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CONNECTION ASSESSMENT & APPROVAL PROCESS

System Impact Assessment Report

Erie Shores Wind Development Project

Applicant: **AIM PowerGen Corporation**

CAA ID 2003-106

Long Term Forecasts & Assessments Department &
Consistent Information Set Department

April 20, 2005

System Impact Assessment Report

Erie Shore Wind Development Project

Acknowledgement

The IESO wished 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, PSS/E software developers, equipment manufactures, Hydro One at the time the assessment was carried out. The IESO assumes no responsibility for the accuracy or completeness of such information, mathematical models, including the results of studies carried out by Hydro One 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.

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

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, the connection applicant must be aware that the IESO may revise drafts of this report at any time in its sole discretion without notice to the connection applicant. Although the IESO will use its best efforts to advise the connection applicant of any such changes, it is the responsibility of the connection applicant to ensure that the most recent version of this report is being used.

Hydro One

The results given in this System Impact Assessment report are based on the information available at the time of the study, suitable for a preliminary assessment of this transmission system reinforcement proposal.

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

The short circuit results are only for the purpose of assessing the capabilities of existing breakers and identifying upgrades required to incorporate the proposed facilities. These results should not be used in the design and engineering of any new or existing facilities. The necessary data will be provided by the transmitter(s) and discussed with any connection proponent upon request.

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

The additional facilities or upgrades which are required to incorporate the proposed facilities have been identified to the extent permitted by a 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.

SYSTEM IMPACT ASSESSMENT REPORT

For

ERIE SHORE WIND DEVELOPMENT PROJECT

1.0 INTRODUCTION

This System Impact Assessment has been conducted to examine the impact on the reliability of the IESO controlled grid by the addition of (a) 99 MW, (b) 51 MW of wind power generation into the 115 kV circuit WT1T between Tillsonburg TS and Cranberry Junction. The proposal to generate 99 MW has been selected for development as a result of the Ontario Government's RFP to acquire 300 MW of new renewable power generation, and is scheduled to be in service by the end of 2005.

The connection applicant, AIM PowerGen retained Power Tech Global Inc. to conduct the study. The main report prepared by Power Tech Global is attached to this SIA report as Appendix 1.

2.0 PROPOSED CONNECTION OF ERIE SHORE WIND FACILITY

The Erie Shore wind generation facility will be located at about 30 km from Tillsonburg Junction which will be located about 1.5 km from Tillsonburg TS and about 2 km from Cranberry Junction. The Erie Shore project will be developed in two stages.

First Stage - 99 MW of Generation

The first stage is to develop a 99 MW generation facility consists of sixty six GE1.5 MW, 575V induction generators. They will be connected to four 34.5 kV feeders (W1, W2, E1 and E2) using individual tower-base mounted 1.7 MVA, 34.5 kV/600 V transformers. These four feeders will be connected to a common 34.5 kV collector bus bar via 1200 A, 20 kA circuit breakers and disconnect switches. This 34.5 kV collector bus bar will be connected to the 115 kV circuit WT1T using a single 75/100/125 MVA (ONAN/ONAF/ONAF), 115/34.5 kV transformer T1, two circuit breakers CB1, CB3 and a circuit switcher CS1 as shown in Figure 1.

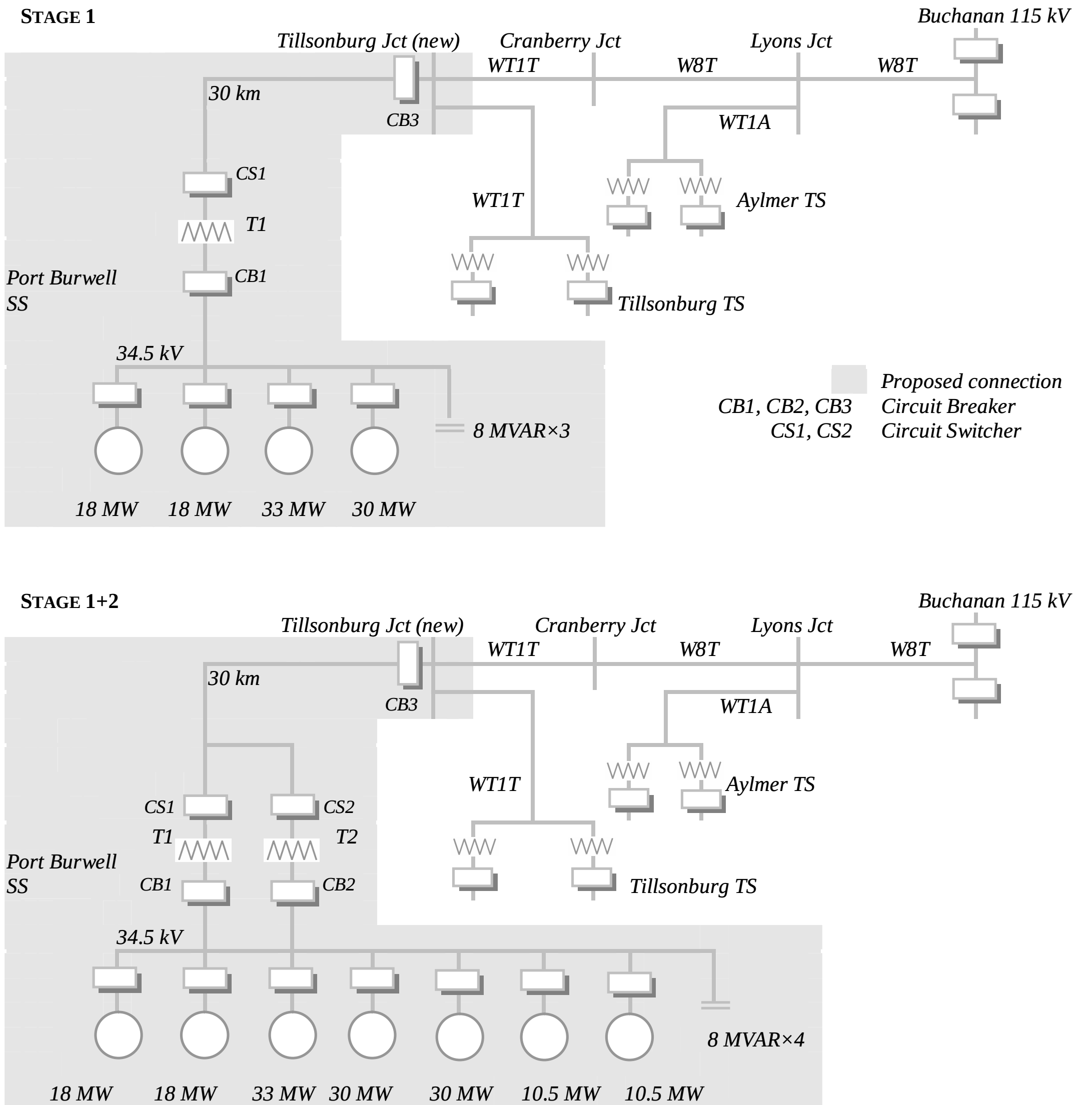
Second Stage - 51 MW of Generation

The second stage is to develop a 51 MW generation facility consists of thirty four induction generators of same type as used in stage 1. They will be connected to three new 34.5 kV feeders (W3, E3 and E4). These three new feeders will also be connected to the same collector bus from stage 1. A new 115/34.5 kV transformer T2 with ratings 35/50/60 MVA (ONAN/ONAF/ONAF), a circuit breaker CB2 and a circuit switcher CS2 will be connected between the collector bus and the 115 kV bus at Port Burwell SS as shown in Figure 1.

