IESO_REP_0589

REPORT

System Impact Assessment Report

Greenwich Lake Wind Generation Station

CONNECTION ASSESSMENT & APPROVAL PROCESS

Final Report

CAA ID 2008-337

Applicant: Renewable Energy Systems Canada Inc.

Market Facilitation Department

December 16, 2009

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System Impact Assessment Report

Greenwich Lake Wind Generation Project

Acknowledgement

The IESO wishes to acknowledge the assistance of Hydro One in completing this assessment.

<u>Disclaimers</u>

IESO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the IESO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether the IESO should issue a notice of approval or disapproval of the proposed connection under Chapter 4, section 6 of the Market Rules.

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

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

<u>HYDRO ONE</u>

<u>Special Notes and Limitations of Study Results</u>

The results reported in this study are based on the information available to Hydro One, at the time of the study, suitable for a preliminary assessment of a new generation or load connection proposal.

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

This study does not assess the short circuit or thermal loading impact of the proposed connection on facilities owned by other load and generation (including OPG) customers.

In this study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent upon request.

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

The additional facilities or upgrades which are required to incorporate the proposed connection have been identified to the extent permitted by a preliminary assessment under the current IESO Connection Assessment and Approval process. Additional facility studies may be necessary to confirm constructability and the time required for construction. Further studies at more advanced stages of the project development may identify additional facilities that need to be provided or that require upgrading.

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GREENWICH LAKE WIND GENERATION PROJECT
IESO SYSTEM IMPACT ASSESSMENT

SIA Findings

Renewable Energy Systems Canada Inc. is developing a new 98.9 MW wind power generation farm west of Dorion, Ontario. The project was awarded a contract under the government RES III, and is expected to start commercial operation at the end of 2010.

Summary

This assessment examined the impact of injecting 98.9 MW of wind power generation to the provincial grid via 230 kV circuits M23L and M24L east of Lakehead TS on the reliability of the IESO-controlled grid.

The following conclusions and recommendations were made:

Conclusions

The analysis concluded that:

(1) The proposed wind farm does not have a material adverse impact on the reliability of the IESO-controlled grid.

(2) The increase in fault levels, due to the proposed Greenwich WF, will not exceed the interrupting capabilities of the existing breakers on the IESO-controlled grid.

(3) Overloads of the 115 kV circuits T1M, A6P and A7L were identified prior to the connection of Greenwich WF. The project reduces the overloads, although it does not completely alleviate them.

(4) For all contingency cases tested with the proposed Greenwich WF, all voltage declines are within the 10% pre and post-ULTC action limit. Thus, the voltage performance meets the voltage decline criteria.

(5) None of the recognized contingencies cause any material adverse impact to the transient performance of the IESO-controlled grid.

(6) The connection impedance between the wind turbine generators and the IESO-controlled grid exceeds the limit derived from Market Rules requirements, resulting in reactive power deficiency. To compensate for this deficiency reactive compensation devices have to be installed as indicated in Section 6.5 of this SIA.

(7) Based on the information provided by the applicant, the fault ride through capability of the wind turbines is adequate.

(8) The change of the 34.5 kV winding configuration from delta to wye grounded is currently being analyzed by Hydro One and the IESO, and the results may be addressed in an SIA addendum.

IESO's Requirements for Connection

The following requirements for the incorporation of Greenwich Lake WF to M23L/M24L have been identified:

(1) A static compensation device of 21 MVAr must be connected to the collector buses. The capacitors will need to be auto-switched via suitable over/under voltage controls.

(2) RES Canada proposed a voltage control scheme in which the WTG and capacitors are set to control HV while the main transformer ULTC on high voltage side is set to control LV. The IESO is investigating the proposed scheme and the scheme may be subject to modifications during the Market Entry process/operation if any concerns are identified.

(3) The generators should not trip for contingencies except for which the generators will be removed by configuration. If generators trip for contingencies for which they are not removed by configuration, the LVRT capability must be upgraded.

(4) During the commissioning period, a set of IESO specified tests must be performed. The commissioning report must be submitted to the IESO within 30 days of the conclusion of commissioning. The field test results should be verifiable using the PSS/E models used for this SIA.

(5) All protection systems must be supplied from separate batteries and separate communication paths.

(6) The autoreclosure of the new 230 kV breakers at the connection point must be blocked. Upon its opening for a contingency, it must be closed only after the IESO approval is granted. The IESO will require reduction of power generation prior to the closure of the breaker followed by gradual increase of power to avoid a power surge.

(7) The generators should not trip for frequency variations that are above the curve in Figure 1.

(8) The applicant is responsible for providing real-time telemetering of following variables to the IESO:

- Active and reactive power measured either at 34.5 kV or 230 kV side of the transformers
- status of new 34.5 kV and 230 kV breakers and disconnect switches
- 230 kV and 34.5 kV voltages at the transformer station
- in service status of the Wind Farm Management System (WFMS)
- voltage controlling set point

Additional telemetry requirements may be identified if necessary by the IESO during Market Entry process.

(9) If the Wind Farm Management System (WFMS) is unavailable, each generator must control its own terminal voltage while capacitors continue to control 34.5 kV voltage.

(10) A disturbance monitoring device must be installed. The applicant is required to provide disturbance data to the IESO upon request.

(11) The registration of the new facilities will need to be completed through the IESO’s Market Entry process before any part of the facility can be placed in-service. If the data or assumptions supplied for the registration of the facilities materially differ from those that were used for the assessment, then some of the analysis might need to be repeated.

(12) The proponent provides a copy of the functionalities of the Wind Farm Management System (WFMS) to the IESO.

(13) The transmitter changes the relay settings of M23L/M24L terminal stations to account for the effect on apparent impedance due to power injection from the wind farm.

Notification of Conditional Approval

From the information provided, our review concludes that the proposed changes will not result in a material adverse effect on the reliability of the IESO-controlled grid. It is recommended that a Notification of Conditional Approval be issued for Greenwich Lake WF subject that the requirements listed in this report will be implemented.

1. Project Description

Renewable Energy Systems Canada Inc. (RES) has proposed to develop a 98.9 MW wind farm located west of Dorion, Ontario, known as Greenwich Lake Wind Farm which has been awarded a Power Purchase Agreement with Ontario Power Authority. It is expected that commercial operation will start at the end of 2010.

The Greenwich Lake Wind Farm will be connected to Hydro One's 230 kV circuits M23L and M24L via a new 230 kV 2×40/50/60 MVA interconnection substation located about 11 km far from the Hydro One right-of-way. The substation is connected to the 230 kV circuits by means of a selector switching system in which two 230 kV circuits are tapped separately. The new substation will consist of two 34.5/230 kV transformers, two 230 kV circuit breakers and associated switchgears, two 34.5 kV buses, and 4 collector line breakers. Each 34.5 kV bus is connected to the step-up transformer via a disconnect switch.

The development will consist of a total of forty three Siemens SMK223 wind turbine generators with a rated power output of 2.3 MW each. Two back-to-back AC/DC links and a 2.6 MVA, 0.06 pu reactance (on 2.6 MVA base), 0.69/34.5 kV transformer connects each generator to one of the four 34.5 kV collector circuits C1, C2, C3 or C4. Each collector circuit will have following number of generators:

Siemens SMK223 (2.55 MVA, 2.3 MW each)					
Collector	1		2		Total
Circuit ID	C1	C2	C3	C4	
Number of generators	11	10	11	11	43
Maximum MW	25.3	23.0	25.3	25.3	98.9

– End of Section –

2. General Requirements

Generators

1. Each generator must satisfy the Generator Facility requirements in Appendix 4.2 of Market Rules.

The Market Rules (appendix 4.2, reference 1) require that the generation facility connecting to the IESO-controlled grid must have the minimum capability to supply reactive power continuously in the range of 90% lagging to 95% leading power factor based on active power output at its generator terminals for at least one constant 230 kV system voltage. The connection applicant shall submit the generator's reactive capability curve to the IESO as evidence that the generator is capable of meeting the reactive power requirements.

If necessary, shunt capacitors must be installed to offset the reactive power losses within the facility in excess of the maximum allowable losses. If generators do not have dynamic reactive power capabilities as described above, dynamic reactive compensation devices must be installed to make up the deficient reactive power.

2. The generators must be able to ride through recognized contingencies on the IESO-controlled grid that do not disconnect the facility by configuration.

3. The connection and disconnection of the generators must minimize any adverse effects on the IESO-controlled grid.

Connection Equipment (Breakers, Disconnects, Transformers, Buses)

1. Appendix 4.1, reference 2 of the Market Rules states that under normal conditions voltages are maintained within the range of 220 kV to 250 kV. Thus, the IESO requires that the 230 kV equipment in Ontario must have a maximum continuous voltage rating of at least 250 kV.

   Fault interrupting devices must be able to interrupt fault current at the maximum continuous voltage of 250 kV.

If revenue metering equipment is being installed as part of this project, please be aware that revenue metering installations must comply with Chapter 6 of the IESO Market Rules for the Ontario electricity market. For more details the applicant is encouraged to seek advice from their Metering Service Provider (MSP) or from the IESO metering group.

2. The Transmission System Code (TSC), Appendix 2 establishes maximum fault levels for the transmission system. For the 230 kV system, the maximum 3 phase symmetrical fault level is 63 kA and the single line to ground (SLG) symmetrical fault level is 80 kA (usually limited to 63 kA).

   The TSC requires that new equipment be designed to sustain the fault levels in the area where the equipment is installed. If any future system enhancement results in an increased fault level higher than the equipment's capability, the connection applicant is required to replace the equipment at their own expense with higher rated equipment capable of sustaining the increased fault level, up to the TSC's maximum fault level of 63 kA for the 230 kV system.

3. The connection equipment must be designed so that the adverse effects of failure on the IESO-controlled grid are mitigated.

4. The connection equipment must be designed so that it will be fully operational in all reasonably foreseeable ambient temperature conditions. This includes ensuring that SF6 breakers are equipped with heaters to prevent freezing.

IESO Monitoring and Telemetry Data

In accordance with the telemetry requirements for a generation facility (see Appendices 4.15 and 4.19 of the Market Rules) the connection applicant must install equipment at this project with specific performance standards to provide telemetry data to the IESO. The data is to consist of certain equipment status and operating quantities which will be identified during the IESO Market Entry Process.

As part of the IESO Facility Registration/Market Entry process, the connection applicant must also complete end to end testing of all necessary telemetry points with the IESO to ensure that standards are met and that sign conventions are understood. All found anomalies must be corrected before IESO final approval to connect any phase of the project is granted.

Protection Systems

1. Protection systems must be designed to satisfy all the requirements of the Transmission System Code as specified in Schedules E, F and G of Appendix 1 and any additional requirements identified by the transmitter. New protection systems must be coordinated with existing protection systems.

2. Facilities designated as essential to power system reliability must be protected by two redundant protection systems according to section 8.2.1a of the TSC. These redundant protections systems must satisfy all requirements of the TSC but in particular they may not use common components, common battery banks or common secondary CT or PT windings.

This facility is designated as essential to power system reliability and therefore the above protection requirements apply.

3. Protective relaying must be set to ensure that transmission equipment remains in-service for voltages between 94% of the minimum continuous and 105% of the maximum continuous values in the Market Rules, Appendix 4.1.

4. The Applicant is required to have adequate provision in the design of protections and controls at the facility to allow for future installation of Special Protection Scheme (SPS) equipment.

5. Any modifications made to protection relays by the transmitter after this SIA is finalized must be submitted to the IESO as soon as possible or at least six (6) months before any modifications are to

be implemented on the existing protection systems. If those modifications result in adverse impacts, the connection applicant and the transmitter must develop mitigation solutions.

Send documentation for protection modifications triggered by new or modified primary equipment (i.e. new or replacement relays) to connection.assessments@ieso.ca.

For protection modifications that are not associated with new or modified equipment (i.e. protection setting modifications) please send documentation to protection.settings@ieso.ca.

6. Protection systems within the generation facility must only trip the appropriate equipment required to isolate the fault. After the facility begins commercial operation, if an improper trip of the 230 kV circuits M23L/M24L occurs due to events within the facility, the facility may be required to be disconnected from the IESO-controlled grid until the problem is resolved.

Frequency Requirements

The facility must be capable of operating continuously for grid frequencies in the range between 59.4 Hz and 60.6 Hz as specified in Appendix 4.2, Reference 3 of the Market Rules.
The facility must be capable of operating at full active power for a limited period of time for grid frequencies as low 58.8 Hz. Generators must not trip for under-frequency system conditions that are below 60 Hz but above 57.0 Hz and above the curve shown in Figure 1.

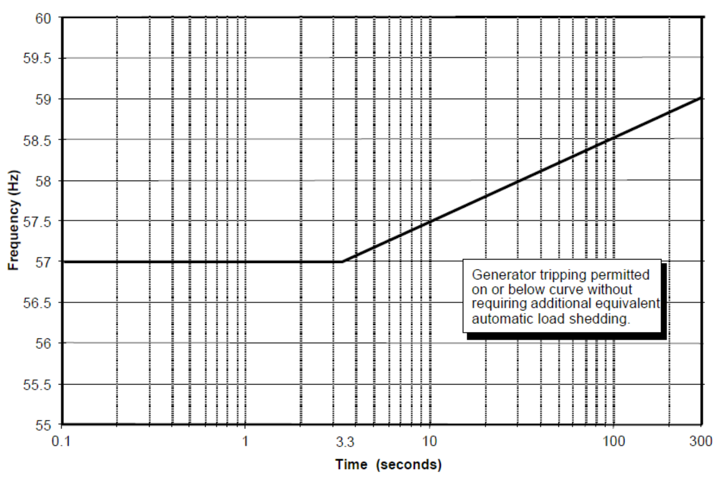


Figure 1: Setting for Grid Under-frequency Trip Protection

Miscellaneous

1. The generators must operate in the voltage control mode. Operation of the facility in power factor control or reactive power control is not acceptable.

2. Connection Applicant is required to install at the facility a disturbance recording device with clock synchronization that meets the technical specifications provided by Hydro One. The device will be used to monitor and record the response of the facility to disturbances on the 230 kV system in

order to verify the dynamic response of generators. The quantities to be recorded, the sampling rate and the trigger settings will be provided by Hydro One.

Facility Registration/Market Entry Requirements

The connection applicant must complete the IESO Facility Registration/Market Entry process in a timely manner before IESO final approval for connection is granted. Models and data, including any controls that would be operational, must be provided to the IESO. This information should be submitted at least seven months before energization to the IESO-controlled grid, to allow the IESO to incorporate this project into IESO work systems and to perform any additional reliability studies.

