 MTS JCT	36.1	47.1
	Markham #4 MTS JCT	Buttonville	23.6	24.1
P46	Parkway TS	Markham #4 MTS JCT	35.4	46.4
	Markham #4 MTS JCT	Buttonville	22.8	23.3
V1P	Richmond Hill JCT	Parkway TS	44.9	42.0
	Richmond Hill JCT	Richmond Hill 2 JCT	29.9	34.6
	Richmond Hill # 2 JCT	Richmond Hill MTS #2	21.6	8.6
	Richmond Hill JCT	Richmond Hill MTS #1	24.4	25.7
	Vaughan #1 JCT	Richmond Hill JCT	17.1	20.5
	Vaughan #1 JCT	Vaughan #1 PH JCT	41.9	48.0
	Vaughan #1 PH JCT	Vaughan #1	42.1	48.2
	Toronto Star JCT	Vaughan #1 JCT	14.0	14.0
	Toronto Star JCT	Vaughan MTS #2	25.0	25.1
	Claireville TS	Toronto Star JCT	27.7	27.6
V75P	Richmond Hill #2 JCT	Parkway TS	40.7	37.8
	Richmond Hill JCT	Richmond Hill #2 JCT	26.3	30.8
	Richmond Hill #2 JCT	Richmond Hill MTS #2	20.7	8.1
	Vaughan #1 JCT	Richmond Hill JCT	13.4	16.5
	Richmond Hill JCT	Richmond Hill MTS #1	25.1	26.4
	Vaughan #1 JCT	Vaughan #1 PH JCT	41.5	47.3
	Vaughan #1 PH JCT	Vaughan MTS #1	41.7	47.5
	Toronto Star JCT	Vaughan #1 JCT	16.7	16.7
	Toronto Star JCT	Vaughan MTS #2	25.8	26.0
	Claireville TS	Toronto Star JCT	31.9	31.8
C35P	Parkway	Markham #3 JCT	6.7	9.8
	Markham #2 JCT	Cherrywood 230 TS	33.8	37.7
C36P	Parkway	Markham #3 JCT	12.3	13.0
	Markham #2 JCT	Cherrywood 230 TS	29.4	33.2
P21R	Parkway	Markham #1 JCT	54.3	55.4
	Leaside JCT	IBM JCT	83.3	85.1
	Richview	Finch JCT	18.9	19.4
P22R	Parkway	Markham #1 JCT	42.4	43.4
	Leaside JCT	IBM JCT	65.1	66.6
	Finch JCT	Richview	6.5	6.4
T3	Parkway 500 kV	Parkway 230 kV	64.9	65.5
T4	Parkway 500 kV	Parkway 230 kV	64.7	65.4
T13	Claireville 500 kV	Claireville 230 kV	88.0	89.0
T14	Claireville 500 kV	Claireville 230 kV	90.0	91.1
T15	Claireville 500 kV	Claireville 230 kV	85.1	86.1
T16	Claireville 500 kV	Claireville 230 kV	68.3	69.1

5.2.3 Post-contingency Analysis

The following table shows the post-contingency loading in terms of the LTE rating for the study period. All elements are within long term emergency ratings for 2010 and 2014 scenarios. For the loss of C550VP + Parkway T4+ Claireville T14, Claireville T13 may be loaded near its emergency rating (up to 97%). Sensitivity studies show that for the companion contingency, loss of C551VP+Parkway T3+ Claireville T16, Claireville T15 may be loaded up to 93 % of its emergency rating for the study period. The excessive transformer loading is not caused by the incorporation of Markham MTS #4.scenarios.

(1) Scenario 2010:

	From	To	% of Long Term Emergency Rating							
			C1	C2	C3	C4	C5	C6	C7	C8
P45	Parkway TS	Markham #4 MTS JCT	27.9	0.0	27.9	27.9	0.0	27.9	27.9	56.7
	Markham #4 MTS JCT	Buttonville	18.1	0.0	18.1	18.1	0.0	18.1	18.1	36.7
P46	Parkway TS	Markham #4 MTS JCT	27.4	57.0	27.3	27.4	57.1	27.3	27.3	0.0
	Markham #4 MTS JCT	Buttonville	17.5	37.3	17.6	17.6	37.2	17.6	17.6	0.0
V1P	Richmond Hill JCT	Parkway TS	34.2	33.9	31.2	31.5	31.0	0.0	70.6	31.4
	Richmond Hill JCT	Richmond Hill 2 JCT	22.9	22.4	19.9	20.2	19.8	0.0	45.3	20.1
	Richmond Hill # 2 JCT	Richmond Hill MTS #2	16.6	16.6	16.6	16.6	16.6	0.0	35.7	16.6
	Richmond Hill JCT	Richmond Hill MTS #1	18.7	18.8	18.8	18.8	18.8	0.0	41.0	18.8
	Vaughan #1 JCT	Richmond Hill JCT	13.7	12.9	10.9	10.8	11.0	0.0	23.0	10.9
	Vaughan #1 JCT	Vaughan #1 PH JCT	30.8	32.3	32.2	32.3	32.2	0.0	67.8	32.3
	Vaughan #1 PH JCT	Vaughan #1	31.0	32.4	32.4	32.5	32.4	0.0	68.0	32.4
	Toronto Star JCT	Vaughan #1 JCT	10.7	10.9	12.9	12.3	13.3	0.0	21.7	12.7
	Toronto Star JCT	Vaughan MTS #2	18.2	19.3	19.2	19.3	19.2	0.0	42.3	19.3
	Claireville TS	Toronto Star JCT	19.9	21.1	23.5	23.0	23.8	0.0	46.0	23.3
V75P	Richmond Hill #2 JCT	Parkway TS	21.4	30.8	27.7	28.6	27.5	66.2	0.0	28.4
	Richmond Hill JCT	Richmond Hill #2 JCT	10.7	19.7	16.9	17.6	16.8	41.1	0.0	17.5
	Richmond Hill #2 JCT	Richmond Hill MTS #2	16.3	15.9	15.9	15.9	15.9	35.8	0.0	15.9
	Vaughan #1 JCT	Richmond Hill JCT	5.1	10.2	8.2	8.3	8.4	18.7	0.0	8.5
	Richmond Hill JCT	Richmond Hill MTS #1	19.8	19.3	19.3	19.3	19.3	41.1	0.0	19.3
	Vaughan #1 JCT	Vaughan #1 PH JCT	33.2	32.0	32.0	31.9	32.0	67.8	0.0	31.9
	Vaughan #1 PH JCT	Vaughan MTS #1	33.3	32.1	32.1	32.1	32.1	68.0	0.0	32.1
	Toronto Star JCT	Vaughan #1 JCT	21.6	12.9	15.4	14.4	15.8	25.2	0.0	14.7
	Toronto Star JCT	Vaughan MTS #2	20.8	19.9	19.9	19.9	19.9	41.7	0.0	19.9
	Claireville TS	Toronto Star JCT	34.0	24.2	26.9	25.9	27.2	50.0	0.0	26.2
C35P	Parkway	Markham #3 JCT	20.4	4.7	0.0	18.8	0.0	3.5	4.2	18.2
	Markham #2 JCT	Cherrywood 230 TS	42.3	25.7	0.0	32.9	0.0	25.6	26.6	33.2
C36P	Parkway	Markham #3 JCT	18.2	8.7	24.2	0.0	23.7	6.9	7.2	0.0
	Markham #2 JCT	Cherrywood 230 TS	38.0	22.2	29.6	0.0	29.9	22.2	23.8	0.0
P21R	Parkway	Markham #1 JCT	37.8	41.1	38.7	38.4	38.7	40.9	44.3	38.5
	Leaside JCT	IBM JCT	58.9	64.1	60.4	60.0	60.3	63.7	69.0	60.0
	Richview	Finch JCT	16.2	15.9	16.4	15.5	16.9	17.9	17.3	16.0
P22R	Parkway	Markham #1 JCT	24.6	32.2	29.4	30.2	29.5	33.8	38.7	30.3
	Leaside JCT	IBM JCT	38.3	50.2	45.9	47.2	45.9	52.7	60.4	47.3
	Finch JCT	Richview	14.9	5.4	8.6	7.7	8.9	3.8	4.1	7.9
T3	Parkway 500 kV	Parkway 230 kV	70.3	52.9	55.6	55.2	55.7	52.7	55.9	55.3
T4	Parkway 500 kV	Parkway 230 kV	0.0	52.8	55.4	55.1	55.5	52.5	55.7	55.2
T13	Claireville 500 kV	Claireville 230 kV	95.9	72.1	72.7	72.5	72.7	70.4	80.2	72.4
T14	Claireville 500 kV	Claireville 230 kV	0.0	73.3	73.8	73.6	73.8	71.5	81.4	73.6
T15	Claireville 500 kV	Claireville 230 kV	81.9	69.3	69.6	69.9	69.5	71.6	84.0	69.9
T16	Claireville 500 kV	Claireville 230 kV	65.8	55.7	55.9	56.2	55.9	57.6	0.0	56.2