The number of wind turbines and power injections to the collector bus from each feeder at each stage is summarized below.

Feeder	*W1*		*W2*		*W3*		*E1*		*E2*		*E3*		*E4*		*Total*	
Stage 1	12	18.0 MW	12	18.0 MW	00	00.0 MW	22	33.0 MW	20	30.0 MW	00	00.0 MW	00	00.0 MW	66	99.0 MW
Stage 2	00	00.0 MW	00	00.0 MW	20	30.0 MW	00	00.0 MW	00	00.0 MW	07	10.5 MW	07	10.5 MW	34	51.0 MW
Total	12	18.0 MW	12	18.0 MW	20	30.0 MW	22	33.0 MW	20	30.0 MW	07	10.5 MW	07	10.5 MW	100	150.0 MW

FIGURE 1 : PROPOSED CONNECTION



3.0 GENERATORS

The GE 1.5 MW, 60 Hz variable speed wind turbine employs a doubly-fed induction generator with a power converter interfacing the rotor and the grid. This wind turbine is capable of supplying or drawing reactive power to or from the grid, thus contributing to the grid voltage support or correction.

For the transient analysis, Power Tech Global modeled the GE1.5 MW induction generator using the PSS/E model which was available at the time of their analysis. The data used are given in section 9.0 and section 10.0 of the Appendix A. This model has been improved over time from its original version. However, from the limited number of sensitivity studies carried out by the IESO on the currently available model, the IESO has observed deficiencies and has reservations on the accuracy of transient simulation results. Consequently, the IESO assumes no responsibility for the completeness or the dependability on the conclusions drawn from transient simulations.

Requirement 1:

The Appendix 4.2 of the Market Rules requires that each induction generator connecting to the IESO-controlled grid must have the capability to:

- supply available active power continuously to the IESO-controlled grid while operating at facility terminal voltage ranging from 0.95 pu to 1.05 pu of rated facility terminal voltage.
- supply full active power and supply/absorb reactive power in the range of 0.9 lag to 0.95 lead power factor at a set value of the 115 kV voltage at the point new facility is connected to the existing IESO-controlled grid.

These two requirements would effectively limit the impedance between the generator terminal and the existing IESO-controlled grid to maximum of about 0.13 pu based on the MVA rating of the generation facility.

These requirements must be satisfied after completion of stage 1 and stage 2. If above capabilities are not met, additional reactive power compensation must be provided to compensate for excessive reactive power losses occurring between generator terminals and the existing IESO-controlled grid.

Requirement 2:

The applicant has not provided any type test data for generator models. The applicant is required to provide type test data that validates parameters used in the models used for the analysis or to perform commissioning tests to validate parameters eventually given to the IESO. Also actual evidence or test results on reactive power capability of generators used in this project must be provided to the IESO. If the applicant is performing commissioning tests, during the facility registration process, prior to connecting each stage of the development to the IESO-controlled grid, the applicant shall submit a detailed test plan on how the validation of model parameters and demonstration of reactive capabilities will be carried out.

If the data supplied for the registration of the new facilities or data found by the commissioning tests differ significantly from those that were used for the assessment, then some of the analysis might need to be repeated to ensure that no further facilities could be adversely affected.

Requirement 3:

Appendix 4.2 of the Market Rules requires that generators be able to operate continuously at available active power output for system frequencies between 59.4 to 60.6 Hz. For under-frequency system conditions, the generators shall not trip for frequency variations that are above the curve shown in Figure 2.

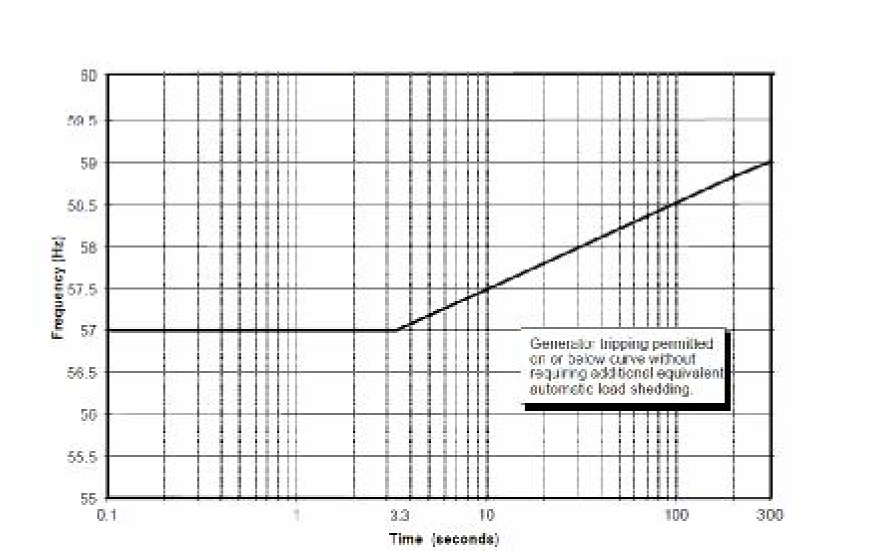


FIGURE 2 – STANDARD FOR SETTING UNDER-FREQUENCY TRIP PROTECTION FOR NEW GENERATORS

Requirement 4:

None of the new generators should trip for contingencies except for faults where the generator will be removed by configuration. This would mean during a fault in the system external to circuits WT1T, WT1A and W8T, no generator should be allowed to trip. Therefore, each generator should have sufficient low voltage ride through capability to remain connected to the IESO-controlled grid during disturbances.

Conversely, if the new facility causes any unacceptable performance to the existing power system, measures such as special protection schemes or operating limits must be used to prevent occurrence of those adverse effects.