As part of the IESO Facility Registration/Market Entry process, the connection applicant must provide evidence to the IESO confirming that the equipment installed meets the Market Rules requirements and matches or exceeds the performance predicted in this assessment. This evidence shall be either type tests done in a controlled environment or commissioning tests done on-site. In either case, the testing must be done not only in accordance with widely recognized standards, but also to the satisfaction of the IESO. Until this evidence is provided and found acceptable to the IESO, the Facility Registration/Market Entry process will not be considered complete and the connection applicant must accept any restrictions the IESO may impose upon this project's participation in the IESO administered market or connection to the IESO-controlled grid.

The evidence must be supplied to the IESO within 30 days after completion of commissioning tests. Failure to provide evidence may result in disconnection from the IESO-controlled grid.

If the submitted models and data differ materially from the ones used in this assessment, then further analysis of the project will need to be done by the IESO.

Reliability Standards

Prior to connecting to the IESO controlled grid, the proposed facility must be compliant with the applicable reliability standards set by the North American Electric Reliability Corporation (NERC) and the North East Power Coordinating Council (NPCC). A list of applicable standards, based on the proponent's/connection applicant's market role/OEB licence can be found here:

http://www.ieso.ca/imoweb/ircp/reliabilityStandards.asp

In support of the NERC standard EOP-005, the proponent/ connection applicant may meet the restoration participant criteria. Please refer to section 3 of Market Manual 7.8 (Ontario Power System Restoration Plan) to determine its applicability to the proposed facility.
The IESO monitors and assesses market participant compliance with these standards as part of the IESO Reliability Compliance Program. To find out more about this program, visit the webpage referenced above or write to ircp@ieso.ca.

Also, to obtain a better understanding of the applicable reliability obligations and find out how to engage in the standards development process, we recommend that the proponent/ connection applicant join the IESO's Reliability Standards Standing Committee (RSSC) or at least subscribe to their mailing list at rssc@ieso.ca. The RSSC webpage is located at: http://www.ieso.ca/imoweb/consult/consult_rssc.asp.

– End of Section –

3. Review of Connection Proposal

3.1 Proposed Connection Arrangement

The proposed connection arrangement is shown in Figure 2.

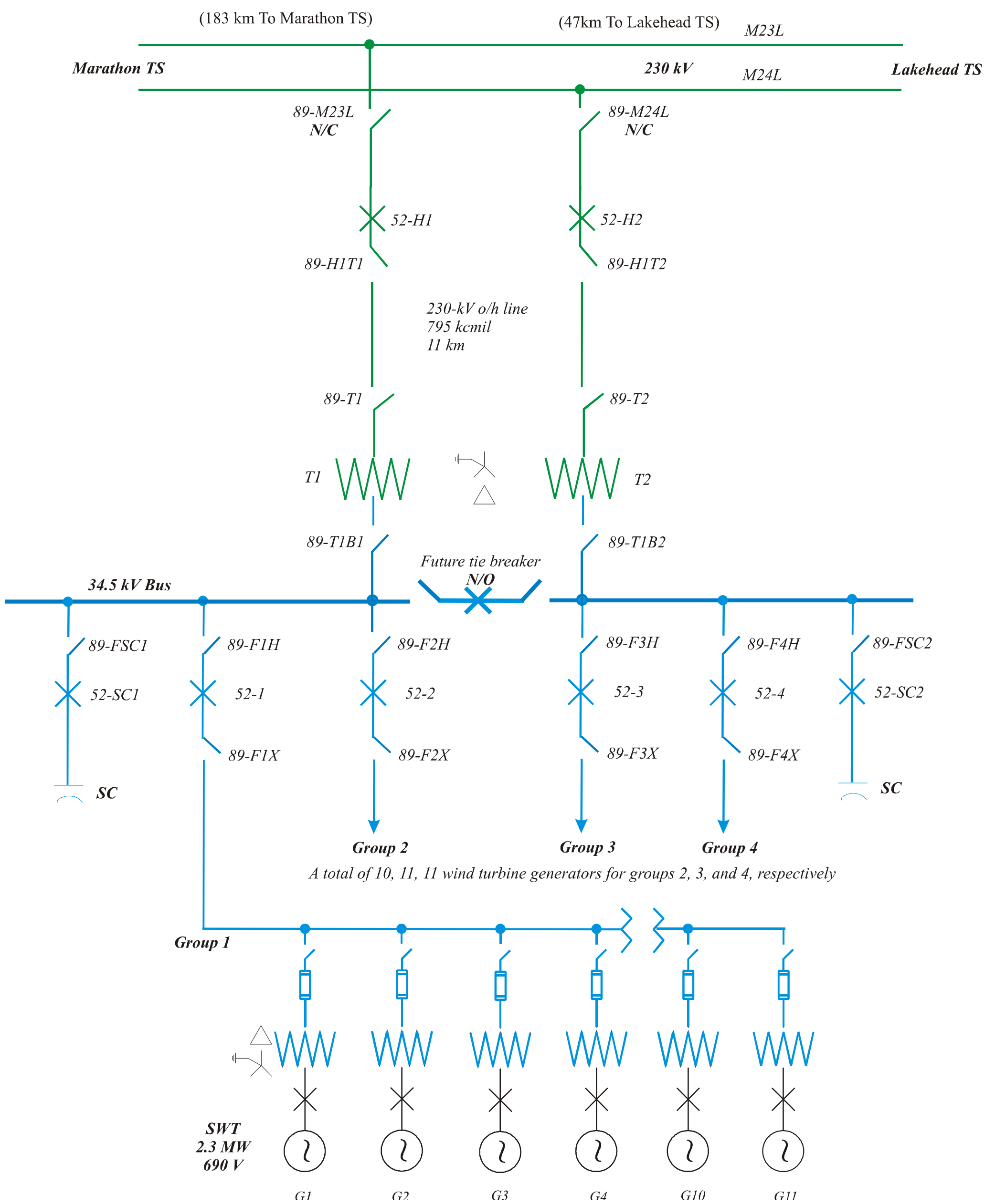


Figure 2: Proposed Connection Arrangement

3.2 Existing System

Greenwich Lake WF is proposed to connect to the existing Hydro One 230 kV circuits M23L/M24L between Marathon TS and Lakehead TS. The graphs below display the MW flow out M23L, Lakehead TS and MW flow out M23L at Marathon TS. Since M24L and M23L are double circuits and have very similar flows only flows on M23L are shown here. These are hourly average samples from Jan 1 to Dec 31, 2007 obtained from IESO real-time data. Positive values mean flow out of the station.

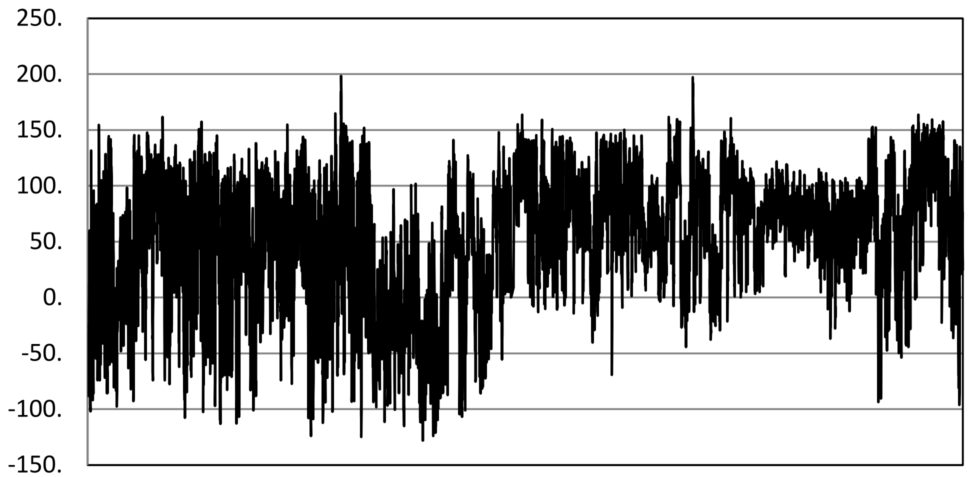


Figure 3: MW flow on M23L at Lakehead TS

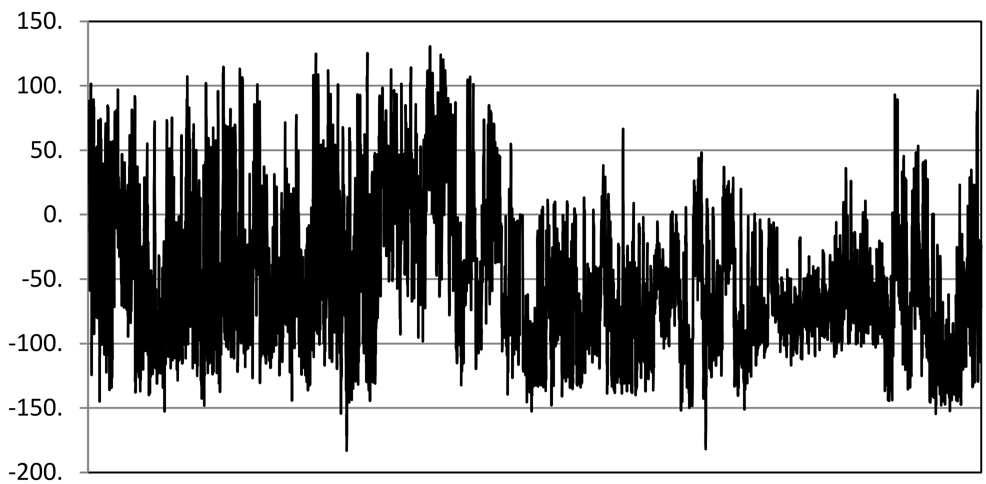


Figure 4: MW flow on M23L at Marathon TS

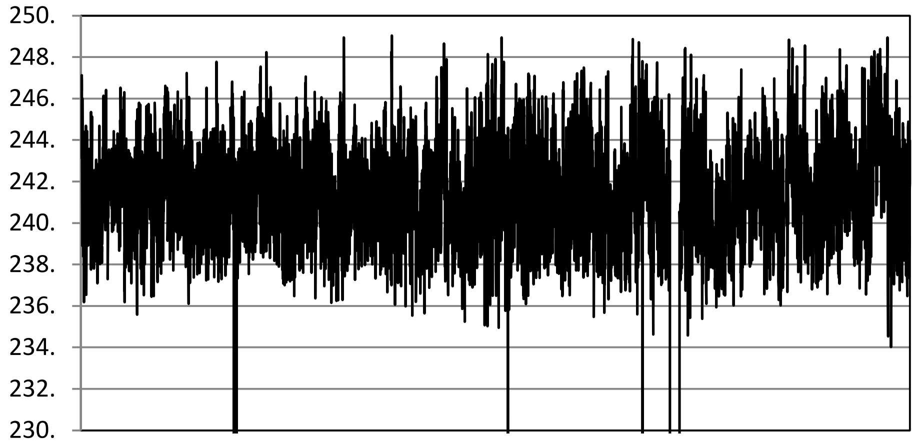


Figure 5: Voltage at Lakehead TS

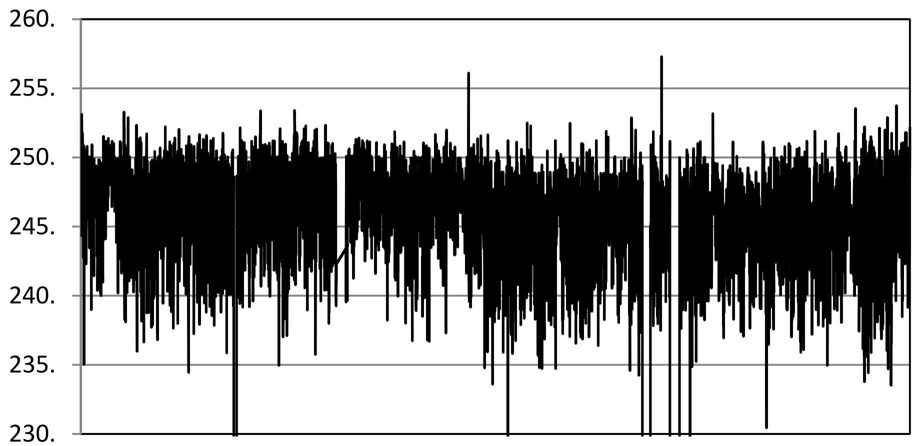


Figure 6: Voltage at Marathon TS

The followings can be observed.

Lakehead TS		Marathon TS	
Average voltage	241.5 kV	Average voltage	245.9 kV
M23L MW load (max)	198.3 MW	M23L MW load (max)	130.5 MW
M23L MW load (min)	-128.1 MW	M23L MW load (min)	-183.1 MW

4. Data Verification

4.1 Generator

A generator connecting to the IESO-controlled grid must have the capability to perform the following unless specified otherwise.

- Supply reactive power continuously at all active power outputs in the range of 0.9 lag to 0.95 lead power factor based on rated active power at its generator terminals for at least one constant 230 kV system voltage, and
- Supply full active power continuously while operating at a generator terminal voltage ranging from 0.95 pu to 1.05 pu of the generator's rated terminal voltage

The details of the generator data used in this assessment are given in Appendix A.

4.2 Transformer

Specifications for the 34.5/230 kV step-up transformer is listed below.

Transformation	240/34.5 kV
Rating	40/50/60 MVA ONAN/ONAF/ONAF
Impedance	0.073 pu based on 40 MVA
Configuration	3 phase, high side: wye, low side: delta
Tapping	on-load tap changers at HV (± 10% in 17 steps)

The connection applicant indicated a change of the 34.5 kV winding configuration from delta to wye grounded. This change is currently being analyzed at Hydro One and the IESO and any conclusions and requirements may be addressed in an SIA addendum.

4.3 Circuit Breakers and Switches

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

Breakers and switches	LV	HV
Rated line-to-line voltage	34.5 kV	250 kV
Interrupting time	-	50 ms
Rated continuous current	-	2000 A
Rated short circuit breaking current	-	63 kA

4.4 Collector System

The 34.5 kV collector system equivalent circuit impedance provided by the connection applicant are listed as follows:

Feeder #	Equivalent Impedance (Ohm)	Equivalent Impedance(pu)
1	0.406+j1.412	0034 + j 0.119
2	0.343+j0.467	0.029 + j 0.039
3	1.139+j4.157	0.096 + j 0.349
4	0.461+j1.618	0.039 + j 0.136

Per unit data are based on 100 MVA & 34.5 kV.

