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CONNECTION ASSESSMENT & APPROVAL PROCESS

System Impact Assessment for

Prince Park Wind Development Project

Applicant: Superior Wind Energy Inc.

Final Report

CAA ID 2004-117

Long Term Forecasts & Assessments Department &
Consistent Information Set Department

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System Impact Assessment Report

Prince Park Wind Development Project

Acknowledgement

The IESO wished to acknowledge the assistance of Hydro One and the Great Lakes Power Limited (GLPL) 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, software developers, Hydro One and GLPL 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/GLPL 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 IESO base case models made by the consultant. The IESO reserves the right to repeat any or all connection studies performed by the consultant if necessary to meet IESO requirements.

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.

Transmitter (s)

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

PRINCE PARK 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) 199 MW of wind power generation into the new 230 kV circuit K24G between MacKay TS and Third Line TS located in the Great Lakes Power Limited (GLPL) system. 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 placed in service by March 31, 2006.

The connection applicant, Superior Wind Energy Inc. retained Algal and Associates Ltd. to conduct this study which was performed under the guidance of IESO. Initially, the transient analysis was performed using GE1.5 machines. However, later Superior Wind Energy decided to use NM82 machines for this project. Thus, the transient analysis was repeated with an equivalent number of NM82 60Hz machines put in-place. Subsequently, Superior Wind Energy again decided to use GE1.5 machines. Thus, the transient analysis was redone with a newer beta 3.2 version of the GE1.5 machine models.

The original report done with GE1.5 machines is attached to this SIA report as Appendix 1, the second report done with NM82 machines is attached as Appendix 2, and the third report done with GE1.5 beta model is attached as Appendix 3. Each report has its own appendices identified by A (base load flow plots), B (summary of load flow results), C (induction generator model data) and D (transient stability plots).

2.0 PROPOSED TRANSMISSION REINFORCEMENT IN GREAT LAKES POWER LIMITED

In the GLPL network, plans are in place to build a new 230 kV connection between Wawa TS and Third Line TS (W23K from Wawa to MacKay and K24G from Mackay to Third Line). These changes would accompany a number of modifications to the GLPL network including elimination of existing Anjigami circuits No 1, 2, Sault circuits No 1, 2, building a new 230/115 kV transformer station at MacKay, building a new 230 kV switching station at Third Line and several other upgrades and re-termination of circuits.

A diagram of the GLPL system and the proposed transmission reinforcement is displayed in the Figure 1 of Appendix 1. The complete SIA report produced by the IESO on this transmission reinforcement is now available on the IESO public web site. Please go to http://www.theimo.com/imoweb/pubs/caa/caa_PAReportGLP.pdf

3.0 PROPOSED CONNECTION OF PRINCE PARK WIND FACILITY

The power injection from the proposed Prince Park generation facility will be incorporated into K24G circuit at a location about 10 km north of Third Line TS. The Prince Park project is to be developed in two stages.

First Stage - 99 MW of Generation

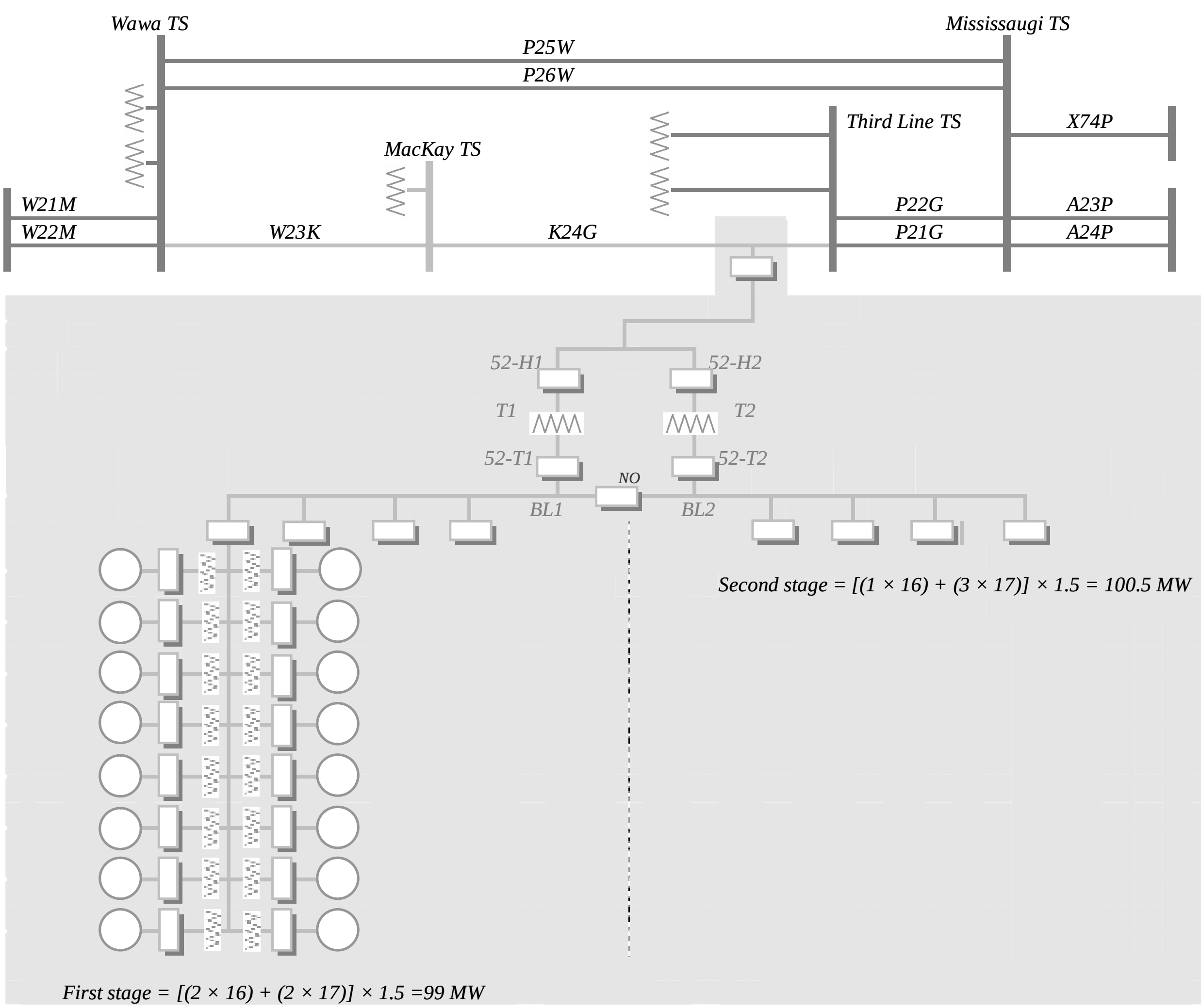
The first stage is to develop a 99 MW generating facility consists of sixty six 1.67 MVA, 575V, GE 1.5 MW, 60 Hz variable speed wind turbines that employ a doubly-fed induction generator with a power converter interfacing the rotor to the grid. The wind turbines are capable of supplying or drawing reactive power to or from the grid, thus contributing to grid voltage support or correction.