If any special protection scheme requirements or operating limitations that are not identified by the IESO at the time of this SIA, but are identified at a later stage after performing detailed operating analysis, those requirements and operating limitations must be implemented.

Requirement 5:

Appendix 4.15 and Appendix 4.19 of the Market Rules list the IESO requirements with respect to the information on generator monitoring that must be made available to the IESO on a continual basis from all generators connected to the IESO-controlled grid. The applicant is required to install all the equipment needed for the IESO to continuously monitor these variables. It is required that at the minimum, the following quantities be monitored at the Erie Shore project.

- Net active and reactive power injection from the new generation facility
- status of new circuit switches and circuit breakers between collector bus and Tillsonburg Junction
- 115 kV and 34.5 kV voltages at the transformer station
- frequency at 34.5 kV collector bus

4.0 TRANSFORMERS

The 3-phase 115/34.5 kV transformers T1 and T2 have ratings 75/100/125 MVA (ONAN/ONAF/ONAF) and 35/50/60 MVA at (ONAN/ONAF/ONAF) respectively. They are not equipped with automatic ULTC facilities, but are equipped with off-load tap changers to change the voltage in the range of 113 - 127 kV in 2 kV steps.

The transformers have following impedances.

- T1: X = 0.075 pu, R = 0.075/35 = 0.0021 pu on 75 MVA base.
- T2: X = 0.075 pu, R = 0.075/35 = 0.0021 pu on 35 MVA base.
- Pad mounted transformers: X = 0.0575 pu, R = 0.0575/7.5 = 0.0076 pu on 1.75 MVA base.

Requirement 1:

The components of the impedance between the facility terminals and the existing IESO-controlled grid after stage 1 and stage 2 are completed are given below. The facility MVA base is 110 MVA for stage 1 and 170 MVA for stage 1+2.

For stage 1

Equivalent reactance of 66 × 34.5/0.6 kV transformers on 110 MVA base	0.0548 pu
Reactance of 115/34.5 kV transformer (0.075 pu on 75 MVA base) on 110 MVA base	0.1100 pu
Reactance of the 30 km line between Port Burwell SS and new Tillsonburg Jun. on 110 MVA base	0.1078 pu
Total reactance between the facility terminals and the existing IESO-controlled grid	0.2726 pu

For stage 1+2

Equivalent reactance of 100 × 34.5/0.6 kV transformers on 170 MVA base	0.0558 pu
Reactance of parallel 115/34.5 kV transformers (0.075 pu on 75, 35 MVA base) on 170 MVA base	0.1155 pu
Reactance of the 30 km line between Port Burwell SS and Tillsonburg Junction on 170 MVA base	0.1667 pu
Total reactance between the facility terminals and the existing IESO-controlled grid	0.3380 pu

After completion of stage 1 and stage 1+2, the net impedance between the machine terminals and the existing IESO-controlled grid would be exceeding 0.13 pu on facility MVA base. This would mean the total reactive power from the generators would not be available for voltage regulation of the existing 115 kV system due to excessive reactive power losses occurring between machine terminals and the existing IESO-controlled grid. Thus, reactive power supporting devices must be provided by the applicant. The amounts of reactive power compensation required for each stage are given in Section 7.0.

5.0 CIRCUIT BREAKERS AND DISCONNECT SWITCHES

The missing data for each circuit breaker and disconnect switch must be provided to the IESO prior to completion of the IESO's facility registration process.

Circuit Breakers			*Disconnect Switches*		
Rated voltage	115 kV	34.5 kV	Rated voltage	115 kV	34.5 kV
Interrupting time	-	-	Rated continuous current	1200 A	-
Interrupting media	SF6	-	Rated symm. short circuit capability	-	
Rated continuous current	1200 A	-			
Rated symm. short circuit capability	-	-			

IMPORTANT NOTE ON MODELS AND DATA

The applicant is required to ensure that the performance of the equipment that is installed meets or exceeds the predicted performance observed in the computer simulation results obtained using the models and available parameters. The applicant is required to provide type test data that validates parameters and reactive capabilities. If these data are not provided, during the facility registration process, prior to the connection of the new generators to the IESO-controlled grid, the applicant shall submit a detailed test plan to the IESO on validation of model parameters and reactive capabilities of the generators.

These requirements are independently applicable for each stage of the development.

6.0 ANALYSIS OF PROPOSED CONNECTION ARRANGEMENT

Since the maximum power injection from Erie Shore development is below 250 MW, it is sufficient that this generation project has a single connection between the generation facility and the IESO-controlled grid. Thus, the proposed connection arrangement in terms of number of connecting circuits is acceptable to the IESO.

However, the IESO Transmission Assessment Criteria state that new or modified facilities must not reduce the existing level of reliability of existing facilities. Specifically, if the new connection increases the fault exposure of the existing system significantly, it is necessary to install new circuit breakers to separate protection zones to eliminate the additional exposure. Thus, the originally proposed circuit switcher at new Tillsonburg Junction will have to be replaced with a circuit breaker CB3 as shown in Figure 1.

This breaker must be rated as follows:

- Maximum Operating Voltage – 127 kV
- Rated Interrupting Time – 5 cycles or less
- Short circuit symmetrical duty – 50 kA

> It is required that a 115 kV breaker be installed at the point of connection of the new 115 kV line to the existing IESO-controlled grid. The breaker is required to be rated for continuous operation at 127 kV and have a short current interrupting capability of 50 kA.

7.0 SUMMARY OF COMPUTER ANALYSIS

Pre-contingency conditions

- The following projects that are ahead of the Erie Shore project are included in the analysis.
  - TransAlta generation in Sarnia – 490MW
  - ATCO at Brighton Beach – 625 MW
  - Sithe generation in Brampton – 1009 MW
  - Thorold GS – 273 MW
  - Bruce Wind Generation – 200 MW
  - Port Albert Wind Farms – Goderich 50 MW
  - Imperial Oil GS – 285 MW
  - Sithe generation in Mississauaga – 765 MW
  - Pickering A, one unit only – 550 MW
  - Portlands Energy Centre – 550 MW
  - Collingwood Wind Generation – 200 MW
  - Northern Cross – Goderich – 50 MW
  - Vision Quest embedded wind generation at Douglas Point – 15 MW
- The study was performed for a system with all transmission elements in service.
- 2004 summer peak conditions were used for the analysis with total Ontario demand of 25,741 MW.
- For voltage decline studies, the active power loads were converted to constant current and constant admittance loads equally and the reactive power loads were converted only to constant admittance loads.

Contingencies

Since the Buchanan 115 kV area is considered to be a local area within the IESO-controlled grid, the IESO Transmission Assessment Criteria require simulation of only single element contingencies that are limited to loss of an element without a fault and phase-to-phase-to-ground fault on any generator or on any transmission equipment with normal fault clearance.

