REPORT

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System Impact Assessment Report

CONNECTION ASSESSMENT & APPROVAL PROCESS

Issue 1.0

FINAL REPORT

Project: Enwave Energy 11 MW Generation Plant

Applicant: Toronto Hydro Electric System

CAA ID 2006-251

Transmission Assessments & Performance Department

February 2, 2007

SYSTEM IMPACT ASSESSMENT REPORT
Enwave Energy 11 MW Generation Plant

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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 preliminary feasibility 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 preliminary feasibility 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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SIA Findings

Conclusions and Recommendations

This System Impact Assessment examined the impact of the proposed Enwave Energy generating facility on the IESO Controlled Grid.

Enwave Energy is planning to develop an Emergency Generation Plant consisting of two 6.875 MVA steam turbine generators embedded within the Toronto Hydro Electric System distribution system. The connection points of this facility to THES 13.8 kV distribution system are located at the John Street Pumping Station being fed by THES feeders A36WR and A38WR. These two feeders are connected to the A13 and A14 buses at the Windsor station, called John TS by Hydro One. The A13 & A14 buses are supplied from Hydro One's "T2Y" and "T4Y" 13.8 kV windings of respectively T2 and T4 115kV/13.8kV, 45/60/75 MVA transformers at John TS

The proposed facility is an embedded generation facility. At this time, the proponent will not be participating in the Ontario Electricity Markets. The generators will operate independent of dispatch instructions from the IESO.

The proposed system configuration is shown in Figure 1.

The study results concluded the following:

This System Impact Assessment has examined the effect of the new generation facility on the reliability of the IESO-controlled grid. The studies concluded that the new generation facility:

(a) will not have a material adverse impact on the reliability of the IESO-controlled grid,

(b) will displace part of the John TS load, but will not result in a net injection of power into the IESO-controlled grid,

(c) will not result in thermal overloading of any existing transmission facilities,

(d) will slightly increase the short circuit current at the station to which it connects, but will not result in short circuit levels in excess of the breakers capability in the IESO controlled grid,

(e) does not affect the transient stability of the power system,

(f) meets the *Market Rules* requirements for the reactive power performance of the generator.

IESO's Requirements for Connection

The *Market Rules* do not specify performance standards for non-market participant embedded generators which are smaller than 10 MVA, unless the facility is comprise of generation units whose net output is greater than 50 MVA. However, where a new facility could negatively impact the IESO Controlled Grid (ICG), the IESO will request the applicant to meet specific minimum technical requirements, regardless of

the size of the facility. The size of this proposal is below the above mentioned thresholds and no negative impact on the ICG was identified. Therefore, IESO has the following minimum requirements for the Enwave generation facility.

(1) The proposed generators must not be tripped for under-frequency conditions in the area above the curve in Figure 2 of this report.

(2) THES must respect the *Distribution System Code, Section 6.3.* In particular, THES has to perform an impact assessment of the proposed generation facility on the distribution system and any customers of their distribution system.

(3) The performance of the equipment must meet or exceed the predicted performance observed in simulations done by the IESO for the SIA.

For generation facilities which do not participate in the IESO administered market, the *Market Rules* require monitoring information to be provided to the IESO on a continual basis from facilities including a generation unit rated at greater than 20 MVA or that comprises generation units the ratings of which in the aggregate exceeds 20 MVA. Since the proposed generation plant is 13.75 MVA total, the telemetry for on-line monitoring is not required by the IESO.

Notification of Approval for Connection Proposal

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 for Connection be issued for this project subjected to implementation of above requirements. If the generation facilities either do not meet the specified performance standard when installed or are subsequently determined not to meet those performance standards, the IESO connection approval may be withdrawn until the specified performance standards or their equivalent can be demonstrated.

– End of Section –

System Impact Assessment Report

1. Project Description

Enwave Energy is proposing to develop an Emergency Generation Plant consisting of two 6.875 MVA steam turbine generators embedded within the distribution system of Toronto Hydro Electric System (THES).

This System Impact Assessment examined the impact of the proposed Enwave Energy generation facility on the reliability of the IESO Controlled Grid.