– End of Section –

5. Fault Level Assessment

Fault level studies were completed by Hydro One to examine the effects of the Greenwich Lake Wind Farm on fault levels at existing facilities in the area. Studies were performed to analyze the fault levels with and without Greenwich Lake and other proposed wind farms in the surrounding area. The short circuit study was carried out with the following facilities and system assumptions:

The 6 RES III awarded projects:

- Kruger Energy Chatham Wind Project
- Greenwich Windfarm
- Talbot Windfarm
- Raleigh Wind Energy Centre
- Byran Wind Project
- Gosfield Wind Project

Base case conditions:
Northwestern & Northeastern system

Existing facilities

- Atikokan GS
- Thunder Bay G2 & G3
- Prince I & II WF
- Terrace Bay Pulp CTS STG1 & STG2
- Umbata GS (M2W)
- GLP transmission system reinforcement

New facilities

- Wawatay G4
- Lac Seul GS
- Algoma Steel GS
- Lakehead TS SVC
- Mississagi TS SVC
- Series capacitors at Nobel SS in each of the 500kV circuits X503E & X504E to provide 50% compensation for the line reactance
- Porcupine TS & Kirkland Lake TS SVC
- Mattagami expansion (Upper and Lower Mattagami)

The rest of the system

Existing generation facilities

8 Bruce units
4 Darlington units
6 Pickering units
8 Nanticoke units
4 Lambton units
4 Lennox units
All hydraulic generation
GTAA (44 kV buses at Bramalea TS and Woodbridge TS)

TransAlta Douglas (44 kV buses at Bramalea TS)
TransAlta Sarnia (N6S/N7S)
West Windsor Power (J2N)
Brighton Beach (J20B/J1B)
Imperial Oil (N6S/N7S)
Greenfield Energy Centre (Lambton SS)
St. Clair Energy Centre (L25N & L27N)

All constructed wind farms including:

Erie Shores WF (W8T)
Kingsbridge WF (Goderich TS)
Amaranth WF – Amaranth I (B4V) & Amaranth II (B5V)
Ripley WF (B22D/B23D)
Prince I & II WF (K24)
Underwood (B4V/B5V)
Kruger Port Alma (C23Z/C24Z)

New generation facilities
Committed wind generation:

- Wolfe Island (X4H & X2H)
- Kingsbridge II (159 MW)

Other New generation:

- Sithe Goreway GS (V41H(V72RS)/V42H(V73RS))
- Thorold GS (Q10P)
- East Windsor Cogen (E8F & E9F) + existing Ford generation
- Beck I G7 conversion to 60 Hz
- Greenfield South GS (R24C)
- Halton Hills GS (T38B/T39B)
- Portlands GS (Hearn SS)
- Bruce standby generators

Transmission system configuration

Existing system with the following upgrades:

Bruce x Orangeville 230 kV circuits up-rated
Hurontario SS in service with R19T+V41H(V72RS) open from R21T+V42H(V73RS) (230 kV circuits V41H(V72RS) and V42H (V73RS) extended and connected from Cardiff TS to Hurontario SS)
Allanburg x Middleport 230 kV circuits (Q35M and Q26M) installed
Claireville TS 230 kV re-configured as per SIA CAA ID 2006-220 and operated ***open***
V75R terminated at Richview for a total of six 230 kV circuits between Claireville TS and RichviewTS
Two 245 Mvar (@ 230 kV) shunt capacitor banks installed at Orangeville TS and Detweiler TS, one per station
Four 250 Mvar (@ 250 kV) shunt capacitor banks installed at Middleport TS
Two 250 Mvar (@ 250 kV) shunt capacitor banks installed at Nanticoke TS
One 250 Mvar (@ 250 kV) shunt capacitor banks installed at Buchanan TS
LV shunt capacitor banks installed at Meadowvale and Halton TS
Essa-Stayner 115 kV circuit replaced by 2 x 230 kV circuits; Stayner TS converted to 230 kV; 230/115 kV auto installed to supply Meaford TS
New 230/115 kV autotransformer at Cambridge-Preston TS
1250 MW HVDC line ON-HQ in service

Tilbury West DS second connection point for DESN arrangement using K2Z and K6Z
Windsor area transmission reinforcement :

- 230 kV transmission line from Sandwich JCT (C21J/C22J) to Lauzon TS
- New 230/27.6 DESN, Leamington TS, that will connect C21J and C22J and supply part of the existing Kingsville TS load
- Replace Keith 230/115 kV T11 and T12 transformers
- 115 kV circuits J3E and J4E upgrades

System Assumptions

Lambton TS 230 kV operated ***open***
Richview TS 230 kV operated ***open***
Claireville TS 230 kV operated ***open***
Leaside TS 230 kV operated ***open***
Leaside TS 115 kV operated ***open***
Middleport TS 230 kV bus operated ***open***
Hearn SS 115 kV bus operated ***open* –** as required in the Portlands SIA
Cooksville TS 230 kV bus operated ***closed***
Cherrywood TS north & south 230kV buses operated ***open***
All capacitors in service
All tie-lines in service and phase shifters on neutral taps
Maximum voltages on the buses

The following table summarizes the symmetric fault levels near Greenwich Lake WF and corresponding breaker ratings.

Bus	All Wind Farms O/S		All Wind Farms I/S		Breaker Ratings Symmetrical (kA) (1)
	Total Fault Current Symmetrical (kA)		Total Fault Current Symmetrical (kA)		
	3-phase fault	L-G	3-phase fault	L-G	
Lakehead 230 kV	7.45	7.37	8.68	8.13	29.5
Lakehead 115 kV	18.35	20.4	19.94	21.64	29.5
Marathon 230 kV	4.44	4.50	4.70	4.67	19.1
Marathon 115 kV	5.48	6.72	5.68	6.91	39.3
Greenwich 230 kV HV#1	-	-	4.64	3.19	63
Greenwich 230 kV HV#2	-	-	4.65	3.22	63

(1) Worst case rating
(2) The 65 kA rating applies to breakers PL4 & KL4; the 70kA rating to remaining 230 kV breakers at Lambton SS.

The results show that the fault levels in the surrounding area of the Greenwich Lake area are below the symmetrical breaker ratings. Fault levels increase slightly when all the wind farms are in service with the highest increase at Lakehead of 1.6 kA.

Therefore, it can be concluded that the increases in fault level, due to the proposed Greenwich Lake WF, will not exceed the interrupting capabilities of the existing breakers on the IESO-controlled grid.

– End of Section –

6. System Impact Studies

This connection assessment was carried out to identify the effect of the proposed facility on thermal loading of transmission interfaces in the vicinity, the system voltages for pre/post contingencies, the ability of the facility to control voltage and the transient performance of the system.

6.1 Assumptions and Background

Winter 2011 peak load conditions were used for this study, along with the following assumptions:

System Conditions

All transmission system elements were in service.

Stations in the area were set to operate at 0.9 load power factors measured at the HV side of the transformers.

The load in NW was scaled to the extreme weather coincident peak load of 922 MW (Forecasted normal weather coincident peak is 887 MW).

Marathon TS pre-contingency voltage was maintained within the 120 kV to 126 kV range as per *115 kV Voltages SCO.*

Area generation was assumed in-service with the dispatch pattern outlined in the following table.

MW	G1	G2	G3	G4	G5	G6	G7	Total
Aguasabon GS	20	20						40
Cameron GS	9	9	9	11	10	9	20	77
Alexander GS	11	11	11	12	12			57
Pine Portage GS	32	32	32	32				128
Wawatay GS	4	4	4	6				18
Umbata GS	10	10						20
Total								340

Modeling Assumptions

- Terrace Bay Pulp distribution system with a new generator, STG2, was added to the base case
- Aguasabon GS governor and exciter model parameters were updated as per information provided by the OPG
- Umbata GS control systems parameters were updated as per model validation report completed by Kestrel
- Cameron G4 and G5 dynamic data were updated as per the information provided by OPG and used in Cameron Falls SIA, CAA ID 2007-EX316

Study Scenarios

Two power transfer scenarios were studied: Transfer East (TE) and Transfer West (TW). The system generation MW dispatch pattern and phase shifters were adjusted to achieve acceptable maximum flow levels across the relevant interfaces as per the following table:

Scenario	TEK	TEM	TWM	OMTE	OMTW	MPFS	MPFN	EWTE	EWTW
Transfer East	350	425	-	300	-	-	25	325	-
Transfer West	-	-	350	-	300	75	-	-	350

The interfaces are defined as follows:

Interface	Definition
TEK	Transfer east of Kenora
TEM	Transfer east of Mackenzie
TWM	Transfer west of Mackenzie
OMTE	Ontario-Manitoba transfer east
OMTW	Ontario-Manitoba transfer west
MPFS	Minnesota power flow south
MPFN	Minnesota power flow north
EWTE	East-West transfer east
EWTW	East-West transfer west

6.2 Protection Impact Assessment

A Protection Impact Assessment (PIA) was completed by Hydro One to examine the impact of the new generators on existing transmission system protections. The existing protections for M23L/M24L at Marathon TS and Lakehead TS were described in the PIA report and the proposed protection settings were analyzed based on preliminary fault calculation. Finally, the proposed protection solutions and recommendations were presented.

The existing zone 1 setting reach at Marathon TS and Lakehead TS will be reduced to block short of the HV tap at Greenwich Wind facility. This setting will be equivalent to approximately 35 km of the line from Lakehead TS; as a result, the overlap of the zone 1 reach from each terminal will be compromised and about 48 km M23L/M24L will be covered only by zone 2 protection. To allow for blocking signal the clearing timing of the zone 2 faults will be delayed by 50 ms. Therefore, dynamic simulations were performed to examine the impact of the 50 ms delay in the clearing time on the system reliability and wind farm operation.

It was concluded in the PIA report that detailed fault calculations should be run to derive new apparent impedance due to the proposed connection and the existing line protection settings and the reclosing schemes at terminal stations should be revised.

The IESO concluded that the proposed protection adjustments have no material adverse impact on the IESO-controlled grid.

6.3 Thermal Analysis

The assessment examined the effect the proposed facility would have on the thermal loadings of the Lakehead/Marathon area 230/115 kV transmission elements.

The *Ontario Resource and Transmission Assessment Criteria* requires that all line and equipment loads be within their continuous ratings with all elements in service, and within their long-term emergency ratings with any element out of service. Lines and equipment may be loaded up to their short-term emergency ratings immediately following the contingencies to effect re-dispatch, perform switching, or implement control actions to reduce the loading to the long-term emergency ratings.

Hydro One provided continuous and 15-min thermal ratings for the summer and winter weather conditions. 15-min Limited Time Ratings (LTR) were calculated based on 100% pre-flows, 4 km/h wind and 30˚C for summer ratings and 80% pre-flows, 4 km/h wind and 10˚C for winter ratings. The aforementioned pre-flows were due to the fact that pre-contingency loading observed on some of the circuits were exceeding 80% and 75% of their summer and winter ratings respectively. Also, it should be noted that the continuous and 15-min LTR summer ratings are the same since 15-min LTR ratings were calculated based on 100% pre-load.

The ratings as well as lengths of the circuits are summarized in the following table. The MVA continuous and 15-min ratings were calculated based on the minimum allowable 230 kV and 115 kV system voltages of 235 kV and 113 kV, respectively.

Cct	From	To	L (km)	Max Temp	Rating Temp	Summer Ratings				Winter Ratings			
						Continuous		15-Minute		Continuous		15-Minute	
						A	MVA	A	MVA	A	MVA	A	MVA
A21L/A22L	Mackenzie TS	Lakehead TS	191.1	93	93	*930*	379	*930*	379	*1080*	440	*1190*	485
M23L/M24L	Lakehead TS	Marathon TS	228.8	95	95	*950*	387	*950*	387	*1100*	448	*1200*	489
W21M	Marathon TS	Wawa	164.7	93	93	*930*	379	*930*	379	*1080*	440	*1190*	485
W22M	Marathon TS	Wawa	164.7	111	111	*1080*	440	*1080*	440	*1210*	493	*1320*	538
A5A	Alexander SS	Minnova J	82.99	66	66	*430*	84.2	*430*	84.2	*580*	113.5	*610*	119.4
	Minnova J	Schreiber J	8.00	66	66	*430*	84.2	*430*	84.2	*580*	113.5	*610*	119.4
	Schreiber J	Aguasabon SS	9.17	66	66	*430*	84.2	*430*	84.2	*580*	113.5	*610*	119.4
A1B	Aguasabon SS	Terrace Bay Pulp J	4.54	84	84	*570*	111.6	*570*	111.6	*680*	133.1	*720*	140.9
	Terrace Bay Pulp J	Terrace Bay SS	0.02	150	127	*790*	154.6	*790*	154.6	*870*	170.3	*930*	182.0
T1M	Terrace Bay SS	Angler Switch J	52.67	70	70	*460*	90.0	*460*	90.0	*600*	117.4	*640*	125.3
	Angler Switch J	Pic J	2.93	70	70	*460*	90.0	*460*	90.0	*600*	117.4	*640*	125.3
	Pic J	Marathon TS	3.27	150	127	*790*	154.6	*790*	154.6	*870*	170.3	*930*	125.3
A6P	Alexander SS	Reserve J	10.0	69	69	*490*	107	*490*	107	*640*	140	*680*	149
	Reverse J	Port Arthur TS	90.9	66	66	*260*	57	*260*	57	*350*	77	*350*	77
A7L	Alexander SS	Reserve J	15.8	61	61	*310*	68	*310*	68	*440*	96	*460*	101
	Reserve J	Lakehead TS	86.0	60	60	*310*	68	*310*	68	*440*	96	*460*	101

A8L	Alexander SS	Lakehead TS	95.7	66	66	*430*	94	*430*	94	*580*	127	*610*	133

The following are the pre-contingency flows and post-contingency flows for various circuits in the local area prior to and after the connection of Greenwich Lake. Two scenarios, Transfer East (TE) and Transfer West (TW), were studied and the pre-contingency flow on each circuit is expressed in MVA, Amperes and percentage of continuous rating. The post-contingency loadings of the monitored circuits include loading in MVA, ampers, and percentage of loading over LTR. Ratings for summer and winter were considered.

Pre-contingency load flows on the circuit and its companion circuit, are very similar for double circuits A21L/A22L, M23L/M24L, and W21M/W22M. Contingencies associated with loss one of double circuits, A21L/A22L, M23L/M24L, and W21M/W22M are simulated for thermal studies. Simulation results indicate that there is no difference in power flowing over one of the double circuits following the contingency of its companion circuit. Therefore, only results for A21L, M23L and W21M are shown in this report.