However, some of the contingencies simulated are more severe than what are required by the IESO Transmission Assessment Criteria. They are simulated to examine the robustness of the area with the wind farm placed in-service.

Contingencies for Voltage Decline Studies

- VC_1 = Loss of Buchanan T3
- VC_2 = Loss of M31W+M32W
- VC_3 = Loss of W44LC+W45LC
- VC_4 = Loss of D4W+D5W
- VC_5 = Loss of B560V+B561M
- VC_6 = Loss of N21W+N22W
- VC_7 = Loss of wind farm

Contingencies for Transient Stability Studies (the fault location is Buchanan or Bruce)*

- SC_1= 3 ph on W12W
- SC_2 = 3 ph on M31W
- SC_3 = LLG on N21W+N22W
- SC_4 = LG on W12W with BF
- SC_5 = LLG on M31W+M32W
- SC_6 = LLG on B560V+B561M*
- SC_7 = LLG on D4W+D5W
- SC_8 = LLG on W44LC+W45LC
- SC_9 = wind gust

Types of Simulations Done

Following contingencies were simulated with system conditions given below in order to investigate the impact on the system wide impact as well as the local area impact.

System wide Impact					
Case	*Summary of system conditions*			*Simulations done*	
	IESO demand	*AIM generation*	*BLIP*	*Voltage decline*	*Transient stability*
A_1	Peak	150 MW	3000 MW	VC_1,VC_2,VC_3,VC_4,VC_5,VC_6	SC_1,SC_2,SC_3,SC_4,SC_5,SC_6, SC_7,SC_8
A_2	Peak	150 MW	-1500 MW	VC_1,VC_2,VC_3,VC_4,VC_5,VC_6	SC_1,SC_2,SC_3,SC_4,SC_5,SC_6,SC_7,SC_8
A_3	Peak	100 MW	3000 MW	-	-
A_4	peak	100 MW	-1500 MW	-	-
Local area Impact					
Case	*Summary of system conditions*			*Simulations done*	
	IESO demand	*AIM generation*	*BLIP*	*Voltage decline*	*Transient stability*
B_1	peak	150 MW	-	-	-
B_2	light	150 MW	-	-	-
B_3	peak	100 MW	-	VC_7	SC_1,SC_4,SC_9
B_4	light	100 MW	-	VC_7	-

Impact on Local Voltages and Reactive Power Compensation

The impact of the wind farm on local voltages is covered in sections 3.0 and 4.0 of the Appendix 1 for the development of 150 MW and 100 MW respectively. This study was performed also to determine the optimal size and location for reactive power compensation devices.

It should be noted that the wind farm model used in the studies originally assumed a collector bus operating at 27.6 kV. Further evaluation performed by the developer after the studies were finalized, indicated that it would be more economical to build a 34.5 kV collection system; hence the design of the wind farm was changed. It was concluded that moving to a higher distribution voltage would not significantly affect the results of the studies and would likely result in less reactive power losses in the wind farm distribution system. Hence, the studies were not repeated for the 34.5 kV design except for the analysis done to find the LVRT requirement.

A brief summary of the study results, for the original 27.6 kV design is presented in Tables 1 and 2. Some of the results were obtained from Appendix A of the consultant’s report and others were obtained from additional simulations performed by the IESO.

Table 1. 150 MW Erie Shores Wind Farm

Peak Load Conditions (Buchanan Transformers on tap 1.0)							
Case	*WF Output @ 27.6 kV collector bus*	*WF Output @ 115 kV Tillsonburg bus*	*Flow on W8T into Buchanan 115 kV*	*Flow on Buchanan 230/115 kV transformers*	*Buchanan Voltage*	*Tillsonburg Voltage*	
						Existing LV caps I/S	*Existing LV caps O/S*
In service Vt @1.04 pu	149 MW, 13.2 MVAR	144 MW, -15.8 MVAR	34.1 MW, -20.8 MVAR	330 MW 123 MVAR	126.1 kV	122.5 kV	118. kV
In service Vt @1.00 pu	148.9 MW, 6.6 MVAR	144 MW, -24.7 MVAR	33.4 MW, -34.4 MVAR	330 MW 141 MVAR	125.7 kV	118.6 kV	114.4 kV
Loss of wind, with farm connected in pf control	0 MW, 9.6 MVAR	0 MW -10 MVAR	-113.9MW, -18.4 MVAR	501 MW 138MVAR	125.4 kV	118.4 kV	100.2 kV
Loss of WF no shunt cap	0 MW 0 MVAR	0 MW, -.5 MVAR	-110.6MW, -27.3 MVAR	495 MW 147 MVAR	125.2 kV	115.9 kV	100.2 kV
10 MVAR shunt cap switched in post cont	0 MW 0 MVAR	0 MW, -10.6 MVAR	-114.1 MW -18 MVAR	504 MW 141 MVAR	126 kV	119.1 kV	104.2 kV
20 MVAR shunt cap switched in post cont at AIM LV	0 MW 0 MVAR	0 MW, -21.8 MVAR	-118.7 MW -7.9 MVAR	508 MW 129 MVAR	126.2 kV	121.9 kV	108.2 kV
20 MVAR shunt cap switched in post cont at Tillsonburg	0 MW 0 MVAR	0 MW, -0.6 MVAR	-117.9MW, -7.9MVAR	504 MW 129 MVAR	125.6 kV	121.4 kV	108.4 kV
Off Peak Load (Buchanan Transformers on tap 1.0)							
Case	*WF Output @ 27.6 kV collector bus*	*WF Output @ 115 kV Tillsonburg bus*	*Flow on W8T into Buchanan 115 kV*	*Flow on Buchanan 230/115 kV transformers*	*Buchanan Voltage*	*Tillsonburg Voltage*	
						Existing LV caps I/S	*Existing LV caps O/S*
In service Vt @1.04 pu	149 MW -22.1 MVAR	144.4 MW -51.9 MVAR	105.9 MW, -23.4 MVAR	61 MW, 6 MVAR	130.3 kV	127.6 kV	123.2 kV
In service Vt @1.00 pu	148 MW -28.2MVAR	144 MW -61.1 MVAR	105.3 MW -37 MVAR	61 MW, 22 MVAR	130 kV	124 kV	119.7 kV
Loss of wind, with farm connected in pf control	0 MW, -4 MVAR	0 MW, 3.3 MVAR	-34.3 MW 37.4 MVAR	219 MW, -23.4 MVAR	131.9 kV	139 kV	125.5 kV
Loss of WF no shunt cap	0 MW 0 MVAR	0 MW, -0.8 MVAR	-29 MW 38.5 MVAR	219 MW -150 MVAR	132	140 kV	126.6 kV
10 MVAR shunt cap switched in post cont	0 MW 0 MVAR	0 MW -15.1 MVAR	-35.5 MW 55.9 MVAR	219 MW -164 MVAR	131.4	143 kV	129.9 kV
20 MVAR shunt cap switched in post cont at AIM LV	0 MW 0 MVAR	0.1 MW -31.6 MVAR	-36.3 MW 71.3 MVAR	221 MW -183.6 MVAR	131.8	147 kV	133.3 kV
20 MVAR shunt cap switched in post cont at Tillsonburg	0 MW 0 MVAR	0.1MW -0.8 MVAR	-36.2 MW 72.7 MVAR	221 MW -184 MVAR	131.8	147.3 kV	133.5 kV