The generators are intended to operate as emergency back-up for Enwave's deep lake water cooling pumps in the event of failure of both THES feeders supplying John Street Pumping Station (JSPS), or both THES feeders supplying Metro Toronto Convention Centre (MTCC). Upon restoration of THES supply, Enwave operator will switch over from emergency supply to the utility supply. In this mode of operation, the generators will be isolated from the grid.

The generators could also operate in parallel with the system. In this case, the generator units would be connected to John TS via THES system, only through JSPS 13.8 kV bus, and A36WR and A38WR feeders. The existing connection arrangement is shown in Figure 1 of this report.

The proposed facility would be an embedded generation facility. At this time, the proponent will not be participating in the Ontario Electricity Markets, and the generators will operate independent of dispatch instructions from the IESO.

For embedded generation, the *Distribution System Code* obligates the distributors to perform an impact assessment that "*shall set out the impact of the proposed generation facility on the distributor's distribution system and any customers of the distributor including:*

(a) any voltage impacts, impacts on current loading settings and impacts on fault currents;
(b) the connection feasibility;
(c) the need for any line or equipment upgrades;
(d) the need for transmission system protection modifications; and
(e) any metering requirements."

The IESO has received a draft copy of the Connection Impact Assessment (CIA) performed by THES. The CIA has not identified any negative impact of the new generation plant on the THES distribution system.

The new generation plant is scheduled to be in service in March 2007 for commissioning, with a permanent in service date of April 2007.