TE: Year 2011, Initial Conditions, Summer Ratings																				
Circuit	Circuit Section		Summer Ratings (A)		Pre-contingency				Loss of M24L				Loss of A22L				Loss of W22M			
					Flow		Loading (%)		Flow		Loading (%)		Flow		Loading (%)		Flow		Loading (%)	
	From	To	Cont	15-M	MVA	Amps	Cont	15-M	MVA	Amps	Cont	15-M	MVA	Amps	Cont	15-M	MVA	Amps	Cont	15-M
A21L	Mackenzie TS	Lakehead TS	*930*	*930*	180.4	426.7	45.9	45.9	177.4	423.8	45.6	45.6	319.9	780.6	83.9	83.9	178.2	242.7	26.1	26.1
M23L	Lakehead TS	Marathon TS	*950*	*950*	159.7	374.3	39.4	39.4	279.1	669.3	70.5	70.5	149.7	357.6	37.6	37.6	157.8	378.2	39.8	39.8
W21M	Marathon TS	Wawa	*930*	*930*	178.9	427.6	46.0	46.0	172.3	445.7	47.9	47.9	168.3	402.9	43.3	43.3	352.8	919.2	98.8	98.8
A5A	Alexander SS	Minnova J	*430*	*430*	65.9	302.5	70.3	70.3	106.9	495.1	*115.1*	*115.1*	-		-		-		-	
	Minnova J	Schreiber J	*430*	*430*	63.8	296.6	69.0	69.0	102.2	490.2	*114.0*	*114.0*								
	Schreiber J	Aguasabon SS	*430*	*430*	60.1	279.2	64.9	64.9	98.6	472.9	*110.0*	*110.0*								
A1B	Aguasabon SS	Terrace Bay Pulp J	*570*	*570*	97.6	453.0	79.5	79.5	133.0	363.3	63.7	63.7	-		-		-		-	
	Terrace Bay Pulp J	Terrace Bay SS	*790*	*790*	101.1	469.9	59.5	59.5	136.0	651.9	82.5	82.5								
T1M	Terrace Bay SS	Pic J	*460*	*460*	101.1	469.9	*102.2*	*102.2*	136.0	651.9	*141.7*	*141.7*	-		-		-		-	
	Pic J	Marathon TS	*790*	*790*	90.5	417.4	52.8	52.8	126.6	600.2	76.0	76.0								
TE: Year 2011, Greenwich WF In Service, Summer Ratings																				
A21L	Mackenzie TS	Lakehead TS	*930*	*930*	131.9	306.8	33.0	33.0	132.1	308.3	33.2	33.2	239.7	568.2	61.1	61.1	129.1	302.7	32.5	32.5
M23L	Lakehead TS	Marathon TS	*950*	*950*	158.8	372.9	39.3	39.3	243.6	583.5	61.4	61.4	155.5	371.7	39.1	39.1	156.4	379.4	39.9	39.9
W21M	Marathon TS	Wawa	*930*	*930*	177.9	423.3	45.5	45.5	153.1	371	39.9	39.9	174.8	419.2	45.1	45.1	350.6	905.3	97.3	97.3
A5A	Alexander SS	Minnova J	*430*	*430*	62.0	286.3	66.6	66.6	88.4	410.2	95.4	95.4	-		-		-		-	
	Minnova J	Schreiber J	*430*	*430*	60.1	280.2	65.2	65.2	85.2	405.0	94.2	94.2								
	Schreiber J	Aguasabon SS	*430*	*430*	58.4	262.9	61.1	61.1	81.5	378.5	88.0	88.0								
A1B	Aguasabon SS	Terrace Bay Pulp J	*570*	*570*	93.6	435.9	76.5	76.5	117.0	555.3	97.4	97.4	-		-		-		-	
	Terrace Bay Pulp J	Terrace Bay SS	*790*	*790*	97.0	452.4	57.3	57.3	120.0	570.7	72.2	72.2								
T1M	Terrace Bay SS	Pic J	*460*	*460*	97.0	452.4	98.3	98.3	120.0	570.7	*124.1*	*124.1*	-		-		-		-	
	Pic J	Marathon TS	*790*	*790*	85.8	398.5	50.4	50.4	108.9	516.3	65.4	65.4								

TE: Year 2011, Initial Conditions, Winter Ratings																				
Circuit	Circuit Section		Winter Ratings (A)		Pre-contingency				Loss of M24L				Loss of A22L				Loss of W22M			
					Flow		Loading (%)		Flow		Loading (%)		Flow		Loading (%)		Flow		Loading (%)	
	From	To	Cont	15-M	MVA	Amps	Cont	15-M	MVA	Amps	Cont	15-M	MVA	Amps	Cont	15-M	MVA	Amps	Cont	15-M
A21L	Mackenzie TS	Lakehead TS	*1080*	*1190*	180.4	426.7	39.5	35.9	177.4	423.8	39.2	35.6	319.9	780.6	72.3	65.6	178.2	242.7	22.5	20.4
M23L	Lakehead TS	Marathon TS	*1100*	*1200*	159.7	374.3	34.0	31.2	279.1	669.3	60.8	55.8	149.7	357.6	32.5	29.8	157.8	378.2	34.4	31.5
W21M	Marathon TS	Wawa	*1080*	*1190*	178.9	427.6	39.6	35.9	172.3	445.7	41.3	37.5	168.3	402.9	37.3	33.9	352.8	919.2	85.1	77.2
A5A	Alexander SS	Minnova J	*580*	*610*	65.9	302.5	52.2	49.6	106.9	495.1	85.4	81.2	-		-		-		-	
	Minnova J	Schreiber J	*580*	*610*	63.8	296.6	51.1	48.6	102.2	490.2	84.5	80.4								
	Schreiber J	Aguasabon SS	*580*	*610*	60.1	279.2	48.1	45.8	98.6	472.9	81.5	77.5								
A1B	Aguasabon SS	Terrace Bay Pulp J	*680*	*720*	97.6	453.0	66.6	62.9	133.0	363.3	53.4	50.5	-		-		-		-	
	Terrace Bay Pulp J	Terrace Bay SS	*870*	*930*	101.1	469.9	54.0	50.5	136.0	651.9	74.9	70.1								
T1M	Terrace Bay SS	Pic J	*600*	*640*	101.1	469.9	78.3	73.4	136.0	651.9	*108.7*	*101.9*	-		-		-		-	
	Pic J	Marathon TS	*870*	*930*	90.5	417.4	48.0	44.9	126.6	600.2	69.0	64.5								
TE: Year 2011, Greenwich WF In Service, Winter Ratings																				
A21L	Mackenzie TS	Lakehead TS	*1080*	*1190*	131.9	306.8	28.4	25.8	132.1	308.3	28.5	25.9	239.7	568.2	52.6	47.7	129.1	302.7	28.0	25.4
M23L	Lakehead TS	Marathon TS	*1100*	*1200*	158.8	372.9	33.9	31.1	243.6	583.5	53.0	48.6	155.5	371.7	33.8	31.0	156.4	379.4	34.5	31.6
W21M	Marathon TS	Wawa	*1080*	*1190*	177.9	423.3	39.2	35.6	153.1	371.0	34.4	31.2	174.8	419.2	38.8	35.2	350.6	905.3	83.8	76.1
A5A	Alexander SS	Minnova J	*580*	*610*	62.0	286.3	49.4	46.9	88.4	410.2	70.7	67.2	-		-		-		-	
	Minnova J	Schreiber J	*580*	*610*	60.1	280.2	48.3	45.9	85.2	405.0	69.8	66.4								
	Schreiber J	Aguasabon SS	*580*	*610*	58.4	262.9	45.3	43.1	81.5	378.5	65.3	62.0								
A1B	Aguasabon SS	Terrace Bay Pulp J	*680*	*720*	93.6	435.9	64.1	60.5	117.0	555.3	81.7	77.1	-		-		-		-	
	Terrace Bay Pulp J	Terrace Bay SS	*870*	*930*	97.0	452.4	52.0	48.6	120.0	570.7	65.6	61.4								
T1M	Terrace Bay SS	Pic J	*600*	*640*	97.0	452.4	75.4	70.7	120.0	570.7	95.1	89.2	-		-		-		-	
	Pic J	Marathon TS	*870*	*930*	85.8	398.5	45.8	42.8	108.9	516.3	59.3	55.5								

TW: Year 2011, Initial Conditions, Summer Ratings																				
Circuit	*Circuit Section*		*Summer Ratings (A)*		*Pre-contingency*				*Loss of M24L*				*Loss of A22L*				*Loss of W22M*			
					Flow		*Loading (%)*		*Flow*		*Loading (%)*		*Flow*		*Loading (%)*		*Flow*		*Loading (%)*	
	From	*To*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*
A21L	*Lakehead TS*	*Mackenzie TS*	*930*	*930*	134.2	321.9	34.6	34.6	128.5	316.6	34.0	34.0	238.6	581.1	62.5	62.5	129.6	320.2	34.4	34.4
M23L	*Marathon TS*	*Lakehead TS*	*950*	*950*	156.3	369.0	38.8	38.8	273.1	677.8	71.3	71.3	155.6	368.6	38.8	38.8	154.4	411.4	43.3	43.3
W21M	*Wawa TS*	*Marathon TS*	*930*	*930*	179.7	422.6	45.4	45.4	180.6	436.2	46.9	46.9	179.5	422.5	45.4	45.4	373.5	966.8	*104.0*	*104.0*
A6P	*Alexander SS*	*Reserve J*	*490*	*490*	66.5	305.3	62.3	62.3	74.0	342.9	70.0	70.0	-		-		-		-	
	Reverse J	*Port Arthur TS*	*260*	*260*	56.9	261.0	*100.4*	*100.4*	64.1	298.2	*114.7*	*114.7*								
A7L	*Alexander SS*	*Reserve J*	*310*	*310*	62.5	286.9	92.5	92.5	70.8	328.3	*105.9*	*105.9*	-		-		-		-	
	Reserve J	*Lakehead TS*	*310*	*310*	62.1	285.6	92.1	92.1	70.2	327.4	*105.6*	*105.6*								
A8L	*Alexander SS*	*Lakehead TS*	*430*	*430*	69.3	318.0	74.0	74.0	78.5	364.2	84.7	84.7	-		-		-		-	
TW: Year 2011, Greenwich WF In Service, Summer Ratings																				
A21L	*Lakehead TS*	*Mackenzie TS*	*930*	*930*	131.8	317.9	34.2	34.2	132.1	345.0	37.1	37.1	239.7	588.7	63.3	63.3	131.3	318.2	34.2	34.2
M23L	*Greenwich J*	*Lakehead TS*	*950*	*950*	150.7	360.4	37.9	37.9	266.8	703.4	74.0	74.0	153.8	373.4	39.3	39.3	149.8	361.2	38.0	38.0
W21M	*Wawa TS*	*Marathon TS*	*930*	*930*	122.5	289.0	31.1	31.1	155.8	384.7	41.4	41.4	126.3	299.9	32.2	32.2	244.0	583.3	62.7	62.7
A6P	*Alexander SS*	*Reserve J*	*490*	*490*	64.1	295.2	60.2	60.2	73.2	339.9	69.4	69.4	-		-		-		-	
	Reverse J	*Port Arthur TS*	*260*	*260*	54.2	250.4	96.3	96.3	63.2	294.5	*113.3*	*113.3*								
A7L	*Alexander SS*	*Reserve J*	*310*	*310*	59.4	273.5	88.2	88.2	69.6	323.5	*104.4*	*104.4*	-		-		-		-	
	Reserve J	*Lakehead TS*	*310*	*310*	59.0	272.6	87.9	87.9	69.0	322.7	*104.1*	*104.1*								
A8L	*Alexander SS*	*Lakehead TS*	*430*	*430*	65.8	303.1	70.5	70.5	77.2	358.8	83.4	83.4	-		-		-		-	

TW: Year 2011, Initial Conditions, Winter Ratings																				
Circuit	*Circuit Section*		*Winter Ratings (A)*		*Pre-contingency*				*Loss of M24L*				*Loss of A22L*				*Loss of W22M*			
					Flow		*Loading (%)*		*Flow*		*Loading (%)*		*Flow*		*Loading (%)*		*Flow*		*Loading (%)*	
	From	*To*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*	*MVA*	*Amps*	*Cont*	*15-M*
A21L	*Lakehead TS*	*Mackenzie TS*	*1080*	*1190*	134.2	321.9	29.8	27.1	128.5	316.6	29.3	26.6	238.6	581.1	53.8	48.8	129.6	320.2	29.6	26.9
M23L	*Marathon TS*	*Lakehead TS*	*1100*	*1200*	156.3	369.0	33.5	30.8	273.1	677.8	61.6	56.5	155.6	368.6	33.5	30.7	154.4	411.4	37.4	34.3
W21M	*Wawa TS*	*Marathon TS*	*1080*	*1190*	179.7	422.6	39.1	35.5	180.6	436.2	40.4	36.7	179.5	422.5	39.1	35.5	373.5	966.8	89.5	81.2
A6P	*Alexander SS*	*Reserve J*	*640*	*680*	66.5	305.3	47.7	44.9	74.0	342.9	53.6	50.4	-		-		-		-	
	Reverse J	*Port Arthur TS*	*350*	*350*	56.9	261.0	74.6	74.6	64.1	298.2	85.2	85.2								
A7L	*Alexander SS*	*Reserve J*	*440*	*460*	62.5	286.9	65.2	62.4	70.8	328.3	74.6	71.4	-		-		-		-	
	Reserve J	*Lakehead TS*	*440*	*460*	62.1	285.6	64.9	62.1	70.2	327.4	74.4	71.2								
A8L	*Alexander SS*	*Lakehead TS*	*580*	*610*	69.3	318.0	54.8	52.1	78.5	364.2	62.8	59.7	-		-		-		-	
TW: Year 2011, Greenwich WF In Service, Winter Ratings																				
A21L	*Lakehead TS*	*Mackenzie TS*	*1080*	*1190*	131.8	317.9	29.4	26.7	132.1	345.0	31.9	29.0	239.7	588.7	54.5	49.5	131.3	318.2	29.5	26.7
M23L	*Greenwich J*	*Lakehead TS*	*1100*	*1200*	150.7	360.4	32.8	30.0	266.8	703.4	63.9	58.6	153.8	373.4	33.9	31.1	149.8	361.2	32.8	30.1
W21M	*Wawa TS*	*Marathon TS*	*1080*	*1190*	122.5	289.0	26.8	24.3	155.8	384.7	35.6	32.3	126.3	299.9	27.8	25.2	244.0	583.3	54.0	49.0
A6P	*Alexander SS*	*Reserve J*	*640*	*680*	64.1	295.2	46.1	43.4	73.2	339.9	53.1	50.0	-		-		-		-	
	Reverse J	*Port Arthur TS*	*350*	*350*	54.2	250.4	71.5	71.5	63.2	294.5	84.1	84.1								
A7L	*Alexander SS*	*Reserve J*	*440*	*460*	59.4	273.5	62.2	59.5	69.6	323.5	73.5	70.3	-		-		-		-	
	Reserve J	*Lakehead TS*	*440*	*460*	59.0	272.6	62.0	59.3	69.0	322.7	73.3	70.2								
A8L	*Alexander SS*	*Lakehead TS*	*580*	*610*	65.8	303.1	52.3	49.7	77.2	358.8	61.9	58.8	-		-		-		-	

Thermal congestion of the Marathon 115 kV and Lakehead 115 kV local area circuits is inherent to the existing 115 kV area configuration. During the summer, T1M and A5A circuits might become overloaded for the Transfer East conditions, while the overloading of A6P and A7L might occur under Transfer West condition. During the winter, the 115 kV circuits T1M is overloaded for Transfer West. With the connection of Greenwich Lake, the flows on T1M and A6P would be under continuous ratings and circuits T1M, A6P and A7L remain overloaded for some post-contingencies. The overloading is an existing system problem, and it is not a result of the proposed wind generating station. It can be seen from the simulation results that the proposed Greenwich Lake WF will slightly mitigate the overloading on the 115 kV system.