Table 2. 100 MW Erie Shores Wind Farm

Peak Load Conditions (Buchanan Transformers on tap 1.0)							
Case	*WF Output @ 27.6 kV collector bus*	*WF Output @ 115 kV Tillsonburg bus*	*Flow into W8T at Buchanan 115 kV*	*Flow on Buchanan 230/115 kV transformers*	*Buchanan Voltage*	*Tillsonburg Voltage*	
						Existing LV caps I/S	*Existing LV caps O/S*
In service Vt @1.04 pu	100 MW, 9 MVAR	98 MW, -11 MVAR	-11.4 MW, -11.4 MVAR	385 MW 117 MVAR	126.1 kV	123.3 kV	117.7 kV
In service Vt @1.00 pu	100 MW, 2.3 MVAR	98 MW, -18.7 MVAR	-11.8 MW, -23.1 MVAR	385 MW 131 MVAR	125.7 kV	120 kV	114.6 kV
Loss of wind, with farm connected in pf control	0 MW 0 MVAR	0 MW -.5 MVAR	-114.1MW, -31.1 MVAR	401 Mw 155MVAR	125.4 kV	118.7 kV	100.2 kV
Loss of WF no shunt cap	0 MW, 0 MVAR	0 MW, -0.5 MVAR	-114.1MW, -15 MVAR	499 MW 156 MVAR	125.2 kV	115.7 kV	100.2 kV
10 MVAR shunt cap switched in post cont	0 MW, 0 MVAR	0 MW, -10.8 MVAR	-113.8 MW, 1 MVAR	500 MW 135 MVAR	126 kV	120.1 kV	104.2 kV
20 MVAR shunt cap switched in post cont at AIM LV	0 MW, 0 MVAR	0 MW, -23.1 MVAR	-113.9 MW, 1.1 MVAR	508 MW 114 MVAR	126.2 kV	124.7 kV	108.3 kV
20 MVAR shunt cap switched in post cont at Tillsonburg	0 MW, 0 MVAR	0 MW, -0.6 MVAR	-114.1 MW, -15.1 MVAR	504 MW 114 MVAR	125.6 kV	124.8 kV	108.4 kV
Off Peak Load (Buchanan Transformers on tap 1.0)							
Case	*WF Output @ 27.6 kV collector bus*	*WF Output @ 115 kV Tillsonburg bus*	*Flow into W8T at Buchanan 115 kV*	*Flow on Buchanan 230/115 kV transformers*	*Buchanan Voltage*	*Tillsonburg Voltage*	
						Existing LV caps I/S	*Existing LV caps O/S*
In service Vt @1.04 pu	100 MW -24 MVAR	98 MW -45 MVAR	62.6 MW, -14.6 MVAR	110 MW -89.4 MVAR	130.9 kV	130.4 kV	125 kV
In service Vt @1.00 pu	0 MW -30.2 MVAR	97 MW -53.5 MVAR	62 MW -26.3 MVAR	110 MW -75.4 MVAR	130.6 kV	127.4 kV	122 kV
Loss of wind, with farm connected in pf control	0 MW, -4 MVAR	0 MW, 3.3 MVAR	-34.8 MW 37.4 MVAR	219 MW -150 MVAR	131.9 kV	139 kV	125.5 kV
Loss of WF no shunt cap	0 MW 0 MVAR	0 MW, -0.8 MVAR	-35 MW 41.8 MVAR	219 MW -165 MVAR	132.0 kV	140 kV	126.6 kV
10 MVAR shunt cap switched in post cont	0 MW 0 MVAR	0 MW, -5.2 MVAR	-35.5 MW 56 MVAR	220 MW -165 MVAR	131.4 kV	147.3 kV	129.9 kV
20 MVAR shunt cap switched in post cont at AIM LV	0 MW 0 MVAR	0 MW, -32 MVAR	-36.3 MW 72.2 MVAR	221 MW -184 MVAR	131.8 kV	147.3 kV	133.4 kV
20 MVAR shunt cap switched in post cont at Tillsonburg	0 MW 0 MVAR	0 MW, -08 MVAR	-36.2 MW 72.2 MVAR	221 MW -184 MVAR	131.8 kV	147.3 kV	133.5. kV

Based on study results obtained with 27.6 kV collection system that are summarized in Tables 1 and 2, it can be concluded that with 100 MW or 150 MW in-feed in service:

- The wind farm has no significant effect on the Buchanan 115 kV voltage.
- The active and reactive power flow in Buchanan 115/230 kV transformers are reduced.
- The power flow and losses in 115 kV lines WT1T (Cranberry Jct to Tillsonburg Jct) and W8T are reduced.
- The voltage profile on 115 kV lines WT1T and W8T is improved.

Post-Contingency Voltage Decline

The contingencies tested do not indicate any voltage declines that are greater than 10 % for pre or post ULTC action of any transformer in the IESO-controlled grid. Thus, it meets the voltage change requirement specified in the IESO Transmission Assessment Criteria.

The IESO investigated the post-contingency voltage decline (with 34.5 kV machine terminal voltage) in the event of the loss of 100 MW wind farm when operating at 0.9 lag power factor due to a contingency associated with the new 115 kV circuit between the wind farm and the tap point to the existing IESO-controlled grid at new Tillsonburg Junction. The followings would be the projected percentage pre-ULTC voltage changes.