– End of Section –

2. Review of Connection Proposal

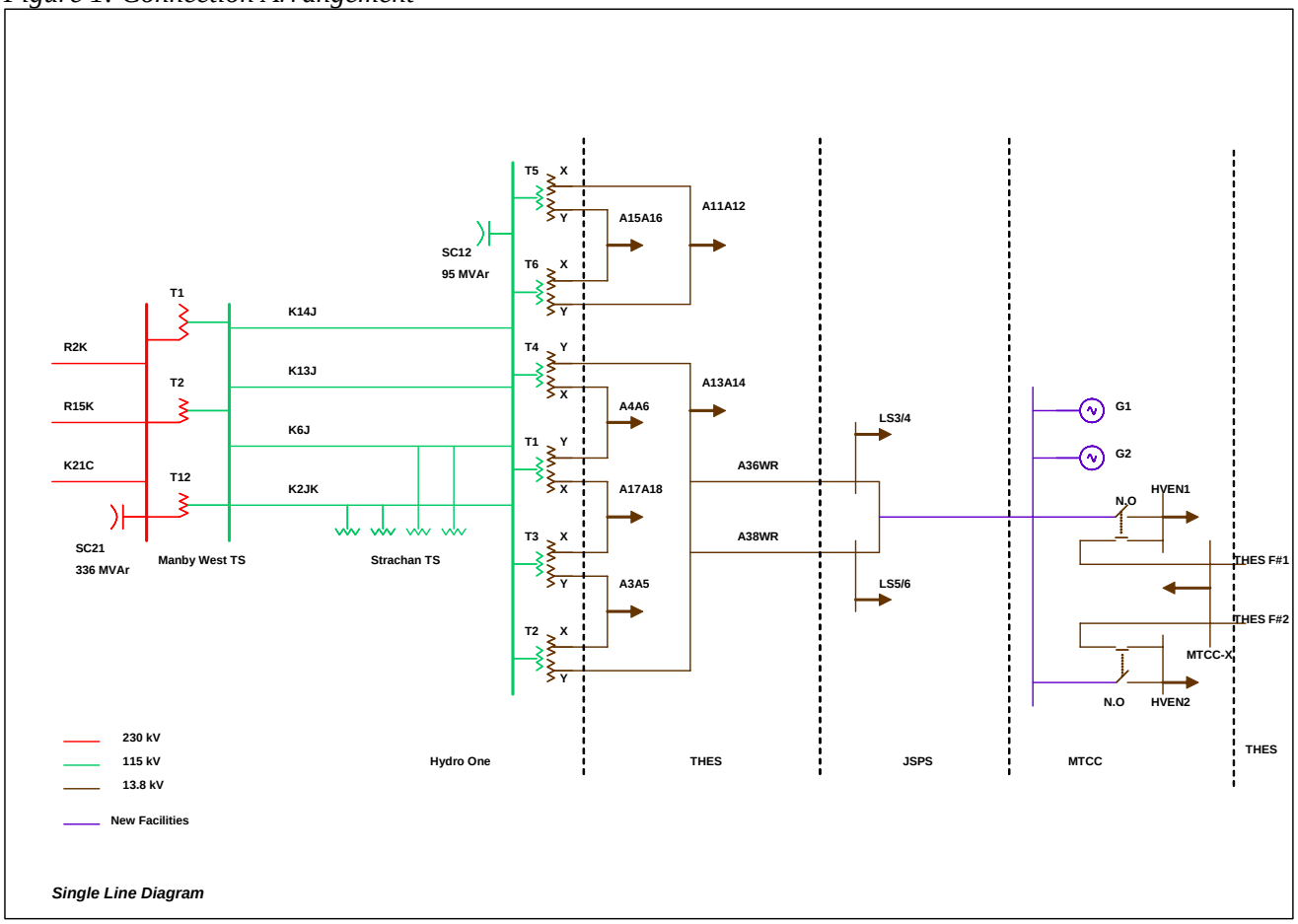
2.1 Connection Arrangement

When the generators operate in parallel with the system, the connection points of the facility to THES 13.8 kV distribution system are located at the John Street Pumping Station (JSPS), fed by THES feeders A36WR and A38WR. These two feeders are connected to the A13 and A14 buses at the Windsor station, called John TS by Hydro One. The A13 & A14 buses are supplied from Hydro One's "T2Y" and "T4Y" 13.8 kV windings of respectively T2 and T4 115kV/13.8kV, 45/60/75 MVA transformers at John TS.

An automatic transfer scheme in the existing 13.8 kV HVEN1 and HVEN2 switchgears at MTCC will be used to prevent the generators getting connected to the Toronto Hydro system through MTCC.

The proposed connection arrangement is shown in Figure 1 below.

Figure 1: Connection Arrangement



2.2 On-line Monitoring

The *Market Rules* (Chapter 4 section 7.3) require that for generation facilities which do not participate in the IESO administered market monitoring information to be provided to the IESO on a continual basis from facilities including a generation unit rated at greater than 20 MVA or that comprises generation units the ratings of which in the aggregate exceeds 20 MVA. Since the proposed generator plant is below the above thresholds, telemetry for on-line monitoring is not required by the IESO.