These sixty six turbines will be connected to four 34.5 kV feeders (16, 16, 17, 17) using tower base-mounted 1.75 MVA, 34.5 kV/575 V turbine step-up transformers, 600 V terminal breakers and disconnect switches. These four feeders will be connected to a common 34.5 kV collector bus bar BL1. This collector bus bar will be connected to K24G circuit via a single 75/100/125 MVA, 230/34.5 kV step-up transformer T1 and three circuit breakers (one located at the tap point to K24G circuit) using a 15 km long overhead transmission line. The reactance of the transformer T1 is 0.08 pu on 75 MVA base. The reactance of turbine step-up transformers is 0.0579 pu on 1.75 MVA base. The proposed connection arrangement is shown in Figure 1.

Second Stage – 100 MW of Generation

The second stage is to develop an additional 100.5 MW of generation with sixty seven generators that are similar to the ones used in stage 1. These sixty seven turbines will be connected to four feeders (16, 17, 17, 17) using turbine step-up transformers, breakers and switches as in stage 1. These four feeders will be connected to a common 34.5 kV collector bus bar BL2. This collector bus bar will be connected to a single 75/100/125 MVA, 230/34.5 kV step-up transformer T2. The outputs of the two 230/34.5 kV step-up transformers T1 and T2 will be connected to a common 230 kV busbar which would be connected to K24G via a circuit breaker located at the tap point to K24G. The two 34.5 kV busbars BL1 and BL2 belong to stage 1 and 2 would be connected by a tie breaker which would be kept normally open. The reactance of the transformer T2 is 0.08 pu on 75 MVA base.

FIGURE 1 : PROPOSED CONNECTION



4.0 GENERATORS

For transient analysis, following three types of induction generator models were used.

(a) GE1.5 model – the data are given in Appendix C of Appendix 1
(b) NM82 model – the data are given in Appendix C of Appendix 2
(c) GE1.5 beta version 3.2 model – the data are given in Appendix C of Appendix 3

Requirement 1:

It is required that each induction generator connecting to the IESO-controlled grid must have the capability to perform the followings.

- supply full 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 lagging to 0.95 leading power factor at a set value of the 230 kV bus. This 230 kV bus is the point where the new facility is connecting to the existing IESO-controlled grid.

The above two requirements would effectively limit the impedance between the terminal of the generation facility and the existing IESO-controlled grid to maximum of about 0.13 pu based on MVA rating of the generating facility. These requirements must be satisfied for stage 1 and stage 1+2 separately. If above two capabilities are not met, additional reactive power compensation must be provided to compensate for the excessive reactive power losses occurring between the generator facility terminals and the HT point.

It must be emphasized that the IESO has not conducted benchmarking to verify the accuracy of PSS/E models for GE1.5 induction generators. From the limited number of sensitivity studies carried out by the IESO, the IESO has observed deficiencies in the PSS/E model 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 2:

The applicant has not provided any type test data for the 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 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 the data 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:

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 the connecting circuit K24G, 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 limitations must be used to prevent occurrence of those adverse effects.

If any special protection scheme requirements or operating limitations are not identified by the IESO at the time of this SIA, but are identified at a later stage after performing detailed operating analysis considering various outage conditions, operating scenarios, weather conditions or any other, those requirements and limits must be implemented.

Requirement 4:

Appendix 4.2 of the Market Rules requires that generators be able to operate continuously with 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.