Event	*∆V % at Tillsonburg 115 kV bus*	*∆V % Tillsonburg 27.6 kV bus*
The new circuit is lost when the wind farm operates full MW output and at 0.9 lag power factor	- 4.8	- 4.8
Switching on a 24 MVAR single capacitor at Tillsonburg 27.6 kV bus simultaneously with the contingency	- 1.5	- 1.8
Switching on a 6 MVAR single capacitor at Tillsonburg 27.6 kV bus after the contingency occurs	0.8	1.7
Switching of a 8 MVAR single capacitor at Tillsonburg 27.6 kV bus after the contingency occurs	1.1	2.2

Although the percentage voltage decline due to the loss of the wind farm is within the IESO voltage criteria for post-contingency situations, presently the customers who are connected to Tillsonburg TS do not experience this voltage variation of 4.8 %. Since the output of the wind farm would vary significantly due to its dependence on the prevailing wind condition, it is expected that a variation in local voltage could occur quite frequently. In order to mitigate this adverse result on the customers connected to the Tillsonburg TS, it is required that shunt capacitors be installed.

Magnitude of Reactive Power Compensation

Sensitivity studies carried out to identify the optimal size of the shunt capacitors showed that for a development of 100 MW:

- a total of 24 MVAR shunt capacitors connected to 27.6 kV bus of Tillsonburg TS that would automatically switched in post-contingency can reduce the voltage decline at Tillsonburg TS to 1.8 %.
- with the installation of three 8 MVAR shunt capacitors, the voltage change due to a single capacitor switching is than 4 %.

If the Erie Shores wind farm is developed up to 150 MW, then an additional 8 MVAR shunt capacitor may have to be provided.

It is appropriate that part of this reactive compensation is available with thyristor-controlled reactive power device in order to offer continuous, smooth, dynamic and fast reactive power compensation. Since the output of the wind farm would vary significantly depending on the prevailing wind conditions, the amount of reactive power compensation needed to mitigate the voltage change due to loss of wind farm would change accordingly. Therefore, the capacitor bank will need to be controlled via a local under-voltage and over-voltage scheme.

Location of Reactive Power Compensation

The reactive power generated by the wind farm could be lost due to one of the following events:

(a) a contingency associated with the new 115 kV line between the wind farm and Tillsonburg Jct.
(b) a fault on Port Burwell SS 115 kV bus
(c) a fault on Port Burwell SS 34.5 kV or wind farm collector bus
(d) the loss of wind

If the shunt capacitors are connected to the Erie Shores 34.5 kV bus, then they will be available for voltage support only for (d). If the shunt capacitors are connected to the 27.6 or 115 kV bus at Tillsonburg TS, then they will be available to provide voltage support for (a), (b), (c) and (d).

For 100 MW Development

AIM PowerGen is required to provide 24 MVAR of reactive compensation via three shunt capacitors of 8 MVAR each. It is required that controls be provided to switch the shunt capacitors automatically on voltage detection. It is recommended that shunt capacitors be located on the 27.6 kV bus at Tillsonburg TS in order to provide full benefit when the wind farm is lost due to a contingency in new equipment or due to lack of wind. Alternatively, the shunt capacitors could be located at the 34.5 kV bus of applicant owned Port Burwell SS.

For 150 MW Development

AIM PowerGen may be required to provide an additional 8 MVAR of reactive compensation via one additional shunt capacitor. It is required that controls be provided to switch the shunt capacitors automatically on voltage detection. It is recommended that shunt capacitors be located on the 27.6 kV bus at Tillsonburg TS in order to provide full benefit when the wind farm is lost due to a contingency in new equipment or due to lack of wind. Alternatively, the shunt capacitors could be located at the 34.5 kV bus of applicant owned Port Burwell SS.

Wind Gust Simulation

A wind gust simulation was carried out for the doubly-fed induction generator model for a wind gust from 6m/s to 15m/s over 5 s. The simulation assumed that the wind gust sweeps over about 20 % of the farm. Results show that the voltage change at Tillsonburg is only about 2 %. The results of this simulation are presented in section 4.3 of the consultants report.

Impact on Power Flow – Local Area

The results of load flow studies indicated that the power flow on all circuits is expected to be within their thermal limits.

Recognizing that the wind turbine is able to deliver its maximum power for wind speeds higher than or equal to 15 km/hr, the IESO and Hydro One have agreed to modify the criteria for determining the thermal ratings for the transmission facilities to which wind turbine generating projects are connected.

- For transmission facilities within 50 km radius of the wind turbine project the thermal ratings are to be determined using a wind speed of 15 km/hr instead of the normal 4 km/hr value.
- For those transmission facilities whose loadings are directly affected by the output of the wind turbine project, their continuous ratings will be determined using a maximum conductor operating temperature of

127^o C, or the individual sag temperature if it is lower, instead of the normal value of 93^o C (or its sag temperature, if lower).

This relaxed criterion is intended to recognize the wide variation in the output of wind turbine projects and the expectation that none of the projects would deliver full output for more than 50 hours per year while the temperature is at 30^o C. This criterion is to be applied only to the transmission facilities (line tap) that connect the wind turbine project to the system. Therefore, the applicable summer continuous ratings for W8T and WT1T circuits are;

(a) W8T, Buchanan TS to Cranberry Jct.: 860 A at 4 km/h wind or 176 MVA calculated at 118 kV
(b) Cranberry Jct. to new Tillsonburg Jct. that is located about 30 km away from the wind farm: 720 A at 4 km/h wind or 940 A at 15km/h wind. At 15 km/h wind, the line could accommodate an injection of 150 MW.

Impact on Power Flow – System Wide

The results of the linear analysis are presented in Section 5.1.2 of Appendix 1. Extrapolating from consultant's results, it can be concluded that up to 90 % of the power injected by the Erie Shore Wind farm would appear on the 230 kV circuits emanating from Buchanan TS in the eastbound direction. This indicates that the proposed project would increase the congestion on the negative power flow on the BLIP interface.

Transient Stability Analysis

With this wind development on-line, the simulation results obtained using available PSS/E models did not exhibit instability or undamped oscillations for the simulated contingencies under simulated scenarios. It must be emphasized that due to inaccuracies in the dynamic model, damped oscillations do not essentially indicate secure operation of the wind farm.

Short Circuit Current Level

The Hydro One performed short circuit studies as part of Customer Impact Assessment study. The comparison of symmetrical fault currents and symmetrical fault current ratings are shown below.

Bus	*Symmetrical fault current (kA)*		*Breaker ratings (kA)*
	3-phase fault	*L-G*	*Symmetrical*
Existing system + all other project in the queue (no Erie Shores Wind)			
Buchanan 220 kV	30.13	25.43	63 and 52
Buchanan 118 kV	23.65	27.80	52
Detweiler 220 kV	20.96	18.28	40 and 63
Existing system + all other project in the queue (with Erie Shores Wind)			
Buchanan 220 kV	30.59	25.68	63 and 52
Buchanan 118 kV	24.56	28.66	52
Detweiler 220 kV	20.99	18.30	40 and 63

Performance of Transformer ULTC

Several transformers in the vicinity of the proposed wind generation facility are equipped with automatic ULTC facilities. Since the output of the wind farm would vary significantly depending on the prevailing wind conditions, the reactive power injection into the new Tillsonburg Junction would accordingly change and this would potentially increase the number of ULTC operations in existing transformers beyond current levels. This could shorten the life span of those ULTC facilities. Thus, measures must be taken by the applicant to ensure that the duty cycles of existing transformers are not increased beyond current level.