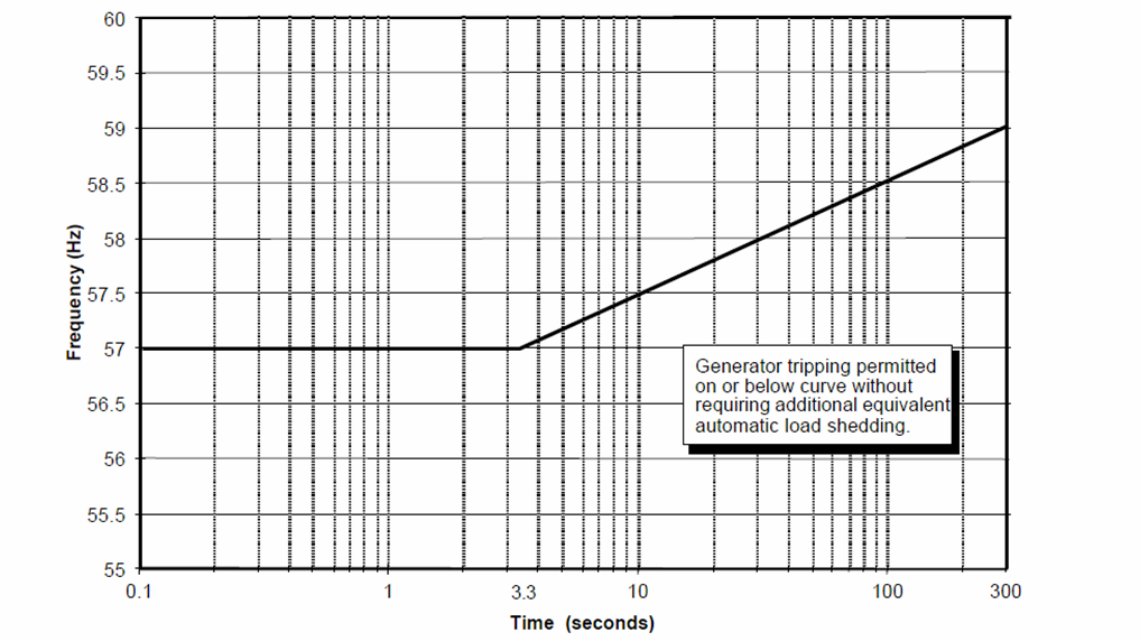
2.3 Protection Systems

Toronto Hydro Electrical System will have to follow the *Distribution System Code* technical requirements for adequate protection at John TS (Windsor station).

2.4 Under-Frequency Tripping

Reference #3 of Appendix 4.2 of the *Market Rul*es requires that generating facilities be capable of operating continuously at full power for a system frequency range between 59.4 to 60.6 Hz. For under-frequency system conditions, generators shall not trip for frequency variations that are above the curve shown in Figure 2.

Figure 2: Standard for Setting Under-Frequency Trip Protection for New Generators



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3. Data Verification

THES has provided the following equipment specifications for new components.

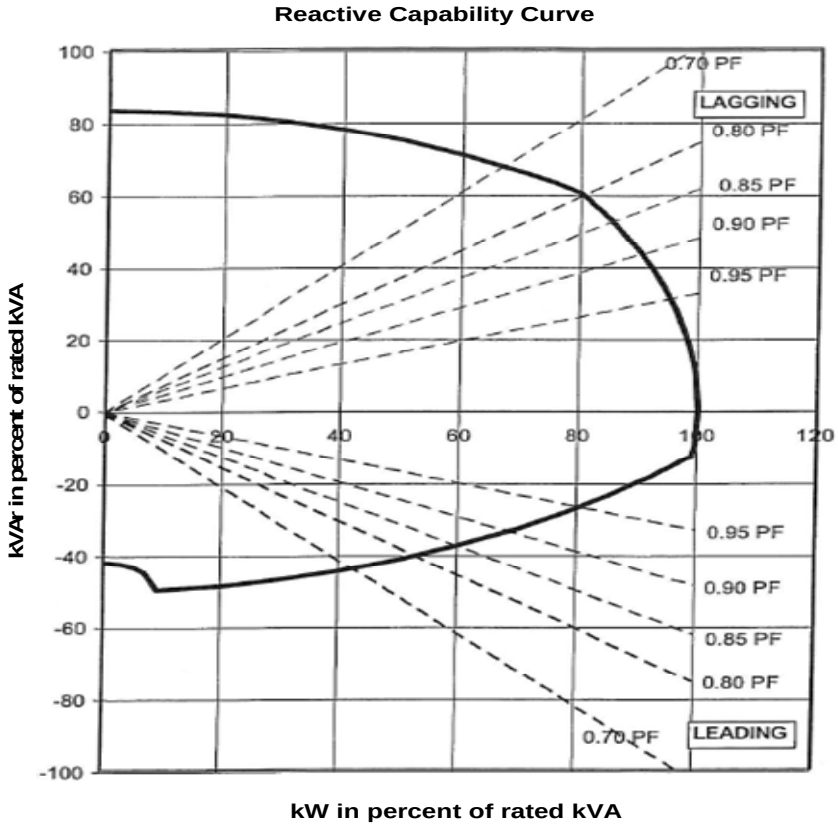
(a) Generators

Two units of 5.5 MW, 5.875 MVA, 13.8 kV, 1800 rpm synchronous generators would be installed.

The proponent has provided the reactive power capability curve shown in Figure 3 for the generators expected to be installed.