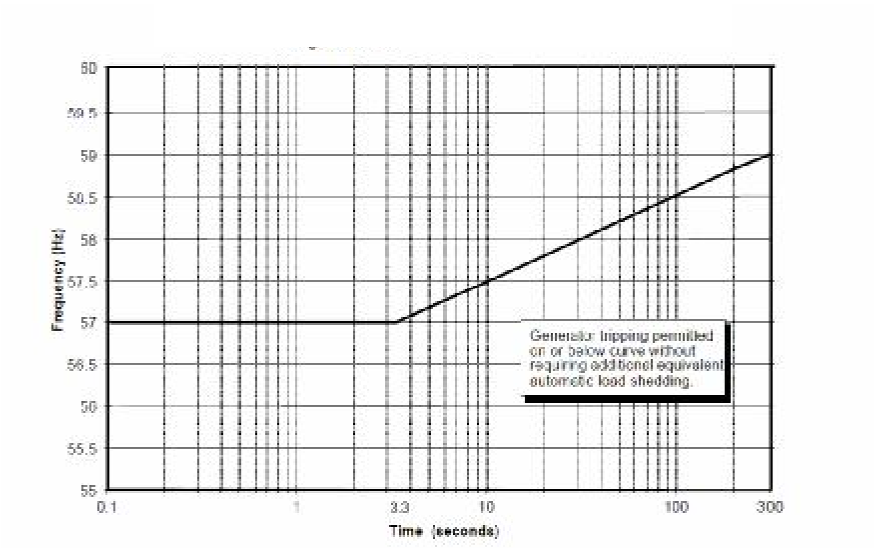


FIGURE 2 – STANDARD FOR SETTING UNDER-FREQUENCY TRIP PROTECTION FOR NEW GENERATORS

Requirement 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 minimum, the following quantities be monitored at the Prince Park project.

- net active and reactive power injection measured either at 34.5 kV or 230 kV side of transformers T1 and T2
- status of 34.5 kV and 230 kV breakers between collector buses and K24G circuit
- status of 34.5 kV tie-breaker
- status of 34.5 kV and 230 kV disconnect switches between collector buses and K24G circuit
- 230 kV and 34.5 kV voltages at the transformer station
- frequency at 34.5 kV collector buses BL1 and BL2

5.0 TRANSFORMERS

Requirement 1:

The components of the impedance between the facility terminals and the IESO-controlled grid after stage 1 and 1+2 are completed are given below. The facility MVA base is 66×1.67 =110 MVA for stage 1 and 133×1.67 =222 MVA for stage 2. The impedance of the 34.5/230 kV transformers T1 and T2 is 0.08 pu on 75 MVA base. The impedance of 0.575/34.5 kV turbine step-up transformers is 0.0579 pu on 1.75 MVA base.

For stage 1

Equivalent impedance of 66 × 34.5/0.575 kV turbine step-up transformers on 110 MVA base	= 0.0551	pu
Impedance of 230/34.5 kV transformer T1 on 110 MVA base	= 0.1173	pu
Impedance of the 15 km line on 110 MVA base	= 0 0165	pu
Total impedance between machine terminals and tap point to existing IESO-controlled grid	= 0.1886	pu

For stage 1+2

Equivalent impedance of 133 × 34.5/0.575 kV turbine step-up transformers on 222 MVA base	= 0.0552	pu
Impedance of parallel 230/34.5 kV transformers T1 or T2 on 222 MVA base	= 0.1184	pu
Impedance of the 15 km line on 222 MVA base	= 0 0333	pu
Total impedance between machine terminals and tap point to existing IESO-controlled grid	= 0.2069	pu

After completion of stage 1 or 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 230 kV system due to excessive reactive power losses occurring between the machine terminals and the existing IESO-controlled grid. Thus, reactive power compensation must be provided by the applicant. The amounts of reactive power compensation required for each stage are given in Section 8.0.

6.0 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 IESO's facility registration process.

Circuit Breakers			*Disconnect Switches*		
Nominal voltage	230 kV	34.5 kV	Nominal voltage	230 kV	34.5 kV
Rated voltage	-	-	Rated voltage	-	-
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 IESO on validation of model parameters and reactive capabilities of the generators. These requirements are independently applicable for each stage of the development.

7.0 Analysis of Proposed Connection Arrangement

7.1 Condition 1

It is necessary that that only up to six 230 kV plus 115 kV breakers trip in a single station in IESO-controlled grid following a single contingency. This is to reduce the over complexity in relay co-ordination between the tripping of circuit breakers for a single contingency.

The above criterion continues to apply after the incorporation of the new generating facility.

7.2 CONDITION 2

Since the maximum power injection from Prince Park 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.

7.3 CONDITION 3

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 existing line length significantly or 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.

For the Prince Park project, the exact length of the new 230 kV tap is 14.74 km. Thus, it is required that a 230 kV breaker be installed at the point of connection of Prince Park power injection to the new K24G circuit. The breaker is required to have an adequate short circuit current interrupting capability exceeding the asymmetrical fault levels in 3 cycles according to the Transmission System Code requirements.