6.4 Voltage Analysis

The assessment of the voltage performance in the Marathon 115 kV area was done in accordance with the IESO's *Ontario Resource and Transmission Assessment Criteria*. The criteria states that with all facilities in service pre-contingency, 115 kV and 230 kV system voltage declines following a contingency shall be limited to 10% both before and after transformer tap changer action.

The voltage decline studies were performed with the Greenwich Lake facility connected to the circuits M23L/M24L. The study was done for peak load conditions and Constant MVA model in both immediate pre-contingency state and in post-ULTC state.

The study results summarized in the following tables indicate that both declines of pre-ULTC and post-ULTC values are within the IESO's criteria of 10%.

TE: Year 2011																		
Monitored Busses		Pre-Cont Voltage kV	***Loss of Greenwich WF***				***Loss of A21L***				***Loss of M23L***				***Loss of W21M***			
Bus Name	Base kV		Pre-ULTC		Post-ULTC		Pre-ULTC		Post-ULTC		Pre-ULTC		Post-ULTC		Pre-ULTC		Post-ULTC	
			kV	%	kV	%	kV	%	kV	%	kV	%	kV	%	kV	%	kV	%
Wawa TS	220	240.6	245.1	*1.9*	251.8	*4.7*	242.6	*0.8*	239.4	*-0.5*	241.7	*0.5*	240.1	*-0.2*	235.6	*-2.1*	223.9	*-6.9*
Marathon TS	220	242.5	247.6	*2.1*	256.5	*5.8*	244.2	*0.7*	238.9	*-1.5*	238.9	*-1.5*	236.1	*-2.6*	237.0	*-2.3*	219.4	*-9.5*
Lakehead TS	220	247.9	248.7	*0.3*	252.7	*1.9*	246.0	*-0.8*	238.8	*-3.7*	246.5	*-0.6*	245.6	*-0.9*	247.8	*0.0*	236.2	*-4.7*
Mackenzie TS	220	248.3	247.0	*-0.5*	250.0	*0.7*	245.2	*-1.2*	242.1	*-2.5*	248.1	*-0.1*	247.4	*-0.4*	249.4	*0.4*	244.4	*-1.6*
Marathon TS	118	124.6	126.8	*1.8*	125.1	*0.4*	125.4	*0.6*	123.1	*-1.2*	122.5	*-1.7*	122.6	*-1.6*	122.5	*-1.7*	122.4	*-1.8*
Alexandra SS	118	124.9	125.1	*0.2*	125.4	*0.4*	124.7	*-0.2*	124.7	*-0.2*	124.4	*-0.4*	124.3	*-0.5*	124.9	*0.0*	124.7	*-0.2*
Leakhead TS	118	121.9	122.0	*0.1*	123.1	*1.0*	121.3	*-0.5*	121.5	*-0.3*	121.6	*-0.2*	121.3	*-0.5*	121.8	*-0.1*	121.6	*-0.2*
Greenwich-M23L	220	246.6	248.9	*0.9*	254.3	*3.1*	245.7	*-0.4*	239.2	*-3.0*	-	-	-	-	245.8	*-0.3*	233.1	*-5.5*
Greenwich-M24L	220	246.5	248.9	*1.0*	254.3	*3.2*	245.7	*-0.3*	239.1	*-3.0*	242.5	*-1.6*	241.0	*-2.2*	245.8	*-0.3*	233.6	*-5.2*
TW: Year 2011																		
Wawa TS	220	244.7	240.9	*-1.6*	242.2	*-1.0*	245.6	*0.4*	243.2	*-0.6*	242.5	*-0.9*	233.9	*-4.4*	240.7	*-1.6*	246.3	*0.7*
Marathon TS	220	244.9	241.2	*-1.5*	238.5	*-2.6*	245.4	*0.2*	242.5	*-1.0*	240.6	*-1.8*	225.0	*-8.1*	240.8	*-1.7*	240.9	*-1.6*
Lakehead TS	220	239.4	239.5	*0.0*	236.6	*-1.2*	237.4	*-0.8*	235.1	*-1.8*	237.3	*-0.9*	221.1	*-7.6*	239.5	*0.0*	238.5	*-0.4*
Mackenzie TS	220	240.2	243.1	*1.2*	239.8	*-0.2*	238.1	*-0.9*	232.6	*-3.2*	242.5	*1.0*	236.1	*-1.7*	241.8	*0.7*	240.2	*0.0*
Marathon TS	118	125.8	124.4	*-1.1*	123.4	*-1.9*	125.9	*0.1*	124.8	*-0.8*	124.3	*-1.2*	122.1	*-2.9*	124.1	*-1.4*	124.2	*-1.3*
Alexandra SS	118	125.4	125.4	*0.0*	125.0	*-0.3*	125.3	*-0.1*	125.0	*-0.3*	124.9	*-0.4*	124.3	*-0.9*	125.4	*0.0*	125.3	*-0.1*
Leakhead TS	118	122.9	122.9	*0.0*	122.0	*-0.7*	122.3	*-0.5*	121.7	*-1.0*	122.1	*-0.7*	121.4	*-1.2*	122.9	*0.0*	122.6	*-0.2*
Greenwich-M23L	220	241.5	240.3	*-0.5*	236.9	*-1.9*	240.2	*-0.5*	237.7	*-1.6*	-	-	-	-	240.9	*-0.2*	240.0	*-0.6*
Greenwich-M24L	220	241.5	240.3	*-0.5*	236.9	*-1.9*	240.2	*-0.5*	237.7	*-1.6*	237.1	*-1.8*	219.0	*-9.3*	240.9	*-0.2*	240.0	*-0.6*

6.5 Reactive Power Compensation

6.5.1 Dynamic Reactive Power Compensation

The following summarizes the IESO required level of dynamic reactive power and the available capability of SMK223 from Siemens document "Reactive Power Capability" (Document PG-R3-30-0000-0113-03).

	Terminal Voltage	Active Power	Reactive Power Capability/Turbine
IESO Required	1.0 pu	1.0 pu	$Q_{gen} = 2.55 \times \sin[\cos^{-1}(0.9)] = 1.11$ Mvar
			$Q_{abs} = 2.55 \times \sin[\cos^{-1}(0.95)] = 0.8$ Mvar
SMK223 Capability	1.0 pu	1.0 pu	$Q_{gen} = 2.3 \times 0.55 = 1.26$ Mvar
			$Q_{abs} = 2.3 \times 0.55 = 1.26$ Mvar

The SMK223 generators can deliver IESO required dynamic reactive power to the generator terminal at rated power and at rated voltage. Thus, the IESO has determined that there is no need to install any additional dynamic reactive power compensation device.

6.5.2 Static Reactive Power Compensation

Greenwich Lake Wind Farm must have the same capability to supply reactive power continuously as required of a synchronous generator with the same apparent power, as measured at the point of connection to the IESO-controlled grid. As such, Greenwich Lake Wind Farm must have a minimum capability of supplying approximately **+35 MVAr** (capacitive) to **-33 MVAr** (inductive) at the connection point for at least one constant 230 kV system voltage at all active power outputs.

Load flow studies were performed to justify a need for static reactive compensation. Besides the conditions described in Chapter 4, additional simulation conditions for these load flow studies include that:

- The 230-kV voltages at Lakehead and Marathon are about 242 and 244 kV, respectively;
- The terminal voltages of the WTGs vary between 0.95 pu and 1.05 pu;
- The 230 kV tap of the step-up transformer at the interconnection substation is set to the position of 246 kV;

The inductive capability of the generation facility was assessed with the WTGs operating at full active power output. The voltage at the connection point is about 236 kV. The WTG units are operated to control the terminal voltages to their lowest values. The generation facility can absorb a maximum reactive power of **36.7 MVAr** at the connection points (16.7 MVAr on M22L and 20 MVAr on M23L), indicating that Greenwich Lake Wind Farm meet the inductive reactive power requirement.

The capacitive capability of the generation facility was assessed with the WTGs operating at full active power output. The voltage at the connection point is about 243 kV. The generation facility can supply a maximum reactive power of **12 MVAr** at the connection points (7.1 MVAr on M23L and 4.9 MVAr on M24L) when the WTG units are operated to control their terminal voltages to the highest values. This indicates that static reactive compensation is required to be installed at both collector buses to meet the capacitive reactive power requirement.

Two capacitor banks, with equipment capacity of **9 MVAr@34.5 kV,** installed at the 34.5 kV bus #1 and **12 MVAr@34.5 kV** at bus #2 will increase the reactive power injection at the connection point. With these capacitor banks, the wind farm can supply a maximum reactive power of **+35 MVAr** at the connection points, which meets the capacitive reactive requirement**.**

Voltage change due to capacitor switching

A switching study was carried out to investigate the effect of the new LV shunt capacitor banks on the voltage changes.

Following summarizes the change in voltage due to switching of a single capacitor of 12 MVAr at the collector bus. All generators are set to operate at a fixed power factor to prevent their dynamic reactive power capability from changing bus voltages, so that the ΔV is only due to capacitor switching. The ΔV has been tested when generators offer no voltage support and at the worst condition, i.e. the generators absorb maximum reactive power so that the ΔV due to cap switching is maximum. The transformers ULTCs have been locked.

LV			**HV**		
PRE	**POST**	**%**	**PRE**	**POST**	**%**
34.56	35.06	1.45	240.9	242.0	0.46

The IESO allows ΔV on a single capacitor switching to be no more than 4 %. The results show that switching of a single capacitor of 9 MVAr/12 MVAr produces less than 4 % voltage increase.

6.6 Transient Analysis

Transient stability analyses were performed considering faults in the Lakehead and Marathon area with the proposed Greenwich Lake WF in-service. Six LLG contingencies for Transfer East and Transfer West cases were tested. It should be noted that since part of circuits M23L/M24L will be covered only by Zone 2 protection as described in the Protection Impact Assessment, additional 50 ms were included in the fault clearing time.

ID	**Contingency**	**Voltage (kV)**	**Location**	**Fault MVA**	**Fault Clearing Time (ms)**	
					Near	**Remote**
SC1	LLG Fault on M23L	230	Marathon	431 - j3359	116+50	116+50
SC2	LLG Fault on W22M	230	Marathon	431 - j3359	116	141
SC3	LLG fault on T1M	115	Marathon	445 - j4006	83	116
SC4	LLG Fault on M23L	230	Lakehead	513 – j5546	83+50	149+50
SC5	LLG Fault on A21L	230	Lakehead	513 – j5546	83	149
SC6	LLG fault on A7L & A8L	115	Lakehead	860 – j8414	116	149

Appendix B shows the transient curves. It can be concluded from the results that, with Greenwich Lake WF on-line, none of the simulated contingencies caused transient instability or undamped oscillations.

6.7 Low-voltage ride through capability

As any other generators, the MK II is expected to trip only for contingencies which remove the generator by configuration or abnormal conditions such as severe and sustained under-voltage, over-voltage, under-frequency, over-frequency etc**.** The severity of under-voltage seen by generator terminals is to be temporarily mitigated by the LVRT capability. The LVRT feature is implemented by injection of additional reactive current by the grid side AC/DC converter to maintain generator terminal voltage in the event of a disturbance in the power system that causes the terminal voltage to drop.

The implementation of LVRT should not require any instant modification to under-voltage protection settings. In PSS/E model for MK II, the LVRT feature accompanies a change of under-voltage settings as shown below (From Siemens Document "UserInputData-SMK223_InputData_SWT-2.3-101_VS_60 Hz_V1.2.xls".

Voltage range	*Event*
1.00 – 0.85 pu	No trip
0.85 – 0.5 pu	Relay 1 trips in 3.1 sec
0.5 – 0.15 pu	Relay 2 trips in 1.835 sec
0.15 – 0.0 pu	Relay 3 trips in 0.24 sec

In order to examine the need for low voltage ride through (LVRT) capability, the terminal voltage of the wind generator was monitored for all six contingencies. The variation of the terminal voltage of the new generation facility is plotted in Figure 7 below. It can be seen that the duration during which the generator terminal voltage drops below 0.5 pu is about 0.16 sec. Therefore, fault ride through capability of the proposed wind turbines is adequate.

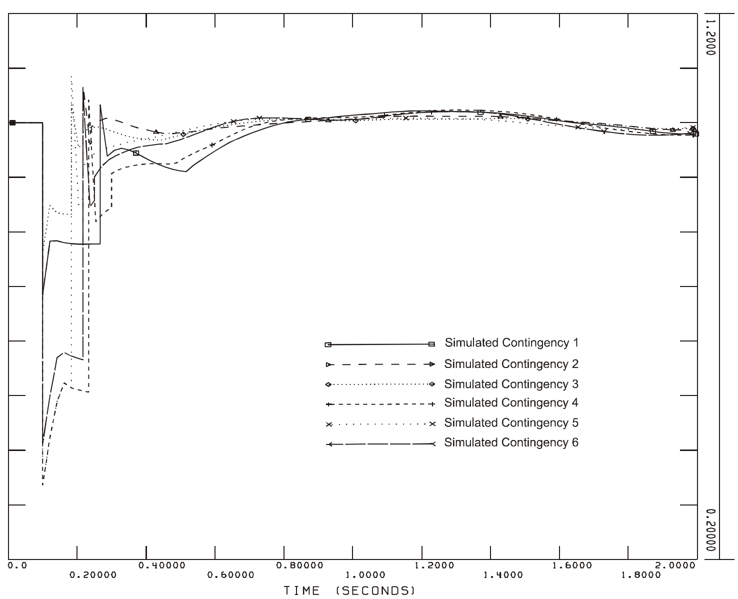


Figure 7: Terminal Voltage of Wind Generator during LLG faults

The LVRT capability must be demonstrated during commissioning by monitoring several variables under a set of IESO specified field tests and the results should be verifiable using the PSS/E model.