At rated output, the kW / kVA ratio is 5.5 MW / 6.875 MVA = 80%. At this ratio, the generator can produce 60% × 6.875 = 4.125 MVAr or absorb 25% × 6.875 = 1.72 MVAr. This level of reactive power generation corresponds to 0.8 lag and 0.95 lead power factor.

Figure 3: Reactive Power Capability Curve



The *Market Rules* do not specify performance standards for non-market participant embedded generators which are smaller than 10 MVA, unless the facility is comprise of generation units whose net output is greater than 50 MVA. The other synchronous generators shall have the capability to supply or absorb reactive power from 0.9 lag to 0.95 lead based on rated active power output and rated

voltage. Although this requirement does not specifically apply to the proposed facility assessed in this SIA, its range of reactive power capability meets the *Market Rules* requirements.

The data for the generator model GENROU driven from data provided by the applicant are given below. Reactances are in per unit on 6875 kVA base.

X_d = 1.987	X'_d = 0.267	X''_d = 0.175	X_q = 1.039	X''_q = 0.196	X_2= 0.19	X_0= 0.1
Ra=0.12242	Rfd=0.835					
T'_{do} = 5.24	T''_{do} = 0.05	T'_{qo} =0.703	T''_{qo} = 0.033	H = 0.824	S(1.0) = 0.15	S(1.2) = 0.40

WR^2= 7570 lb-ft^2
H = 0.231 WR^2 $(rpm)^2$ 10^{-6} / (kVA rating) [kW-s / kVA]

– End of Section –

4. System Description

4.1 Existing Transmission and Distribution

Enwave Energy is proposing to develop an Emergency Generation Plant consisting of two 6.875 MVA steam turbine generators embedded within the Toronto Hydro Electric System distribution system.

The connection points of this facility to THES 13.8 kV distribution system are located at the John Street Pumping Station being fed by THES feeders A36WR and A38WR. These two feeders are connected to the A13 and A14 buses at the Windsor station, called John TS by Hydro One. The A13 & A14 buses are supplied from Hydro One's "T2Y" and "T4Y" 13.8 kV windings of respectively T2 and T4 115kV/13.8kV, 45/60/75 MVA transformers at John TS

John TS is connected to Manby West TS 230/115 kV through four 115 kV circuits: K2JK, K6J, K13J and K14J.

4.2 Area Loads and Load Growth

Figure 3, Figure 4 and Figure 5 represent the load at the A13A14 13.8 kV bus at John TS, during winter, spring and summer conditions, respectively.