8.0 SUMMARY OF COMPUTER ANALYSIS

Pre-contingency conditions

- The following projects that are ahead of Prince Park wind generation project are included in the analysis.
  - the transmission reinforcement in the GLPL system
  - two 38.9 MVAr shunt capacitors and two 40 MVAr shunt reactors at Wawa TS
  - one new 40 MVAr shunt reactor at MacKay TS
  - Macleans Manitoulin wind project by Repower – 54 MW
  - Manitoulin wind farm by Superior Power – 100 MW
- The new projects located south of Barrie are not included in the system model since they are electrically remote from Prince Park wind farm.
- The study is performed for a system with all transmission elements in service.
- The phase shifters are allowed to move their taps pre-contingency, but locked for post-contingency analysis.
- 2004 summer peak conditions are used for the analysis with total Ontario demand of 25,765 MW.
- For voltage decline studies, the active power loads are converted into constant current and constant admittance loads equally and the reactive power loads are converted only into constant admittance loads.
- Three flow scenarios A, B and C are studied with different interface flow levels and generation patterns as shown in the table below. Each of those three scenarios are analyzed with
  - Prince Park generation not incorporated
  - Prince Park stage 1 completed - generation of 100 MW is incorporated
  - Prince Park stage 1 + 2 completed - generation of 200 MW is incorporated

The summary of the system conditions are given in the following table.

Scenario	*Prince Park Gen MW*	*GLP Load MW*	*GLP Gen MW*	*Aubrey Falls, Wells Gen MW*	*East-West Transfer MW*	*OMTR, MPF MW*	*Miss Flow MW*
Scenario A_0	0	350	418	62, 92	325 E	300 E, 75 S	510 E
Scenario A_{100}	100	350	418	62, 92	329 E	302 E, 77 S	610 E
Scenario A_{200}	200	350	418	62, 0	333 E	305 E, 74 S	620 E
Scenario B_0	0	300	75	0, 0	354 W	306 W, 78 S	605 W
Scenario B_{100}	100	300	75	0, 0	347 W	313 W, 77 S	495 W
Scenario B_{200}	200	300	75	0, 0	353 W	308 W, 77 S	395 W
Scenario C_0	0	350	346	124, 190	328 E	302 E, 78 S	610 E
Scenario C_{100}	100	350	346	124,190	327 E	300 E, 76 S	700 E
Scenario C_{200}	200	350	346	124, 190	327 E	299 E, 77S	735 E

Short Circuit Current

The GLPL performed short circuit studies as part of Customer Impact Assessment (CIA) study. A total of 14 buses of 230 kV, 115 kV, 44 kV and 12 kV are selected for the analysis. Three examples of fault currents are shown below with associated sections in the CIA report.

Bus	*Symmetrical Fault Current, kA*	
	3-phase	*LG*
With no Prince Park		
Third Line 230 kV	5.67, Table 2 of CIA	6.07, Table 3 of CIA
Wawa 230 kV	5.36, Table 2 of CIA	5.28, Table 3 of CIA
Mississaugi 230 kV	8.60, Table 2 of CIA	8.41, Table 3 of CIA
With 100 MW Prince Park		
Third Line 230 kV	6.26, Table 2 of CIA	7.15, Table 3 of CIA
Wawa 230 kV	5.46, Table 2 of CIA	5.36, Table 3 of CIA
Mississaugi 230 kV	8.95, Table 2 of CIA	8.69, Table 3 of CIA
With 200 MW Prince Park		
Third Line 230 kV	6.82, Table 2 of CIA	7.63, Table 3 of CIA
Wawa 230 kV	5.55, Table 2 of CIA	5.41, Table 3 of CIA
Mississaugi 230 kV	9.24, Table 2 of CIA	8.87, Table 3 of CIA

Contingencies

Since the GLPL network is considered to be a local area within the IESO-controlled grid, the IESO Transmission Assessment Criteria requires 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 is required by the IESO Transmission Assessment Criteria. They are used to examine the robustness of the area with the wind farm placed in-service under possible other operating conditions than those tested.

Transient Stability

The following contingencies were tested with GE1.5 generator beta version 3.2 model and the associated sections in this SIA report where the results are given in detail are summarised below. Some of the contingencies simulated are more severe than what is required by the IESO Transmission Assessment Criteria. However, they are simulated to examine the robustness of the system. It must be noted that due to inaccuracies in the PSS/E dynamic model for the induction generator, the conclusions are not necessarily correct.

Fault location and lost items	*Local, ms*	*Remote, ms*
• SC1 = 3 ph at P26W at Wawa, loss of P26W+Wawa T2	83	114
• SC2 = 3 ph at W23K at Mackay, loss of W23K	83	114
• SC3 = 3 ph at K24G at MacKay, loss of K24G+Prince Park	83	114
• SC4 = LLG at P22G at Third Line, loss of P22G	83	110
• SC5 = LLG at W22M at Wawa, loss of W22M+Wawa T1	83	110
• SC6 = LLG at A23P+A24P at Mississaugi, loss of A23P+A24P	83	114
• SC7 = LLG at P25W+P26W at Mississaugi, loss of P25W+P26W+Wawa T2+W21M	83	114

Scenario	*With no Prince Park* A_0 B_0 C_0	*With 100 MW Prince Park* A_{100} B_{100} C_{100}	*With 200 MW Prince Park* A_{200} B_{200} C_{200}
A	-	SC6, SC7 = Appendix D of Appendix 2	SC6, SC7 = Appendix D of Appendix 2
B	-	SC1, SC2, SC3, SC4, SC6, SC7 = Appendix D of Appendix 2	SC1, SC2, SC3, SC4, SC6, SC7 = Appendix D of Appendix 2
C	-	SC1, SC2, SC3, SC4 = Appendix D of Appendix 2	SC1, SC2, SC3, SC4 = Appendix D of Appendix 2

Post-Contingency Voltage Decline

The following single element contingencies are tested and the associated sections in this SIA report where the results are given in detail are summarised below.