6.8 Wind Farm Management System

The Wind Farm Management System (WFMS) must coordinate the voltage control process. The proponent must submit a description of the functionalities of the WFMS, including the coordination between the automatic capacitor switching and generator reactive power production to control the voltage at a desired point. This document also must contain the settings of the automatic capacitor switching scheme. If the WFMS is unavailable, the IESO requires each generator controls its own terminal voltage.

– End of Report –

Appendix A

Base and Loadflow Information			
Prated	2.3	Machine Active Power Rating (MW)	SEM
Vrated	0.69	Stator Voltage Rating (kV)	
Frated	60	Rated network frequency (Hz)	FBA
Busbar	90200	Connection busbar number	
Gen ID	1	Generator Identifier	
Rg	0.0000	Generator Resistance in Loadflow (Rs, pu)	RSO
Xg	0.6415	Generator Reactance in Loadflow (Xd'', pu)	XSO
Srated	2.6	Unit Transformer Rating (MVA)	Note
Rt	0.0084	Unit Transformer Resistance (pu)	Note
Xt	0.06	Unit Transformer Reactance (pu)	Note
ICONS	**Value**	**Description**	Ref:
M	2	Model Version Number	
M+1	1	Reactive control mode (1=voltage)	
M+2	1	Fault Ride Through mode (1=enabled)	
M+3	1	Enable Under-voltage relay 1	
M+4	1	Enable Under-voltage relay 2	
M+5	1	Enable Under-voltage relay 3	
M+6	1	Enable Over-voltage relay 1	
M+7	1	Enable Over-voltage relay 2	
M+8	1	Enable Under-frequency relay 1	
M+9	1	Enable Under-frequency relay 2	
M+10	1	Enable Over-frequency relay 1	
CONs	**Value**	**Description**	Ref:
J	54.62		
J+1	1.0927		
J+2	15.591		
J+3	0.1458		
J+4	128.61		
J+5	1.2471		
J+6	1.1432		
J+7	1.1109		
J+8	1.0003		
J+9	1.40		
J+10	1.10		
J+11	0.10		
J+12	22		
J+13	100000		
J+14	2		
J+15	100000		

J+16	2.00		
J+17	0.15		
J+18	0.40		
J+19	0.090		
J+20	0.090		
J+21	0.160		
J+22	1.00		
J+23	2.9		
J+24	58.6		
J+25	0.90		
J+26	50.00		
J+27	10.00		
J+28	0.499		
J+29	24.9		
J+30	1.0878		
J+31	0.0022		
J+32	0.1348		
J+33	0.040		
J+34	2.10		
J+35	0.70		
J+36	1.20		
J+37	0.70		
J+38	1.89		
J+39	2.00		
J+40	0.82		
J+41	0.50		
J+42	0.40		
J+43	4.00		
J+44	1.225	Air density	
J+45	15.00	User defined wind speed for rated power operation (m/s)	
J+46	1		
J+47	0.1739		
J+48	0.6522		
J+49	1.0069		
J+50	13.05		
J+51	-101.5		
J+52	-56.39		
J+53	0.15		
J+54	7.0		
J+55	-8.0		
J+56	45.0	Maximum pitch angle	
J+57	-2	Minimum pitch angle	
J+58	2.0		
J+59	0.060		
J+60	0.9655		
J+61	-4.7283		
J+62	-0.6755		
J+63	0.2174		

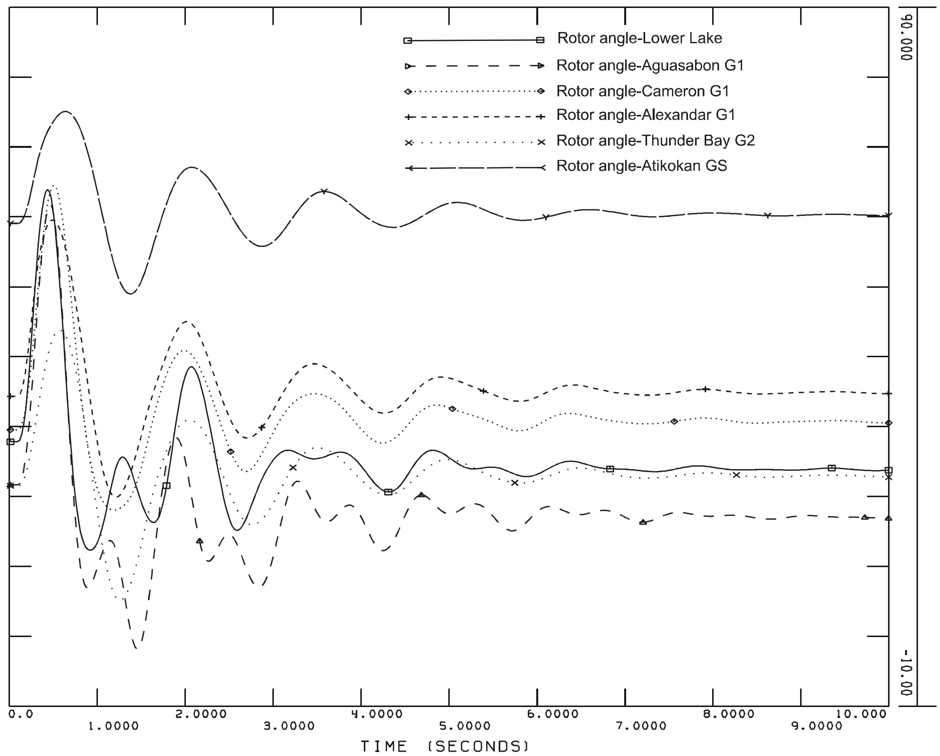
J+64	-0.2174		
J+65	1.00		
J+66	0.85	Under Voltage Relay 1 - Voltage Setting (pu)	
J+67	3.000	Under Voltage Relay 1 - Time Setting (s)	
J+68	0.100	Under Voltage Relay 1 - Relay activation time (s)	
J+69	0.50	Under Voltage Relay 2 - Voltage Setting (pu)	
J+70	1.735	Under Voltage Relay 2 - Time Setting (s)	
J+71	0.100	Under Voltage Relay 2 - Relay activation time (s)	
J+72	0.15	Under Voltage Relay 3 - Voltage Setting (pu)	Not
J+73	0.140	Under Voltage Relay 3 - Time Setting (s)	Not
J+74	0.100	Under Voltage Relay 3 - Relay activation time (s)	Not
J+75	0.85	Under Voltage Relay 3 - Voltage Setting (pu)	
J+76	0.075	Under Voltage Relay 3 - Time Setting (s)	
J+77	0.000	Under Voltage Relay 3 - Relay activation time (s)	
J+78	1.10	Over Voltage Relay 1 - Voltage Setting (pu)	
J+79	1.000	Over Voltage Relay 1 - Time Setting (s)	
J+80	0.000	Over Voltage Relay 1 - Relay activation time (s)	
J+81	1.20	Over Voltage Relay 2 - Voltage Setting (pu)	
J+82	0.200	Over Voltage Relay 2 - Time Setting (s)	
J+83	0.000	Over Voltage Relay 2 - Relay activation time (s)	
J+84	0.95	Under Frequency Relay 1 - Frequency Setting (pu)	
J+85	10.000	Under Frequency Relay 1 - Time Setting (s)	
J+86	0.000	Under Frequency Relay 1 - Relay activation time (s)	
J+87	0.94	Under Frequency Relay 2 - Frequency Setting (pu)	
J+88	0.100	Under Frequency Relay 2 - Time Setting (s)	
J+89	0.000	Under Frequency Relay 2 - Relay activation time (s)	
J+90	1.04	Over Frequency Relay 1 - Frequency Setting (pu)	
J+91	0.100	Over Frequency Relay 1 - Time Setting (s)	
J+92	0.000	Over Frequency Relay 1 - Relay activation time (s)	
J+93	0.10		
J+94	11.47		
J+95	22.91		
J+96	1.836		
J+97	0.050		
J+98	0.025		

DYRE Data (auto-generated from datasheet information. Copy/paste into DYRE file.)

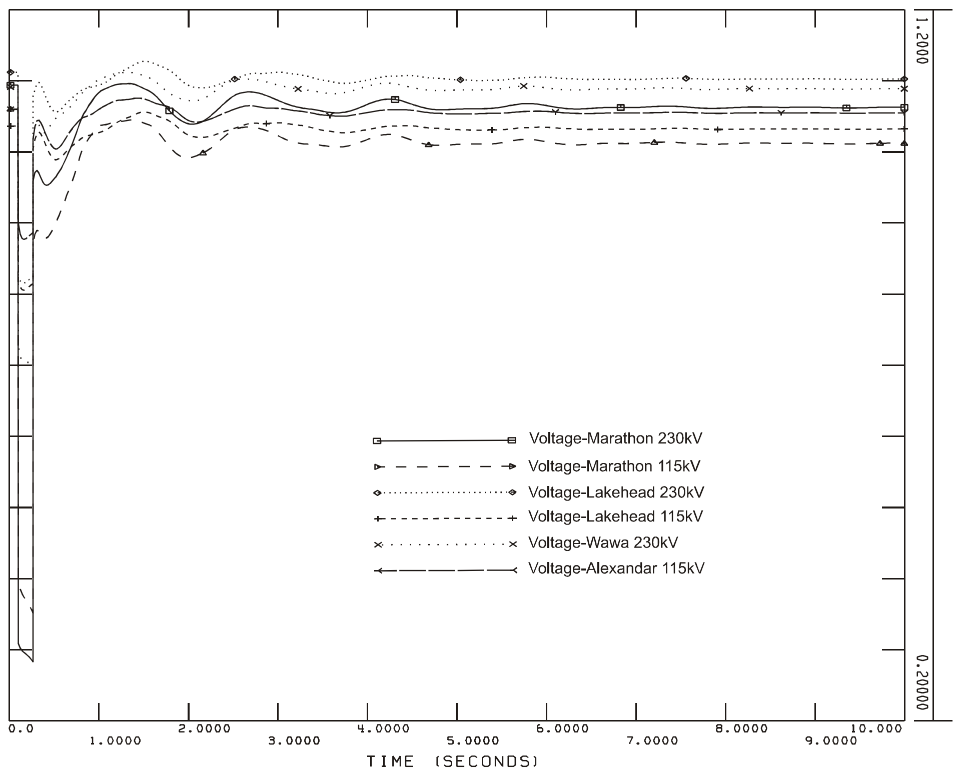
```
/ SMK223 V1.2, 2.3 MW Turbine Data
90200 'USRMDL' 1 'SMK223' 1 1    11 99 20 78
  2 1 1 1 1 1 1 1 1 1 1 54.62 1.0927 15.591 0.1458 128.61 1.2471 1.1432 1.1109 1.0003 1.40 1.10 0.10 22 100000 2 100000
  2.00 0.15 0.40 0.090 0.090 0.160 1.00 2.9 58.6 0.90 50.00 10.00 0.499 24.9 1.0878 0.0022 0.1348 0.040 2.10 0.70 1.20
  0.70 1.89 2.00 0.82 0.50 0.40 4.00 1.225 15.00 1 0.1739 0.6522 1.0069 13.05 -101.5 -56.39 0.15 7.0 -8.0 45.0 -2 2.0 0.060
  0.9655 -4.7283 -0.6755 0.2174 -0.2174 1.00 0.85 3.000 0.100 0.50 1.735 0.100 0.15 0.140 0.100 0.85 0.075 0.000 1.10 1.000 0.000
  1.20 0.200 0.000 0.95 10.000 0.000 0.94 0.100 0.000 1.04 0.100 0.000 0.10 11.47 22.91 1.836 0.050 0.025 /
```

Appendix B

TE-SC1

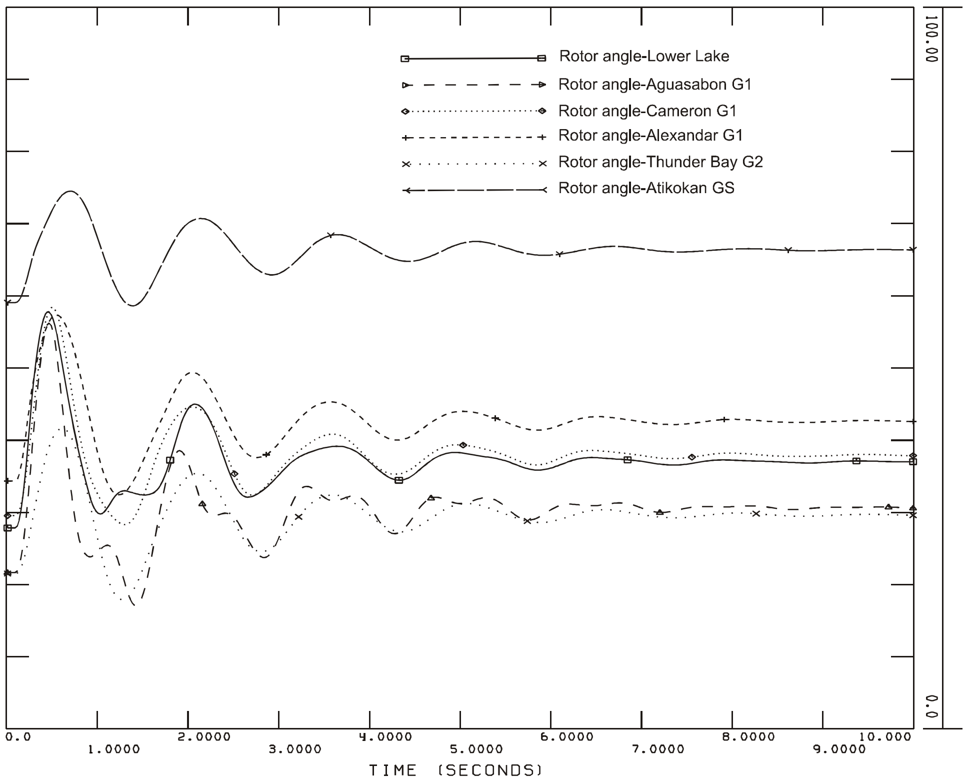


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
90.000
-10.00
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