Figure 3: John TS - A13A14 bus- Winter Load

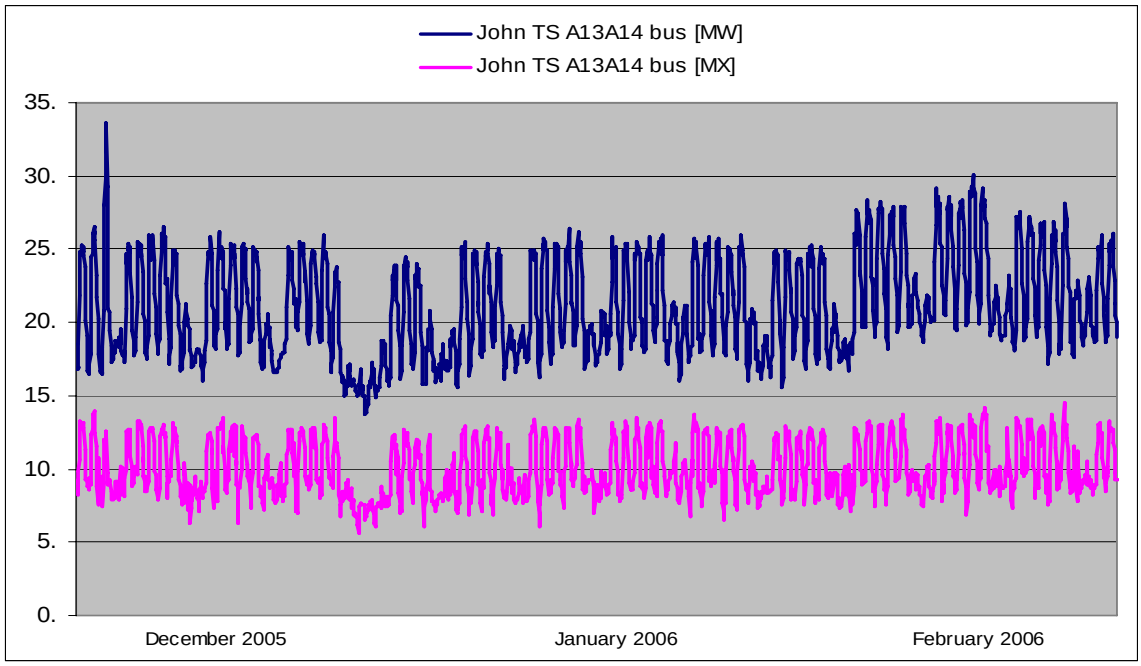


Figure 4: John TS - A13A14 bus- Spring Load

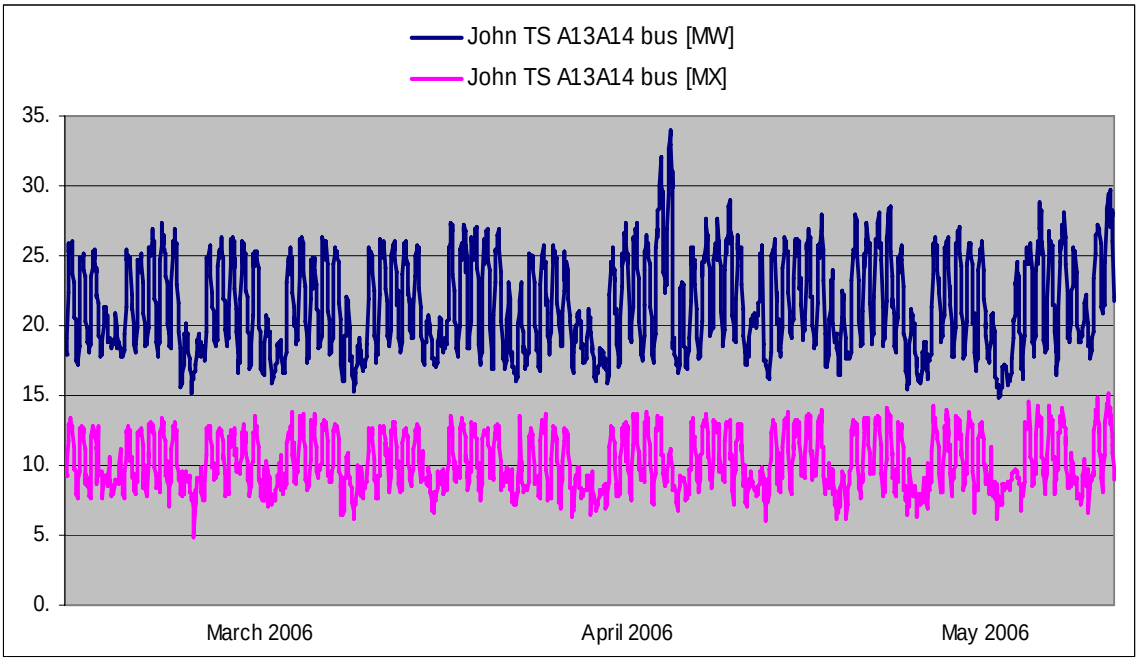
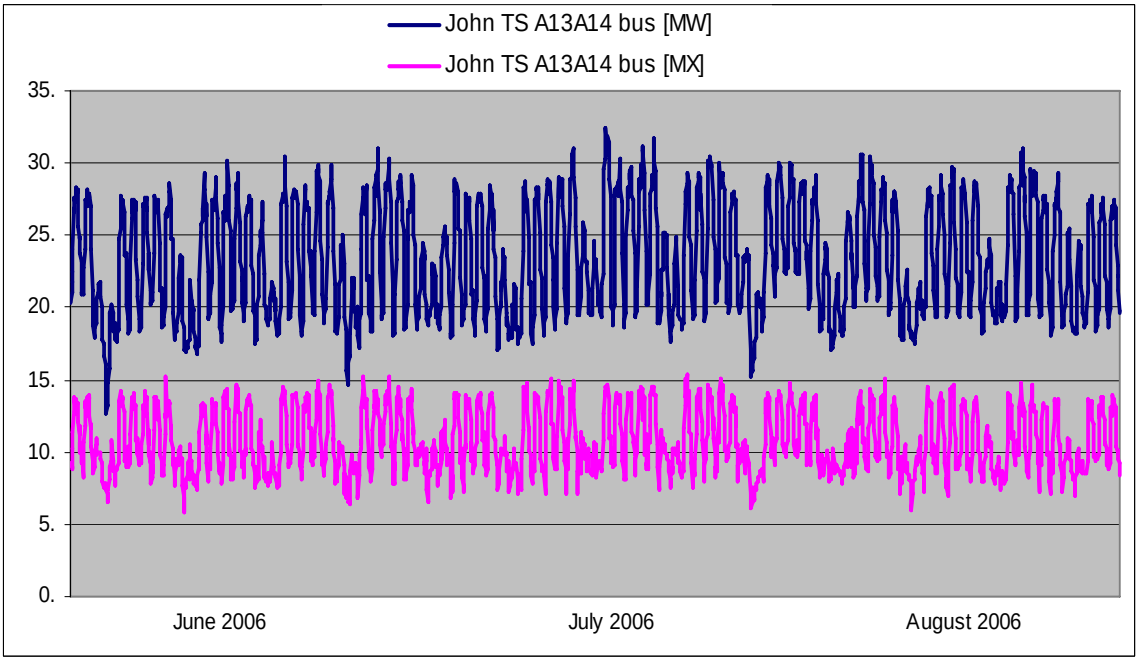