- VC1 = Loss of P26W and T2
- VC2 = Loss of W23K
- VC3 = Loss of K24G
- VC4 = Loss of Prince T1
- VC5 = Loss of Prince T1+T2
- VC6 = Loss of P21G
- VC7 = Loss of X74P

Scenario	*With no Prince Park* A_0 B_0 C_0	*With 100 MW Prince Park* A_{100} B_{100} C_{100}	*With 200 MW Prince Park* A_{200} B_{200} C_{200}
A	VC1 – VC7 = Table 1-1 of Appendix B of Appendix 1	VC1 – VC7 = Table 1-1 of Appendix B of Appendix 1	VC1 – VC7 = Table 1-2 of Appendix B of Appendix 1
B	VC1 – VC7 = Table 2-1 of Appendix B of Appendix 1	VC1 – VC7 = Table 2-1 of Appendix B of Appendix 1	VC1 – VC7 = Table 2-2 of Appendix B of Appendix 1
C	VC1 – VC7 = Table 3-1 of Appendix B of Appendix 1	VC1 – VC7 = Table 3-1 of Appendix B of Appendix 1	VC1 – VC7 = Table 3-2 of Appendix B of Appendix 1

The contingencies tested do not indicate any voltage declines that are greater than 10 % for pre or post ULTC action, thus meeting the required IESO voltage change limits given in IESO Transmission Assessment Criteria.

Reactive Power Compensation

- *Reactive compensation required due to excessive transformer reactive losses*

  The simulations revealed that in order to compensate for excessive reactive losses occurring between the generator terminal and the tap point to K24G, stage 1 would require supplementary 5 MVAr of reactive power injection to be provided at the 230 kV tap point of K24G. After stage 2 is completed, an additional 7.5 MVAr is required at the 230 kV tap point of K24G. However, it would be acceptable to the IESO, if a total compensation of 12 MVAr is equally divided and injected to the 34.5 kV collector buses, 6 MVAr at bus BL1 and 6 MVAr at bus BL2, both to be automatically switched based on the particular collector bus voltage.

Since the output of the wind farm will vary significantly depending on the prevailing wind conditions, the amount of reactive power compensation needed would change accordingly. Therefore, the capacitor bank needs to have appropriate steps and will need to be controlled via a local under-voltage and over-voltage scheme with suitable settings to avoid 'hunting'.

- *Reactive compensation required due to excessive voltage decline caused by loss of wind*

  The simulations revealed that the total loss of reactive power support from the wind generation either due to loss of wind or the loss of both 34.5/230 kV transformers T1 and T2 does not reduce the voltage of the IESO-controlled grid by more than 10 %. Thus, there is no requirement to provide any reactive compensation at the 230 kV system to maintain post-contingency voltages.

Thermal Loading

The summer continuous and the 15-minute STE thermal ratings (at 20^{O}C temperature, wind speed of 4 km/hr and pre-load of 75 % of continuous rating) for W23K and K24G circuits are given below. These limits are applicable for 115 kV as well as 230 kV operations.

Circuit Name	*Continuous Rating*	*STE*
W23K	1265 A	1955 A
K24G	1265 A	1955 A

A minimum number of load flow studies were performed by the IESO on Scenario A_{200} to analyze whether sufficient capability exists within the local area equipment to accept the modified power flow distribution caused by the new power injection. The resulting loading levels of the new circuits are given below.

<table>
<tr><td colspan="4">Pre-contingency MW flow</td><td colspan="3">Pre-contingency MW flow, Current Flow/Continuous Rating</td></tr>
<tr><td>Prince Park</td><td>East-West</td><td>OMTR, MPF</td><td>Miss Flow</td><td>K24G @ 3rd Line</td><td>K24G @ MacKay</td><td>W23K @ MacKay</td></tr>
<tr><td>200</td><td>333 E</td><td>305, 74</td><td>620 E</td><td>365, 0.73</td><td>168, 0.32</td><td>102, 0.19</td></tr>
<tr><td colspan="2" rowspan="2">Contingency</td><td colspan="5">Post-contingency MW Flow, Current Flow/STE</td></tr>
<tr><td colspan="2">K24G @ Third Line</td><td colspan="2">K24G @ MacKay</td><td>W23K @ MacKay</td></tr>
<tr><td colspan="2">Loss of P25W+P26W</td><td colspan="2">543, 0.82</td><td colspan="2">368, 0.52</td><td>342, 0.48</td></tr>
</table>

The simulation results have not indicated any pre-contingency thermal over-loading or any identifiable post-fault thermal concern for the tested contingency.

Low Voltage Ride Through Capability

In order to examine the need for low voltage ride through (LVRT) capability, the loss of P22G for a LLG fault at Third Line terminal was simulated. This particular contingency is electrically much closer to the new generation facility than other contingencies. Thus, it could potentially have a greater impact on the terminal voltage of the facility. The variation of the terminal voltage of the new generation facility is plotted below for 0-1 sec and 100-200 ms for the scenarios A_{100}, A_{200}, B_{100} and B_{200}.

The 100-200 ms plot shows the duration during which the generator terminal voltage drops below 0.7 pu where without the LVRT, the generators would potentially trip by under-voltage protection.