(2) Scenario 2014:

	From	To	% of Long Term Emergency Rating							
			C1	C2	C3	C4	C5	C6	C7	C8
P45	Parkway TS	Markham #4 MTS JCT	36.7	0.0	36.3	36.3	0.0	36.3	36.2	76.1
	Markham #4 MTS JCT	Buttonville	18.7	0.0	18.5	18.5	0.0	18.5	18.5	38.1
P46	Parkway TS	Markham #4 MTS JCT	36.1	76.1	35.7	35.7	77.2	35.7	35.7	0.0
	Markham #4 MTS JCT	Buttonville	18.2	38.0	17.9	18.0	38.6	17.9	17.9	0.0
V1P	Richmond Hill JCT	Parkway TS	32.2	31.7	28.8	29.0	28.5	0.0	65.6	28.9
	Richmond Hill JCT	Richmond Hill 2 JCT	26.6	25.9	23.2	23.4	22.9	0.0	53.4	23.2
	Richmond Hill # 2 JCT	Richmond Hill MTS #2	6.4	6.6	6.6	6.6	6.6	0.0	13.3	6.6
	Richmond Hill JCT	Richmond Hill MTS #1	19.3	19.8	19.7	19.8	19.7	0.0	43.2	19.7
	Vaughan #1 JCT	Richmond Hill JCT	16.6	15.5	13.0	12.9	13.1	0.0	29.0	13.1
	Vaughan #1 JCT	Vaughan #1 PH JCT	35.9	36.9	37.2	37.0	37.1	0.0	79.0	37.2
	Vaughan #1 PH JCT	Vaughan #1	36.1	37.1	37.3	37.1	37.3	0.0	79.2	37.4
	Toronto Star JCT	Vaughan #1 JCT	10.8	11.1	13.2	12.5	13.9	0.0	21.6	13.2
	Toronto Star JCT	Vaughan MTS #2	18.5	19.4	19.3	19.4	19.3	0.0	42.5	19.4
	Claireville TS	Toronto Star JCT	20.0	21.2	23.7	23.1	24.3	0.0	46.0	23.8
V75P	Richmond Hill #2 JCT	Parkway TS	19.2	28.5	25.3	26.1	25.0	61.0	0.0	25.9
	Richmond Hill JCT	Richmond Hill #2 JCT	14.2	23.0	20.0	20.7	19.8	49.2	0.0	20.6
	Richmond Hill #2 JCT	Richmond Hill MTS #2	6.4	6.2	6.2	6.2	6.2	13.1	0.0	6.2
	Vaughan #1 JCT	Richmond Hill JCT	5.2	12.5	9.8	10.2	10.0	24.6	0.0	10.4
	Richmond Hill JCT	Richmond Hill MTS #1	20.5	20.3	20.3	20.3	20.3	43.4	0.0	20.3
	Vaughan #1 JCT	Vaughan #1 PH JCT	38.2	36.4	36.7	36.4	36.7	78.9	0.0	36.6
	Vaughan #1 PH JCT	Vaughan MTS #1	38.3	36.6	36.9	36.5	36.8	79.1	0.0	36.8
	Toronto Star JCT	Vaughan #1 JCT	21.6	13.1	15.7	14.6	16.4	25.0	0.0	15.2
	Toronto Star JCT	Vaughan MTS #2	21.3	20.0	20.0	20.0	20.0	42.6	0.0	20.0
	Claireville TS	Toronto Star JCT	34.2	24.3	27.2	26.1	27.8	50.4	0.0	26.7
C35P	Parkway	Markham #3 JCT	23.8	7.1	0.0	16.8	0.0	6.3	7.1	15.8
	Markham #2 JCT	Cherrywood 230 TS	45.9	28.8	0.0	36.3	0.0	28.5	29.5	36.9
C36P	Parkway	Markham #3 JCT	21.1	8.9	22.3	0.0	21.1	7.8	8.6	0.0
	Markham #2 JCT	Cherrywood 230 TS	41.4	25.1	33.0	0.0	33.5	25.0	26.7	0.0
P21R	Parkway	Markham #1 JCT	39.1	42.0	39.3	39.0	39.3	41.9	45.5	39.0
	Leaside JCT	IBM JCT	60.9	65.5	61.4	60.8	61.3	65.3	70.9	60.8
	Richview	Finch JCT	17.9	16.5	16.7	15.9	18.2	18.1	18.1	16.7
P22R	Parkway	Markham #1 JCT	25.3	33.0	29.7	30.7	29.8	34.5	39.7	30.7
	Leaside JCT	IBM JCT	39.4	51.4	46.3	47.9	46.4	53.8	61.9	47.9
	Finch JCT	Richview	14.6	5.5	9.0	8.0	9.5	3.7	4.7	8.3
T3	Parkway 500 kV	Parkway 230 kV	71.1	53.5	56.4	56.1	56.7	53.2	56.5	56.2
T4	Parkway 500 kV	Parkway 230 kV	0.0	53.4	56.3	56.0	56.5	53.1	56.3	56.1
T13	Claireville 500 kV	Claireville 230 kV	97.3	73.0	73.6	73.4	73.6	71.3	81.3	73.4
T14	Claireville 500 kV	Claireville 230 kV	0.0	74.1	74.8	74.6	74.8	72.5	82.6	74.6
T15	Claireville 500 kV	Claireville 230 kV	83.0	70.1	70.4	70.8	70.4	72.5	85.2	70.8
T16	Claireville 500 kV	Claireville 230 kV	66.7	56.4	56.6	57.0	56.6	58.3	0.0	57.0