This could be achievable by having the wind farm to control the Tillsonburg 115 kV voltage or by having a continuous dynamic reactive power compensating device where the reactive compensation occurs before the ULTC action takes place. Proper control will be required to ensure that the switching of the reactive device takes place due to variations in the reactive output of the wind farm, and not due to the variations in load connected to Tillsonburg TS or Aylmer TS.

If the new transformers T1 and T2 have automatic ULTC facilities, the option should be available either to block this automatic feature and operate on manual mode, or to expand the range of the voltage for which the automatic ULTC action gets triggered.

Low Voltage Ride Through Capability

In order to examine the need for low voltage ride through capability for the 100 MW development, the IESO simulated a LLG fault at Buchanan 115 kV bus which was cleared in 140 ms which corresponds to 5 cycle breakers available at Buchanan 115 KV system. The variation of the 34.5 kV terminal voltage of the DFIGs is plotted below for 0-1 sec and 100-250 ms. The 100-250 ms plot shows the duration during which the generator terminal voltage drops below 0.7 pu where without the LVRT, the generators would immediately trip by under-voltage protection.

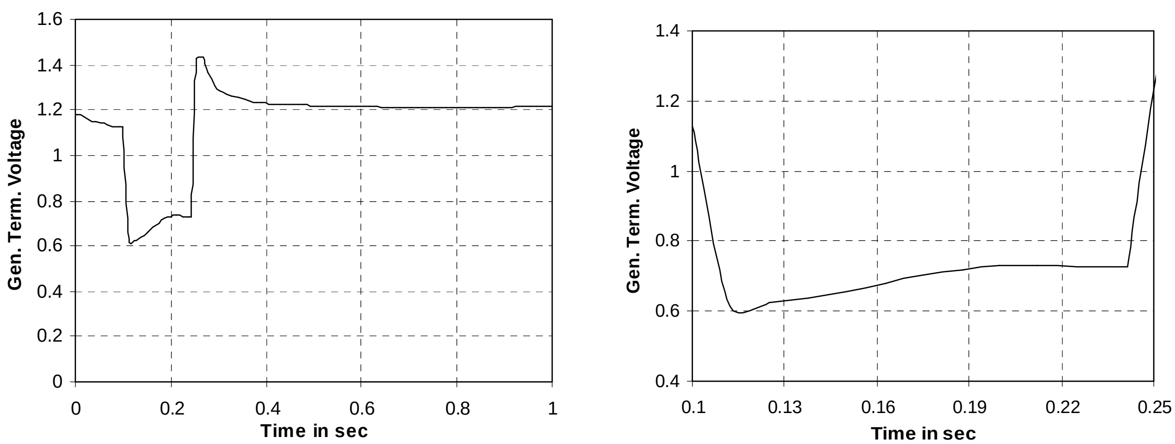


FIGURE 3 – VARIATION OF DFIG TERMINAL VOLTAGE

The actual durations of generator terminal voltage declines with typical under-voltage settings are given below.

Voltage range	*Actual duration in ms*	*Typical trip settings*	
		Without LVRT	*With LVRT*
1.00 - 0.90 pu	-	no trip	no trip
0.90 - 0.85 pu	-	trip in 600 s	trip in 600 s
0.85 - 0.75 pu	-	trip in 10 s	trip in 10 s
0.75 - 0.70 pu	-	trip in 1 s	trip in 1 s
0.70 - 0.30 pu	65	instantaneous trip	Level I = trip in 100 ms
0.30 - 0.00 pu	-	instantaneous trip	Level I = instantaneous trip
0.70 - 0.15 pu	-	instantaneous trip	Level II = trip in 625 ms
0.15 - 0.00 pu	-	instantaneous trip	Level II = instantaneous trip

For the LLG fault at Buchanan 115 kV bus, the generator terminal voltage would drop below 0.7 pu only for 65 ms, and would not drop below 0.3 pu. The minimum voltage recorded was 0.617 pu. Thus, in order to prevent generators from tripping, at least Level I of the LVRT capability must be installed.

Simulation results show that the 100 MW development must be equipped minimum with Level I of LVRT capability to remain connected to the IESO-controlled grid. It must be emphasized that the IESO has observed inaccuracies in the available PSS/E dynamic model for induction generators and consequently, the conclusions on LVRT capability requirement drawn from transient simulations are not necessarily accurate or dependable.

The IESO requirement is the generators must not trip for contingencies for which they are not removed by configuration. When LVRT level I is installed, if the generators still trip for such contingencies, the IESO will require the applicant to install further enhanced LVRT capability to prevent such tripping.

8.0 ASSESSMENT

This assessment examined the impact of incorporation of 100 MW and 150 MW new power injection consisting of a number of GE1.5 wind generators into the 115 kV circuit WT1T.

Since the new connection takes place within a local area in the IESO-controlled grid, the IESO Transmission Assessment Criteria require the simulation of only single element contingencies for the analysis of post-contingency system behavior. The load flow analysis performed on a selected set of scenarios confirmed that under normal conditions, the loading of various circuits would remain within their thermal limits during pre-contingency as well as post-contingency conditions. The load flow results also confirmed that the voltage declines for tested single contingencies would remain less than the IESO required level.

It is important that the wind farm do not trip due to voltage sags of certain depths and durations caused by contingencies in the grid. While the wind farm must trip for faults associated with existing circuits W8T, WT1T, WT1A or the new equipment, the wind farm must not trip for voltage sags occurring at its terminal caused by faults external to above circuits and equipment. Thus, an external control system must be added to the wind farm voltage control system to prevent terminal voltage from dropping below certain levels for certain durations. The simulations showed that the stage 1 must be equipped minimum with the Level I of LVRT capability. However, when placed in service, if the generators still trip for any contingency for which they are not removed by configuration, the IESO will require applicant to take immediate measures to prevent such tripping.

The short circuit study results indicated that the additional power injection from Erie Shore development will not increase the short circuit current beyond interrupting capability of the affected circuit breakers.

This SIA has been based on the results of simulations conducted using data provided by the applicant. Wherever equipment data were not available, the IESO used typical values for this assessment. It must be ensured that the facilities when installed have model data that are acceptable to the IESO. The registration of the new facilities to be installed will need to be completed through the IESO’s facilities registration process before any facility can be placed in-service. The applicant is expected to initiate the facility registration process with the IESO at least seven months before the scheduled commissioning date of the facility. If the data supplied for the registration of the new facilities differ from that used for the assessment, then some of the analysis might need to be repeated to ensure that no further facilities could be adversely affected.