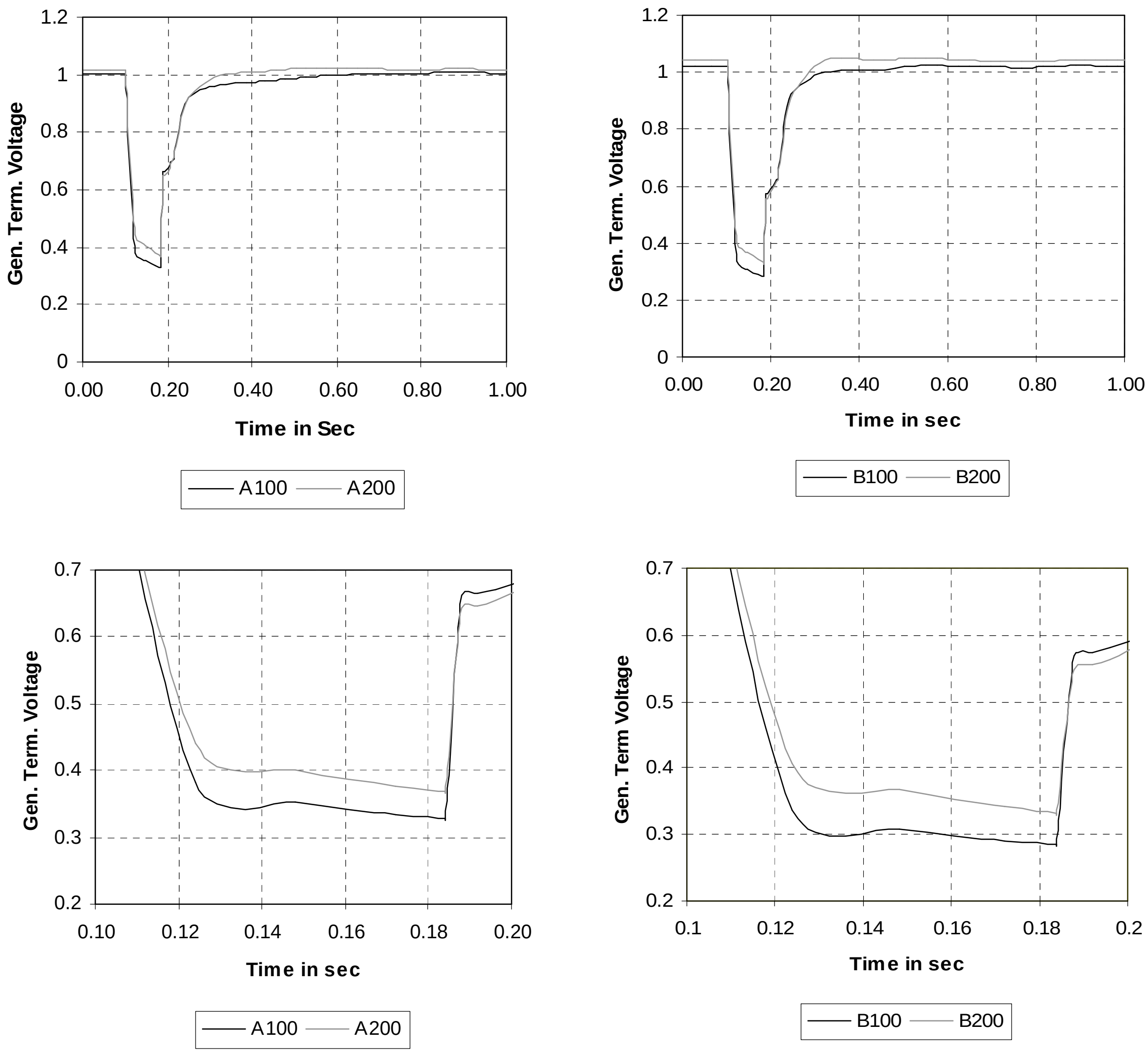


FIGURE 3 – VARIATION OF MACHINE TERMINAL VOLTAGE

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

	Actual duration in sec				*Typical trip settings*	
Voltage range	A_{100}	A_{200}	B_{100}	B_{200}	*Without LVRT*	*With LVRT*
1.00 - 0.90 pu	0.003	0.003	0.003	0.003	no trip	no trip
0.90 - 0.85 pu	0.002	0.002	0.002	0.002	trip in 600 s	trip in 600 s
0.85 - 0.75 pu	0.003	0.003	0.003	0.003	trip in 10 s	trip in 10 s
0.75 - 0.70 pu	0.002	0.002	0.002	0.002	trip in 1 s	trip in 1 s
0.70 - 0.30 pu	0.900	0.088			instantaneous trip	Level I = trip in 100 ms
0.30 - 0.00 pu			0.026	-	instantaneous trip	Level I = instantaneous trip
0.70 - 0.15 pu			0.116	0.112	instantaneous trip	Level II = trip in 625 ms
0.15 - 0.00 pu					instantaneous trip	Level II = instantaneous trip
Minimum voltage	0.327 pu	0.365 pu	0.282 pu	0.328 pu		

The durations for 1.0 - 0.7 pu voltage drops are given for fault-on systems. For the LLG fault at P22G at Third Line TS, the generator terminal voltage would drop below 0.7 pu for 90 ms for scenario A_{100} and for 88 ms for the scenario A_{200}. Similarly, the generator terminal voltage would drop below 0.7 pu for 116 ms for scenario B_{100} and for 112 ms for the scenario B_{200}. Thus, without LVRT capability the generators would instantaneously trip.