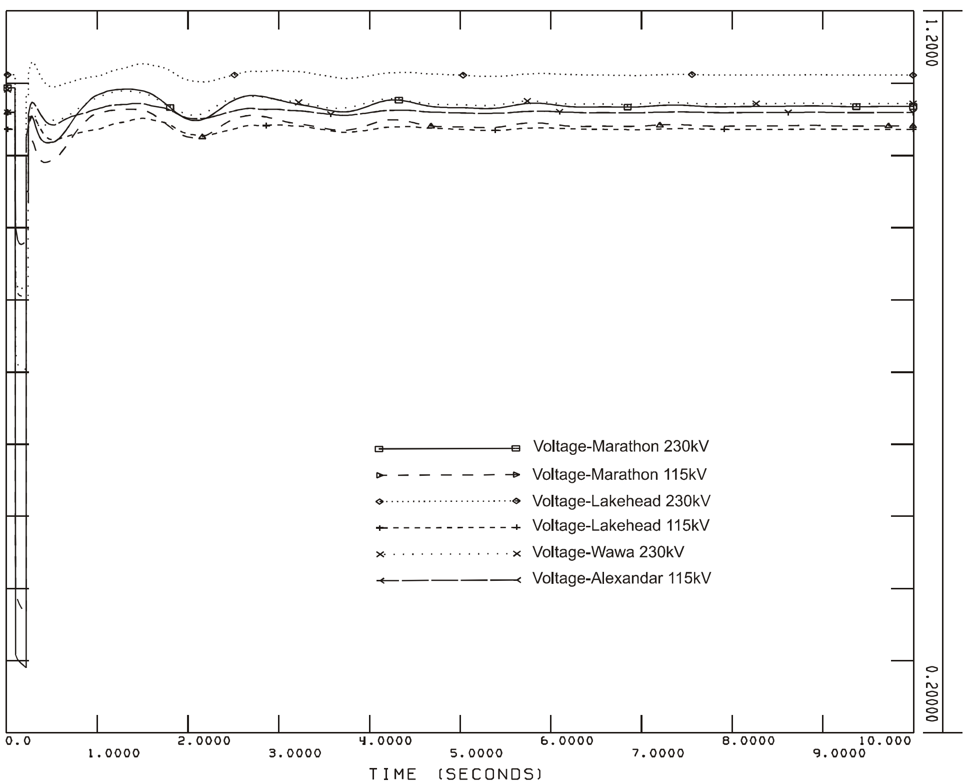


Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

TE-SC2

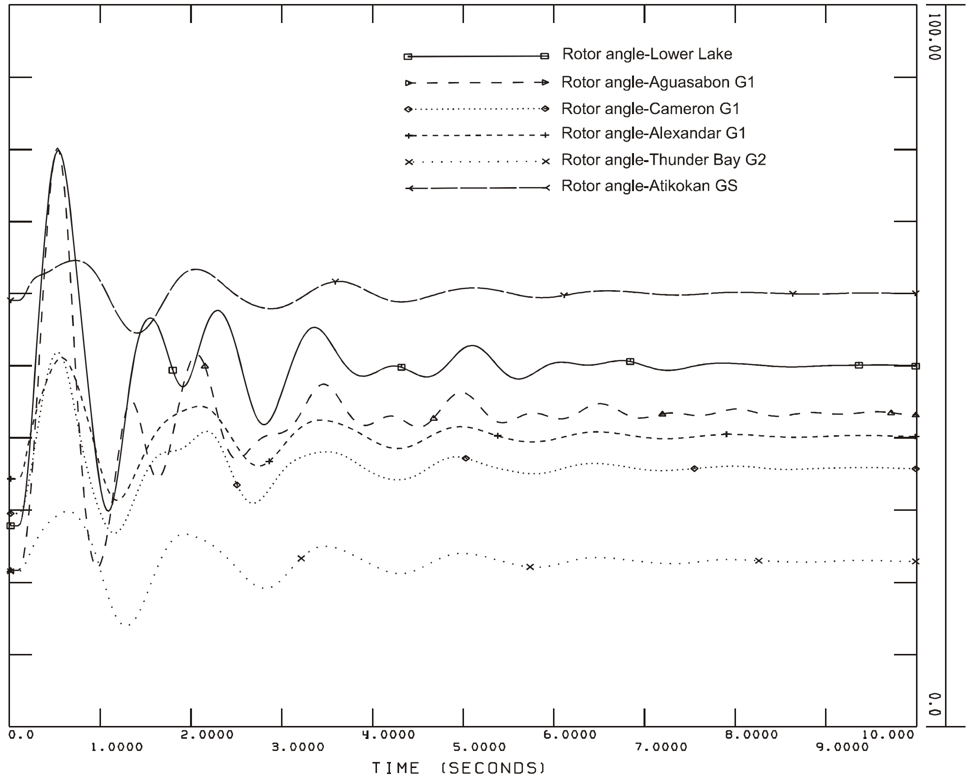


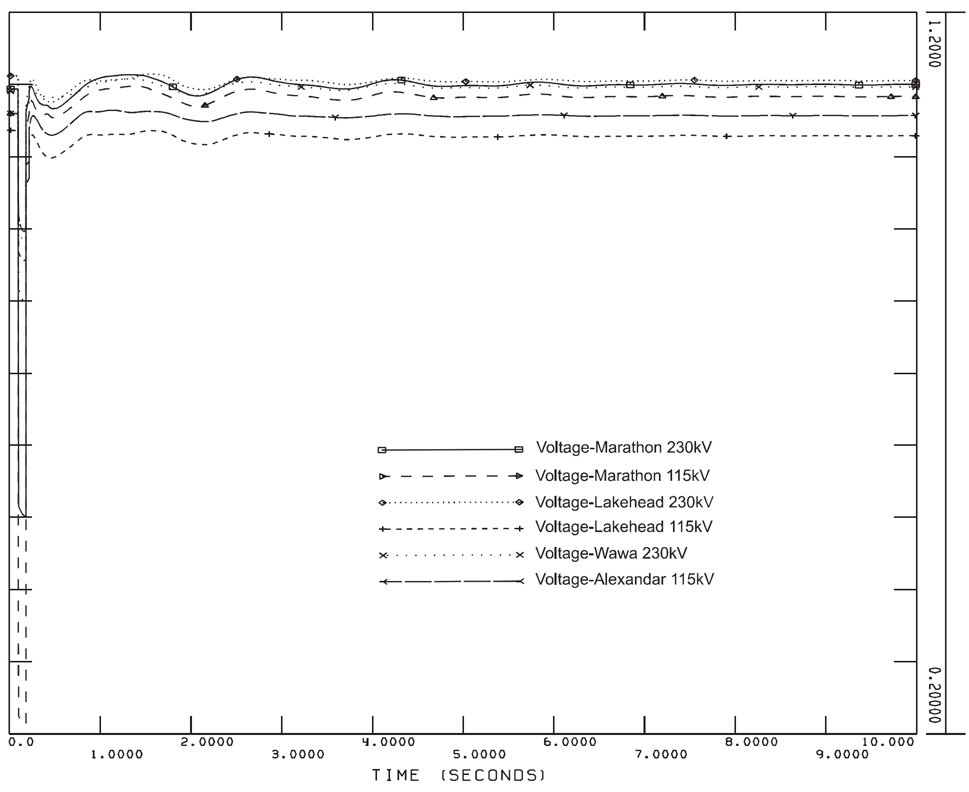
Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
100.00
0.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)



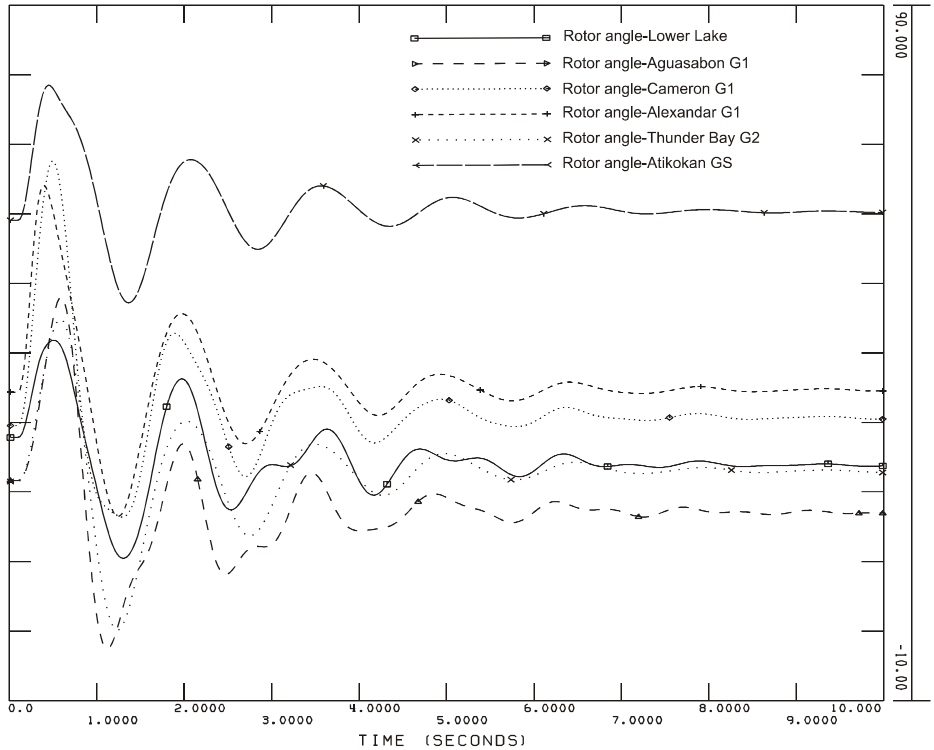
Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

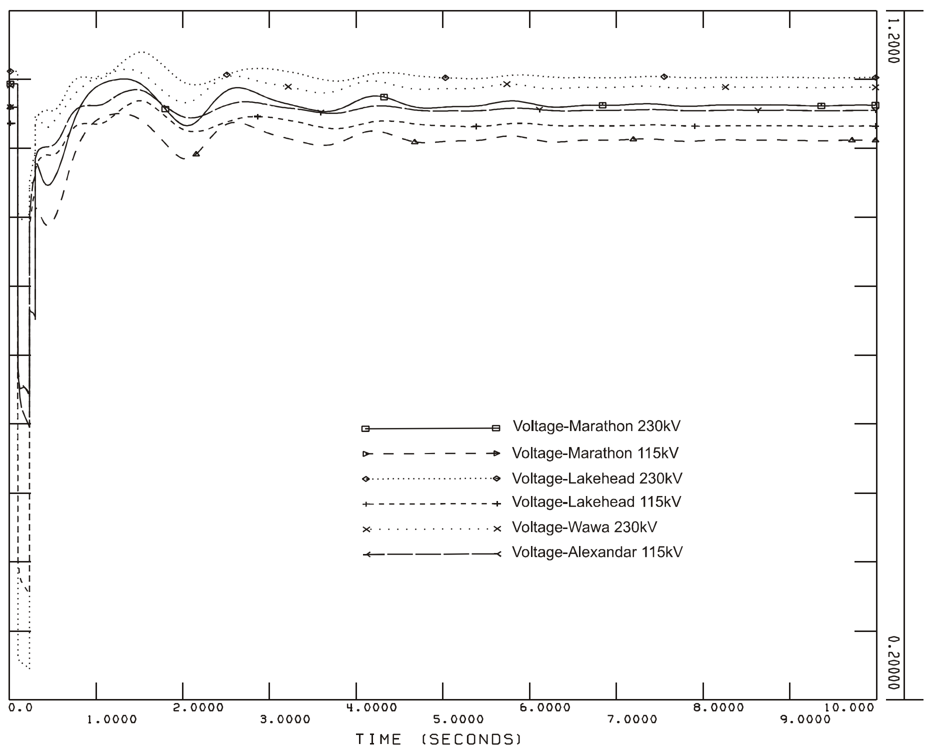
TE-SC3


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
100.00
0.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