Figure 5: John TS - A13A14 bus- Summer Load



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5. Short Circuit Assessment

The impact of the new facility on the distribution system has been conducted by the THES. The analysis includes the short-circuit adequacy of the 13.8 kV breakers connecting A36WR and A38WR feeders to John TS 13.8 kV buses. THES study confirms that the connection of the embedded new facility will not negatively impact their system.

Fault level studies in the transmission system are normally completed by the transmitter, in this case Hydro One, at the IESO request to specifically examine the effect of the proposed system changes on fault levels at existing facilities in the area. In general, small embedded generation facilities behind transformer and distribution feeder impedances, like the one proposed in this SIA, do not have a large impact on the transmission system fault levels.

The 115 kV breakers at John TS are rated at 39.3 kA symmetrical and 45.5 kA asymmetrical short circuit interrupting capabilities. The short circuit levels in 2002 were 20.3 kA 3 phase symmetrical and 16.03 kA asymmetrical.

With the low contribution of the new development to the area fault levels it is considered that the interrupting capability of the John TS breakers will be adequate.

Therefore, no detailed fault level studies were required to be conducted by Hydro One for this particular project.

– End of Section –

6. System Impact Studies

This connection assessment study focused on:

1) Thermal analysis of the transmission elements at John TS.

2) Post-contingency voltage declines at John TS following the loss of the generators

Transient performance of the generation units was not assessed in this study. Due to the combination of size and electrical location of the proposed embedded generation plant, the impact on the power system stability of the units is deemed to be insignificant, and no specific performance is required by the IESO for the generation control systems. Therefore, an IESO study of the control systems is not required for this particular connection.

6.1 Study Assumptions

The PSS/E software was used to carry out the technical analyses.

Based on the information provided by THES, the two new generators were added into the base case. Since the THES distribution system is not modeled in the IESO base cases, the generators were modeled connected directly to the A13A14 13.8kV bus at John TS. This assumption gives more conservative thermal and voltage decline results than using the complete model. However, provided that the results are acceptable, the real impact of the new facility is acceptable, too.

(c) Power System Modeling

To conduct the computer analysis, the IESO PTI base case model was used.

The Toronto zone load was scaled to match the IESO 2009 extreme weather monthly peak load forecast.