Even if the generators are equipped with Level 1 of LVRT capability, still the generators would instantaneously trip as the terminal voltage would drop below 0.3 pu for 26 ms for the scenario B_{100}.

Simulation results show that the generators must be equipped with Level II of LVRT capability to remain connected to the IESO-controlled grid during contingencies for which the generators are not removed by configuration. However, it must be strongly emphasized that the IESO has serious reservations on the currently available PSS/E dynamic model for induction generators and consequently, the conclusions on LVRT drawn from transient simulations are not necessarily accurate or dependable.

The key requirement is that the generators must not trip for contingencies for which they are not removed by configuration. When LVRT level II is installed, if the generators trip for contingencies for which they are not removed by configuration, the IESO will require more enhanced LVRT capability to be installed by the applicant to prevent such tripping.

Performance of ULTC

Since Prince Park step-up transformers T1 and T2 are equipped with 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 ULTC action gets triggered. Since the prevailing wind will vary significantly, the amount of reactive power from wind farm would vary and the number of ULTC operations would increase. This increment would shorten the life span of those ULTC facilities. Therefore, the changes in automatic ULTC of new transformers T1 and T2 may need to be controlled such that their duty cycles are not significantly increased. Also the automatic ULTC of existing transformers in the vicinity may also need to be controlled such that their duty cycles are not increased beyond existing levels.

The above could be achieved by having a continuous dynamic reactive power compensation device where the change in reactive power in-feed occurs before the ULTC action takes place.

9.0 GENERATION REJECTION REQUIREMENT

Since the Prince Park project is already under development, it is prudent to address some of the essential real-time operating requirements as a part of this SIA. It has been identified that a special protection scheme would be required to disconnect the Prince Park facility for certain contingencies. If such a scheme is not available, it would be required to restrict the output of the Prince Park generation facility pre-contingency in order to maintain the security of the power system in the event of certain contingencies.

The existing Mississagi Area G/R scheme includes facilities to arm Lake Superior Power units and Wells units for rejection for the loss of double circuit outages associated with A23P, A24P, X27A, X74P and S22A or for single contingencies with companion circuit out of service. At a minimum, this existing G/R scheme must be modified to reject the Prince Park facility for the loss of double circuit outages associated with the above circuits. That would mean,

(1) open 230 kV breakers 52-H1 and/or 52-H2 for double circuit outages associated with above circuits. This new requirement must be completed for deployment prior to stage 1 (opening of 52-H1) and stage 1+2 (opening of 52-H1 and/or 52-H2) are placed in service *or*

(2) open 34.5 kV breakers 52-T1 and/or 52-T2 for double circuit outages associated with above circuits. This new requirement must be completed for deployment prior to stage 1 (opening of 52-T1) and stage 1+2 (opening of 52-T1 and/or 52-T2) are placed in service. In this case, these two LT breakers must be equipped with dual trip coils to duplicate the generation rejection capability.

The new G/R selection matrix should be as shown below.

CIRCUITS LOST			SELECTED FOR REJECTION						
			WELLS G1	WELLS G2	LSP GTG1	LSP GTG2	LSP SGTG1	PP STAGE 1	PP STAGE 2
A23P detected at Mississagi by LEO or line protection	+	A24P detected at Mississagi by LEO or line protection	X	X	X	X	X	X	X
A23P detected at Mississagi by LEO or line protection	+	X74P detected at Mississagi by LEO or line protection	X	X	X	X	X	X	X
A24P detected at Mississagi by LEO or line protection	+	X74P detected at Mississagi by LEO or line protection	X	X	X	X	X	X	X
X27A detected at Algoma by LEO	+	S22A detected at Algoma by LEO	X	X	X	X	X	X	X
X27A detected at Algoma by LEO	+	X74P detected at Mississagi by LEO or line protection	X	X	X	X	X	X	X
S22A detected at Algoma by LEO	+	X74P detected at Mississagi by LEO or line protection	X	X	X	X	X	X	X

New requirements

The selection for generation rejection must be available for double contingencies shown in the above table or for single contingencies with the companion circuit out of service. It is required that the G/R scheme be duplicated with full built-in redundancy.

If any additional special protection scheme requirements or operating security limits are identified by the IESO after detailed operating studies are completed, those requirements shall be implemented.

10.0 ASSESSMENT

This assessment examined the impact of the incorporation of 99 MW and 199 MW new power injection from a number of GE1.5 wind generators into the new 230 kV circuit K24G between Mackay TS and Third Line TS in the GLPL network. The wind generation facility is connected to K24G using a 15 km long overhead line at a point 10 km North of Third Line TS.

When the new facility is placed in-service, the impedance of the facility connection to the IESO-controlled grid would exceed 0.13 pu on facility MVA base. This would mean the total reactive power capability of the generator facility would not be available for regulation of the voltage of the existing 230 kV system. Thus, it is required that 6 MVAr of automatic compensation be provided at each 34.5 kV collector bus. These capacitor banks need to have appropriate steps and will need to be controlled via a local automatic under-voltage and over-voltage scheme with suitable settings.