5.3 Voltage Analysis

5.3.1 Pre-contingency Analysis

The following are the pre-contingency voltages at various buses within the vicinity of Markham MTS #4 TS under 2010 and 2014 conditions. In cases which more than one instance of the bus exists, the lower voltage is given. All pre-contingency voltages are within IESO criteria.

	Markham MTS #4 230 kV	Markham MTS #4 27.6 kV	Parkway TS 230 kV	Parkway TS 500 kV	Buttonville TS 27.6 kV	Claireville 230 kV
2010	244.2 kV	29.0 kV	244.3 kV	524.1 kV	29.1 kV	245.5 kV
2014	243.0 kV	28.8 kV	243.1 kV	522.7 kV	28.9 kV	244.4 kV

5.3.2 Post-contingency Analysis

The following tables summarize the voltage declines for 2010 and 2014 conditions. Voltages are within IESO criteria for 2010 and 2014 scenarios. The largest pre-ULTC decline, about 8%, was found to exist at Markham MTS #4 for the loss of P45+C35P under 2014 conditions .

(1) Scenario 2010

2010 Projected Voltage Decline Percentages (Pre and Post ULTC)												
	Markham MTS#4 230 kV		Markham MTS #4 27.6 kV		Parkway TS 230 kV		Parkway TS 500 kV		Buttonville TS 27.6 kV		Claireville TS 230 kV	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
C1	1.01	1.29	1.02	-0.63	1.01	1.29	4.02	4.30	1.02	0.23	0.87	1.17
C2	0.14	0.21	1.69	-0.16	0.09	0.15	0.02	0.06	4.79	0.53	0.03	0.08
C3	0.29	0.49	0.29	-0.49	0.29	0.49	0.05	0.14	0.29	0.57	0.08	0.22
C4	0.13	0.31	0.13	-0.70	0.13	0.31	0.03	0.12	0.13	0.36	0.05	0.16
C5	0.45	0.72	1.99	-0.76	0.39	0.65	0.07	0.20	5.09	1.29	0.12	0.30
C6	0.19	0.49	0.19	-0.49	0.19	0.49	0.03	0.19	0.19	0.58	0.28	0.55
C7	0.32	0.72	0.32	-0.23	0.32	0.72	0.01	0.24	0.32	0.84	0.45	0.84
C8	0.28	0.53	1.83	-0.99	0.23	0.46	0.05	0.18	4.47	0.30	0.08	0.24

Note, a sensitivity test was performed for C5, loss of P45+C35P with both 20 Mvar capacitors out -of-service. Results show that the pre-ULTC decline at Markham MTS #4 was 6.25%.