The IESO System Impact Assessment of this project has been based on the results of studies conducted using currently available GE wind generator modeling data. However, the IESO has not validated the parameters used in the computer models. Instead, the IESO has relied on manufacturers' assurances that performance standards that the IESO has specified for the equipment will be met.

The IESO approval is therefore conditional upon the installed wind generators meeting the specified performance standards and, in particular, that they will have the following ability:

- to ride through contingencies on the system that do not disconnect generation facility by configuration
- to start up and shut down without creating excessive in-rush currents or voltage change to the system

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.

9.0 CONCLUSIONS AND RECOMENDATIONS

This System Impact Assessment concluded that:

- The Erie Shore wind generation development connected to WT1T at new Tillsonburg junction will result in an increase in short circuit currents in the area, but they remain within the interrupting capability of new breakers and existing breakers.
- The Erie Shores Wind Farm does not have a significant effect on the Buchanan 115 kV voltage. The new in-feed reduces the active and reactive power flows over the Buchanan 115/230 kV transformers, and reduces the power flow and losses occurring in 115 kV lines WT1T and W8T.
- When the wind farm is at high output, the voltage profile on 115 kV lines WT1T and W8T is improved as compared to the present system.
- To mitigate the impact on the customers connected at Tillsonburg TS, it is required that three 8 MVAR shunt capacitors (for 100 MW development) or possibly four 8 MVAR shunt capacitors (for 150 MW development) be installed and available to be automatically switched on voltage detection on the local bus.
- The wind gust simulation results showed that the voltage change at Tillsonburg TS is only about 2 %.
- The thermal capability of the existing 115 kV transmission will not be exceeded due to the new in-feed of 100 MW or 150 MW.
- The proposed project would increase the congestion on the power flowing eastbound on the 230 kV circuits out of Buchanan (NBLIP interface).
- Based on available models, the results of the transient stability studies indicate that the proposed development would not have a negative impact on transient stability.

10.0 SUMMARY OF REQUIREMENTS

The following requirements have been identified during the SIA performed for the proposed connection. Prior to connecting the new development, the applicant is required to demonstrate to the IESO the compliance with applicable requirements of Appendix 4.2 of the Market Rules and those given below. The IESO approval of this project depends on implementation of these requirements and the implementation of any other additional requirements specified in the Customer Impact Assessment for this project performed by Hydro One.

1. The applicant is responsible for ensuring that the performance of the equipment that is eventually supplied meets or exceeds the predicted performance resulted with the data used in the analysis. The registration of the new facilities to be installed will need to be completed through the IESO’s facility registration process before any part of the facility can be placed in-service. It is required that the applicant initiate the facility registration process with the IESO at least seven months before the facility commissioning date. It must be noted that if the data supplied for the registration of the facilities differ from those that were used for the assessment, then some of the analysis might need to be repeated to ensure that no further facilities could be adversely affected.

2. It is required that a 115 kV breaker be installed at the point of connection of the new 115 kV line to the existing IESO-controlled grid at new Tillsonburg Junction. The breaker is required to be rated for continuous operation at 127 kV, 5 cycles or less and have a short current interrupting capability of 50 kA.

3. The applicant is required to provide type test data that confirms model parameters supplied to the IESO and actual evidence of the reactive capabilities of the generators. If these data are not provided, the applicant must perform commissioning tests to validate model parameters and reactive capabilities eventually given to the IESO. In this case, during the facility registration process, the applicant is required to submit a detailed

test plan to be carried out after installation of the equipment to validate model parameters and reactive capabilities. If the data found from commissioning tests differ from those that were used for the assessment, then some of the analysis might need to be repeated before facilities can be placed in service.

4. The applicant is required to ensure that the proposed generators do not trip for contingencies except for faults for which the generators will be removed by configuration. This would require the generation facility to have adequate low voltage ride through capability to remain connected. When the facilities are placed in service, if the generators trip for any contingency for which they are not removed by configuration, the IESO will require the applicant to install further enhanced LVRT capability to prevent such tripping.

5. The generators used in Erie Shores wind farm must have the automatic reactive power control feature. Each generator must have the capability to operate 0.90 lag or 0.95 lead power factor for a set value of voltage at the connecting point to the 115 kV existing IESO-controlled grid

6. The net impedances between the machine terminals and the existing IESO-controlled grid for stage 1 and 1+2 on facility MVA base are found to be greater than 0.13 pu. Therefore, the facility must be equipped with appropriate automatic reactive power compensating scheme to compensate for the reactive losses occurring in the new connection. For the 100 MW development, AIM PowerGen is required to provide 24 MVAR of reactive compensation via three shunt capacitors of 8 MVAR each. It is required that local controls are provided to switch the shunt capacitors automatically on voltage detection. It is recommended that the shunt capacitors be located at Tillsonburg TS in order to provide full benefit when the wind farm is lost due to a contingency or due to lack of wind. Alternatively, the shunt capacitors could be located at the collector bus. It is also recommended that the reactive compensation is provided through combination of conventional capacitor switching and a fast continuous dynamic reactive compensation device.

7. It is required that for under frequency system conditions the generators must not trip for frequency variations that are above the curve in Figure 2 of this report.

8. The applicant is responsible for ensuring that adequate and continuous real-time telemetering of variables as described in Requirement 5 of Section 4.0 of this report and Appendix 4 of the Market Rules for monitoring of the new facility and revenue metering purposes is available.

9. Care must be taken to ensure that the duty cycle of automatic ULTC facilities of existing transformers not increase beyond current level due to variations in the reactive power output of the wind generation facility.

10. AIM PowerGen is required to follow the Transmission System Code technical requirements of the transmitter for the AIM wind powered generation facility. It may be required that the new transmission equipment and generator protections will have to be coordinated with the exiting schemes. The protection systems must be supplied from separate batteries.

11. AIM PowerGen will install a disturbance monitoring device at the wind farm site which is capable of monitoring the occurrence of disturbances and storing required system data. The AIM PowerGen will provide these data to the IESO for the post-disturbance analysis upon the request of IESO.

11.0 SUMMARY OF CUSTOMER IMPACT ASSESSMENT

Hydro One performed the Customer Impact Assessment (CIA). It concluded that the new power injection would not increase fault levels beyond breaker ratings or would not significantly change customer voltages.

12.0 NOTIFICATION OF APPROVAL

It is recommended that a *Notification of Approval for Connection* be issued for this project subject to implementation of the requirements given in Section 10.0.