Since the new connection takes place in a local area in the IESO-controlled grid, the IESO Transmission Assessment Criteria require the use of only single element contingencies for analysis of post-contingency. 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 under pre-contingency and 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. The tested contingencies included the loss of reactive power support from the wind farm.

With Prince Park wind development on-line, none of the simulated contingencies caused transient instability or undamped oscillations under simulated scenarios. It must be noted that due to inconsistencies in the available DFIG dynamic model, stability results obtained from simulations could be unreliable. Additionally, during certain other real time operating scenarios, outages and weather conditions, the rejection of the new wind facility would be required for certain contingencies in order to maintain the integrity of the power system. As a result, the rejection of Prince Park would be necessary for the double circuit loss of A23P, A24P, X27A, X74P and S22A or for the single circuit loss with the companion circuit out of service. This rejection requirement could be implemented using the existing Mississagi Area G/R scheme.

As this wind power generation becomes a larger part of a resource mix, it is important that the wind farm not trip due to voltage sags on the transmission system. More specifically, the wind farm must not trip for certain depth and duration of the voltage sags occurring at its terminal. In order to prevent this tripping by the under-voltage protection scheme, an external control system must be added to the wind farm voltage control system to prevent the voltage from dropping below certain levels for certain time periods.

The analysis has shown that for an LLG fault at P22G or P21G, the wind farm would trip due to the voltage sag occurring at its terminal. In order for generators to remain connected to the IESO-controlled grid for an LLG fault at P22G or P21G followed by the loss of that faulty circuit, the generators must be equipped with Level II of LVRT capability. However, it has been observed that the PSS/E model for induction generators is not fully dependable due to the inadequacy in the extent of modelling. Thus, when placed in service, if the generators still trip for contingencies for which they are not removed by configuration, the IESO will require more enhanced LVRT capability to be installed by the applicant.

This SIA has been based on the results of simulations conducted using data provided by the applicant. The IESO has not validated the parameters used in the computer models based on actual tests. 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.

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.

11.0 SUMMARY OF REQUIREMENTS

The following requirements have been identified during the SIA performed for the proposed connection. Prior to connecting each stage of the new facility to the IESO-Controlled grid, the applicant is required to demonstrate its compliance to applicable Market Rules given in Appendix 4.2 and to the following requirements.

1. 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 new 230 kV circuit breaker be installed at the tap point of the Prince Park facility to the K24G circuit. This breaker is required to be rated for continuous operation at 260 kV and have an appropriate short circuit current interrupting capability exceeding asymmetrical fault levels in 3 cycles.

3. The applicant is required to ensure that the proposed generators do not trip for recognized 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 to the IESO-controlled grid. The computer simulations revealed that the facility would require Level II of LVRT capability to stay connected during disturbances. It must be emphasized that above requirement has been derived based on dynamic models available at the time of the analysis. The IESO has not fully verified the accuracy of the DFIG model, but limited sensitivity studies have revealed several modelling deficiencies. Thus, when the above level of LVRT is placed in service, if the generators still trip for contingencies for which they are not removed by configuration, then the applicant must install further enhanced LVRT capability to prevent such tripping.

4. Each generator must have the capability to operate at 0.9 lag or 0.95 lead power factor controlling the existing 230 kV voltage. This controllability is not available in the proposed connection due to its high impedance. Therefore, it is required that each 100 MW development connects 6 MVAr of automatically switchable reactive compensation to the 34.5 kV collector bus of that particular phase of the development. This compensation must be automatically switched based on the connected collector bus voltage and must be controlled by a local under/over voltage scheme with appropriate settings to avoid hunting.

5. If transformer HT breakers 52-H1 and 52-H2 are replaced with motorized disconnect switches, it would be acceptable to the IESO in terms of reliability and security of the IESO-controlled grid only if,
   - the transfer trip signals are sent to transformer LT breakers 52-T1 and 52-T2 or the breaker at the tap point to the K24G circuit (depends on the fault location) for fast clearance of faults in the 15 km long new line or in transformers.
   - the generation rejection signals are sent to transformer LT breakers 52-T1 or/and 52-T2.
   - the LT breakers 52-T1 and 52-T2 have dual trip coils for duplication of the G/R capability.

6. A fully duplicated special protection scheme with high speed generation rejection facilities to separately trip the 230 kV breakers 52-H1 or/and 52-H2 or 52-T1 or/and 52-T2 (if 52-H1 and 52-H2 are replaced with disconnect switches) initiated by contingencies identified in Section 9.0 must be available. This new G/R scheme must be fully duplicated. If any additional special protection scheme requirements or operating security limits are identified by the IESO after detailed operating analysis is completed, those requirements must be implemented.

7. All protection systems must be supplied from separate batteries.

8. 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.

9. 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.

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

11. Since the new step-up transformers T1 and T2 are equipped with 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 ULTC action gets triggered. Care must be taken to minimise the number of ULTC operations due to variations in the wind speed and capacitor switching to avoid any significant increase in duty cycles of T1 and T2. The number of ULTC operations in the existing transformers must also not be increased beyond their current levels.

12.0 SUMMARY OF CUSTOMER IMPACT ASSESSMENT

The GLPL performed the Customer Impact Assessment (CIA). It concluded that the new power injection,

- would increase fault levels beyond the LV breaker rating of one customer. The GLPL is to address this concern.
- would not significantly change the voltage at customer connection points.
- would increase the local generation and therefore enhance the self-sustainability of the GLPL system.

13.0 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 11.0.