(2) Scenario 2014

2014 Projected Voltage Decline Percentages (Pre and Post ULTC)												
	Markham MTS#4 230 kV		Markham MTS #4 27.6 kV		Parkway TS 230 kV		Parkway TS 500 kV		Buttonville TS 27.6 kV		Claireville TS 230 kV	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
C1	1.06	1.29	1.08	0.43	1.06	1.29	4.26	0.18	1.07	0.23	0.91	1.13
C2	0.21	0.34	7.41	0.85	0.12	0.23	0.03	0.09	5.11	-0.65	0.04	0.11
C3	0.32	0.53	0.32	0.68	0.32	0.53	0.05	0.16	0.32	0.63	0.09	0.23
C4	0.15	0.34	0.16	0.44	0.16	0.34	0.03	0.13	0.16	0.40	0.06	0.18
C5	0.54	0.82	7.74	-0.21	0.45	0.71	0.08	0.20	5.43	0.09	0.14	0.28
C6	0.19	0.44	0.20	-0.67	0.19	0.44	0.03	0.16	0.20	-0.78	0.29	0.51
C7	0.33	0.62	0.33	-0.44	0.33	0.62	0.01	0.18	0.33	-0.57	0.46	0.74
C8	0.38	0.63	7.58	-0.53	0.29	0.52	0.06	0.17	4.80	-0.91	0.10	0.23

Note, a sensitivity test was performed for C5, loss of P45+C35P with both 2x20 Mvar capacitors out-of-service. Results show that the pre-ULTC decline at Markham MTS #4 was 11.1%.

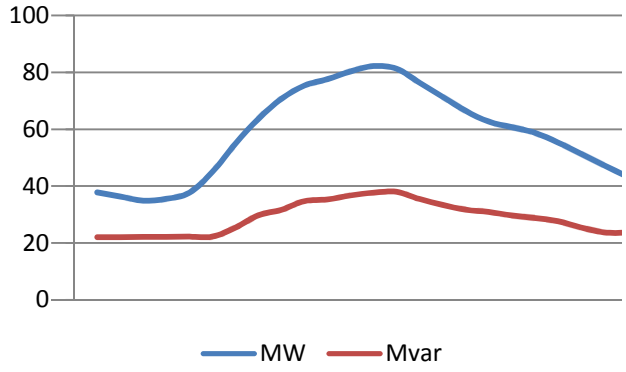
5.4 Capacitor Analysis

5.4.1 Power Factor

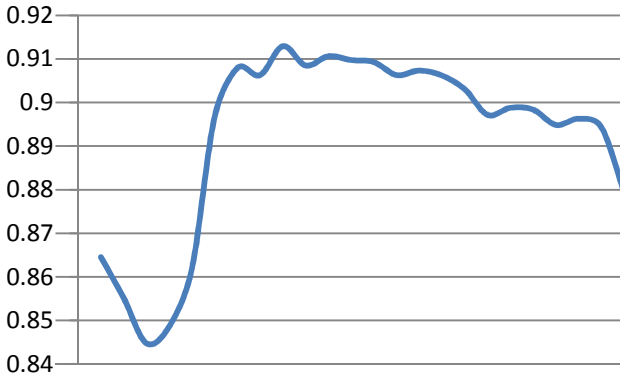
The Market Rules requires that all connected wholesale customers and distributors connected to the IESO-controlled grid shall operate at a power factor within the range of 0.9 lagging to 0.9 leading as measured at the defined meter point. The defined meter point is taken at the HV side of the transformer.

PowerStream expects the LV power factor at Markham MTS #4 to be as low as 0.88 lagging without reactive compensation under summer peak conditions.

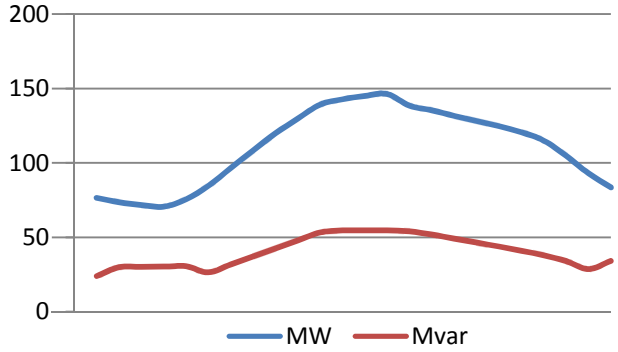
As mentioned previously, some existing load from Buttonville TS , Richmond Hill MTS #2 and Markham MTS #1 will be transferred to Markham MTS #4. To provide insight as to the expected power factor, the following figures show the hourly load consumption and power factor under no reactive compensation conditions at the three stations for June 9, 2008. This is the day at which the highest hourly average Toronto primary demand of 9404 MW was recorded during the period from October 1, 2007 to October 1, 2008