The Central Toronto individual station MW loads were adjusted to match the 2009 load forecast as per HydroOne – Toronto Hydro joint study. The assumed load power factor was 0.9. The above loads were compared with loading that occurred on August 1, 2006 when the highest record on Ontario system peak demand was set and it was found that the forecast reflects a fair load distribution.

Sithe Goreway GS was added to the system with 900 MW output.
Portlands Center GS was added to the system with 550 MW output.
Leaside 115 kV and Hearn 115 kV buses were split to respect the maximum short-circuit levels.

6.2 Thermal Loading Assessment

The incorporation of new generation into THES network essentially reduces the power flow into John TS T2 and T4 transformers compared to the present conditions.

Based on historical data as presented in Figures 3, 4, and 5 above, the minim load connected to 13.8 kV buses A13 and A14 was 15 MW.

Under the extreme conditions with minimum load on the A13 and A14 buses, and Enwave generation at maximum capacity of 11 MW, the new generation facilities will displace the load connected to these buses, but it will not result in a net injection of power into the buses, nor from the distribution system into the transmission system.

Therefore, it can be concluded without any detailed technical power flow simulations that the addition of the new facility will not negatively impact the thermal capability of the IESO controlled grid pre or post-contingency.

As per Distribution System Code, THES has the obligation to assess the thermal impact of the new generation plant on the distribution system.

6.3 Voltage Assessment

IESO's Transmission Assessment Criteria states that after a contingency, with all *facilities* in service pre-contingency, system **voltage declines** are to be limited to 10%.

By adding a generator equipped with an Automatic Voltage Regulator set to regulate terminal voltage at a value close to 1 per unit, it normally helps the voltage performance both pre-contingency and post-contingency, unless the contingency disconnects the generator from the system. Therefore, the only contingency simulated was the loss of the generating plant under the peak load conditions.

The generators were simulated as being connected directly to the 13.8 kV bus at John TS. While this representation will result in more conservative post-contingency voltage changes at John TS buses than the real case, this representation is not representative for the voltage changes at the generator terminals or on the THES feeders.

The IESO recommendation is the generation units to be operated in voltage control mode. However, to observe the maximum post-contingency impact on the IESO-controlled grid, two extreme conditions were studied: 0.8 lagging power factor and 0.95 leading power factor for the generation output. The results obtained under this maximum and minimum reactive output conditions are more conservative than any reactive output between the two limits. The results for a 0.9 lagging power factor are presented in the tables for sensitivity purposes.

The active power was set to maximum output, i.e. 2×5.5 MW. The simulations ware conducted with load being modeled as constant power for both pre and post ULTC movement conditions. The worst voltage decline from post-ULTC action and pre-ULTC actions are presented in the following tables.

Two cases were studied: with John SC11 96 MVAr capacitor in service and out of service.

Case 1:	John SC11 I/S	John TS 118 kV bus		John TS A13A14 buses	
Generation at		kV	% VD	kV	% VD
0.8 lagging p.f	Pre-contingency	124.04		14.99	
	Post-contingency - loss of G1 and G2	123.57	0.38	14.65	2.27
0.9 lagging p.f	Pre-contingency	123.96		14.91	
	Post-contingency - loss of G1 and G2	123.57	0.31	14.65	1.74
0.95 leading p.f.	Pre-contingency	123.58		14.58	
	Post-contingency - loss of G1 and G2	123.57	0.01	14.65	-0.48

Case 2:	John SC11 O/S	John TS 118 kV bus		John TS A13A14 buses	
Generation at		kV	% VD	kV	% VD
0.8 lagging p.f	Pre-contingency	120.50		14.54	
	Post-contingency	120.02	0.40	14.20	2.34
0.9 lagging p.f	Pre-contingency	120.40		14.47	
	Post-contingency	120.02	0.32	14.20	1.87
0.95 leading p.f.	Pre-contingency	120.03		14.12	
	Post-contingency	120.02	0.01	14.20	-0.57

As shown in tables above, the simulated contingency resulted in insignificant voltage changes, well below 10%. Therefore, the *IESO Transmission Assessment Criteria* regarding voltage decline is respected.

– End of Section –

– End of Report –