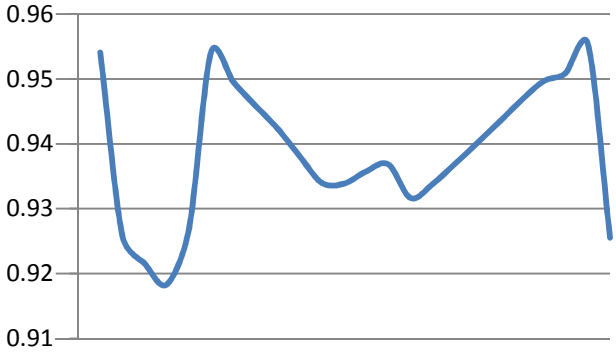
Markham MTS #1 MW and Mvar Consumption



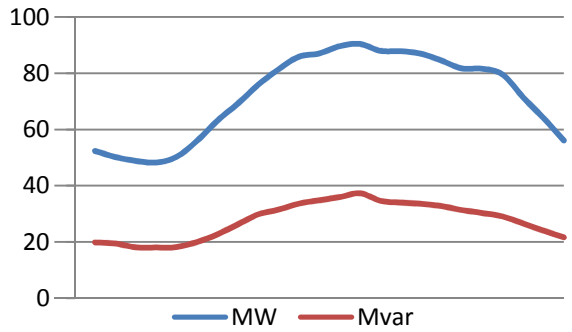
Markham MTS #1 Power Factor



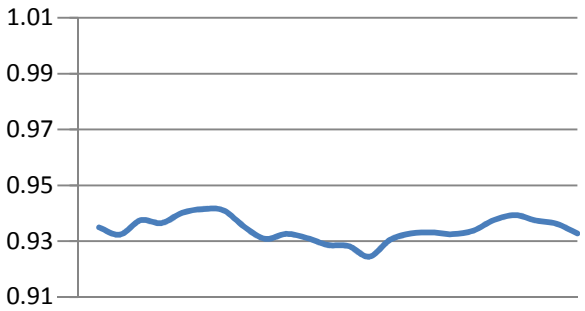
Buttonville TS MW and Mvar Consumption



Buttonville TS Power Factor



Richmond Hill MTS #2 MW and Mvar Consumption



Richmond Hill MTS #2 Power Factor

As shown, the power factors at these stations occurring at peak hours are typically above 0.88.

The following table shows the reactive compensation required for 0.9 power factor on the HV side (accounting for transformer losses) and at a LV power factor of 0.88 based on load flow studies for various load levels.

	0.88 pf		
S_{load} (MVA)	96	136	170
P_{load} (MW)	85	120	150
Q_{load} (Mvar)	45	64	80
$Q_{load}+Q_{transformer\_loss}$ (Mvar)	55.6	85	113
Power factor at HV side	0.84	0.82	0.80
Compensation needed for 0.9 pf (Mvar)	14	27	40

PowerStream has proposed 2x20 Mvar capacitors to be provided as power factor compensation. Assuming a LV power factor of 0.88, this should be sufficient in providing power factor compensation.

Additional reactive compensation may be required in the future should the actual power factor be lower than what was assumed in this report. It is expected that PowerStream commits to regularly reviewing the Market Rule reactive requirements at Markham MTS #4.

5.4.2 Switching Study

The IESO allows a voltage change ΔV on a single capacitor switching to be no more than 4% at delivery point buses. A switching study was carried to investigate the effect of switching in 20 Mvar on the voltage changes at Markham MTS #4. The table below summarizes greatest voltage change observed at each bus.

Step Change	ΔV %	
	Markham MTS# 230 kV	Markham MTS#4 27.6 kV
20 Mvar	0.123%	3.44%

As shown, a step size of 20 Mvar or less meets the IESO requirements.

6.0 Other Findings

In the course of preparing the System Impact Assessment, the following findings unrelated to the incorporation of Markham MTS #4 were uncovered :

- Claireville T13 and Claireville T14 may be loaded to about 97% of the long term emergency ratings for the loss of C550VP + Parkway T4+ Claireville T14 and C551VP+Parkway T3+ Claireville T16, respectively under 2014 conditions. This was studied under split operating conditions at Claireville.