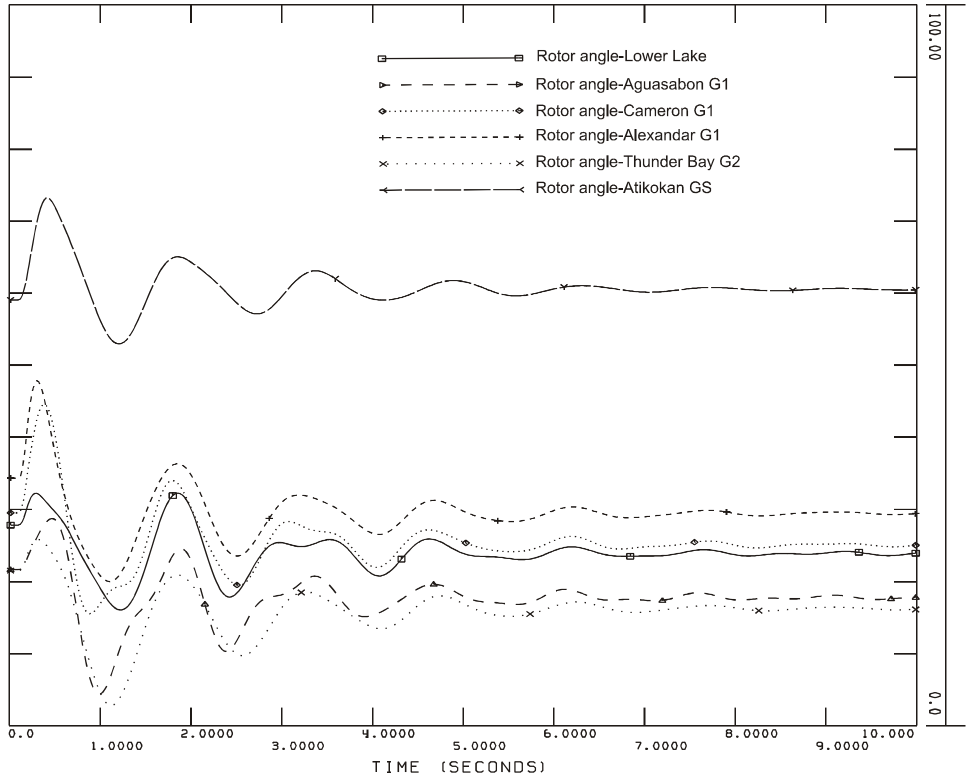

Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

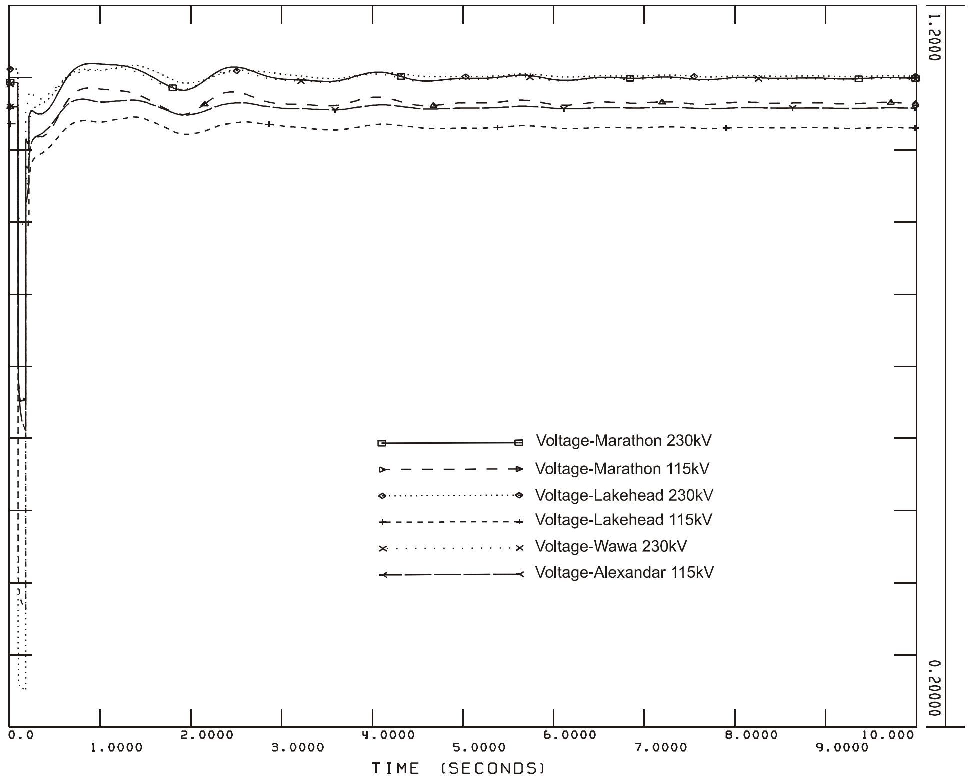
TE-SC4


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
90.000
-10.00
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

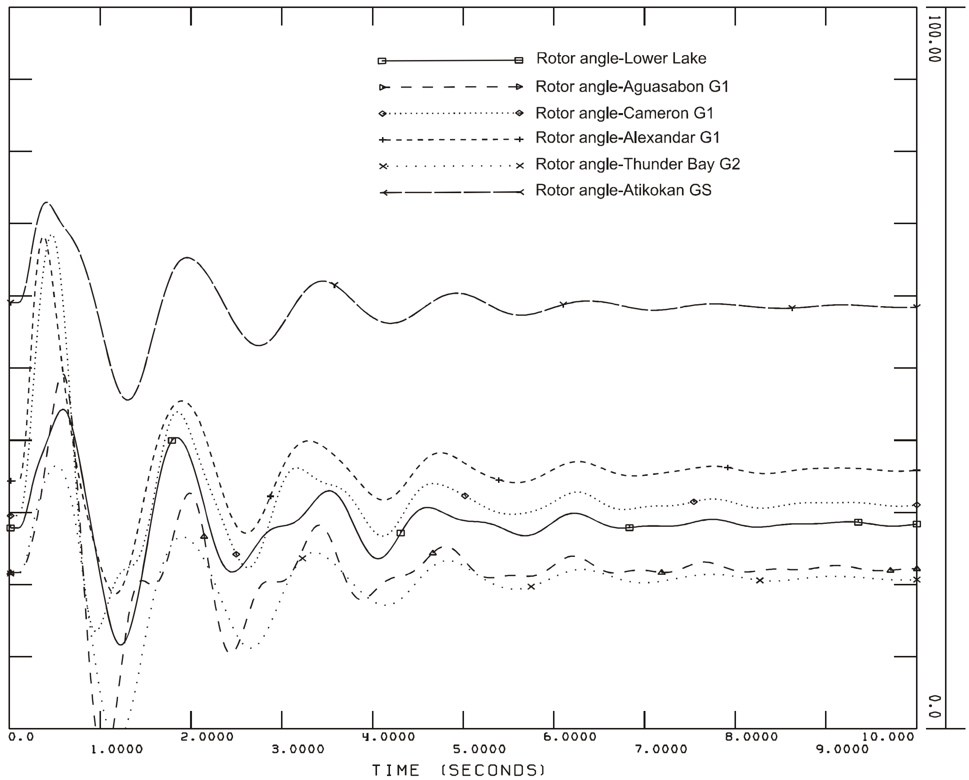

Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

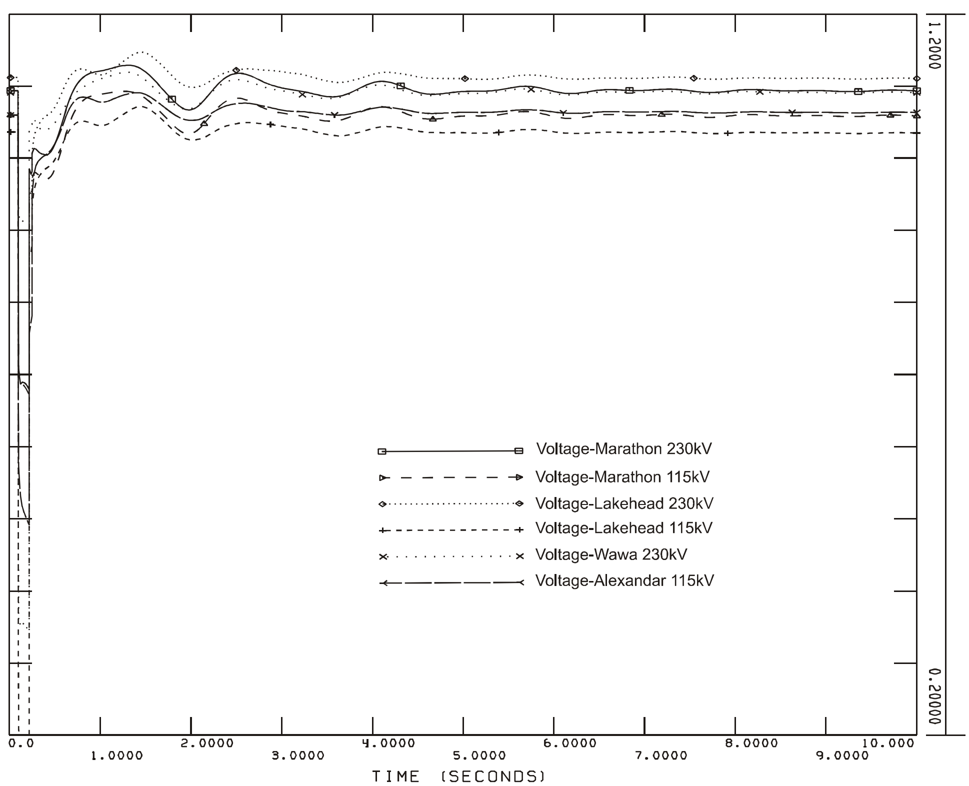
TE-SC5


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
100.00
0.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

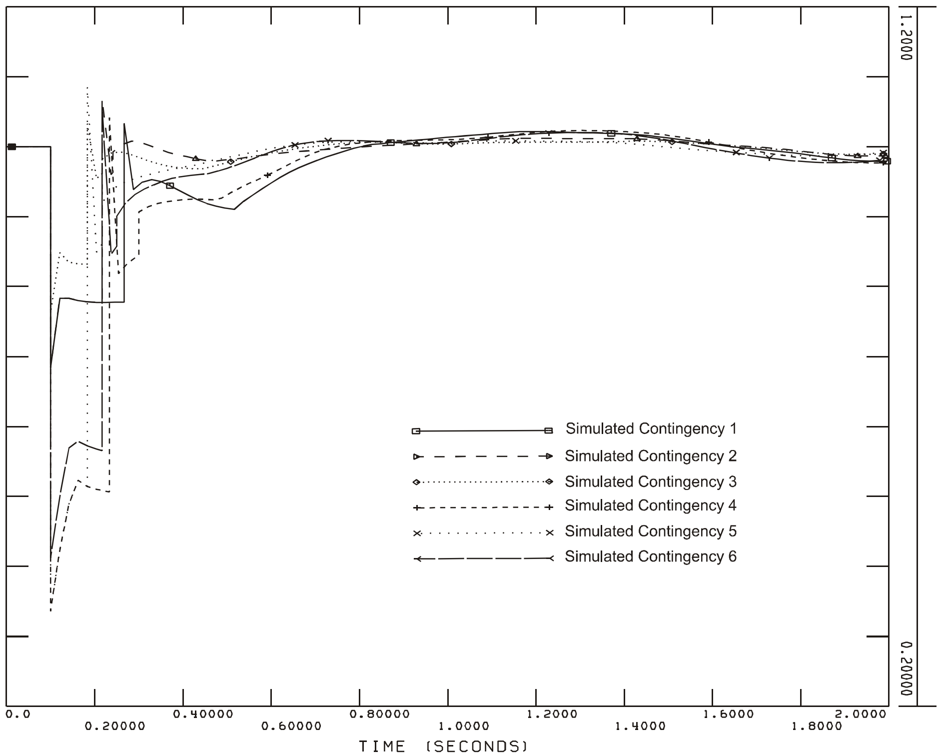

Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

TE-SC6

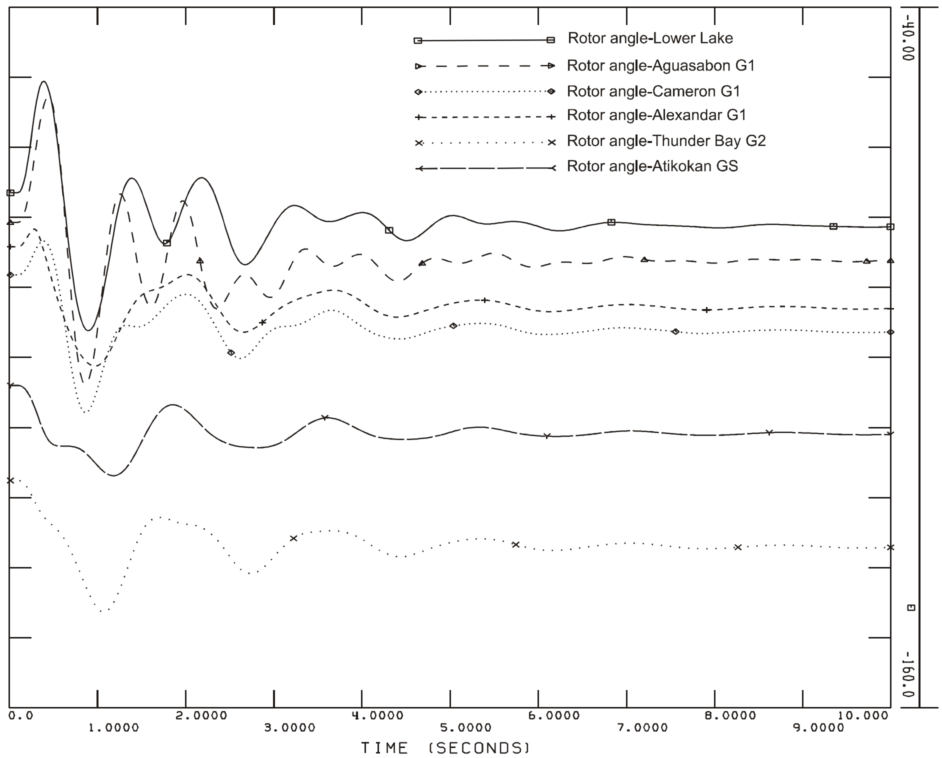

Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
100.00
0.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

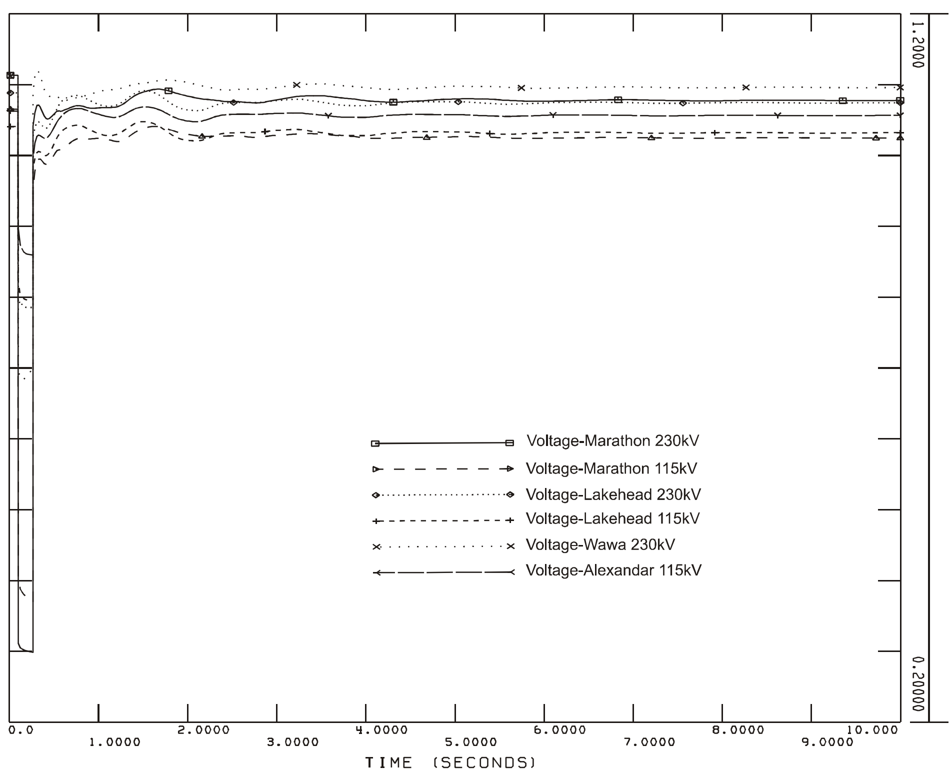

Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

TE-Terminal voltage of Greenwich units

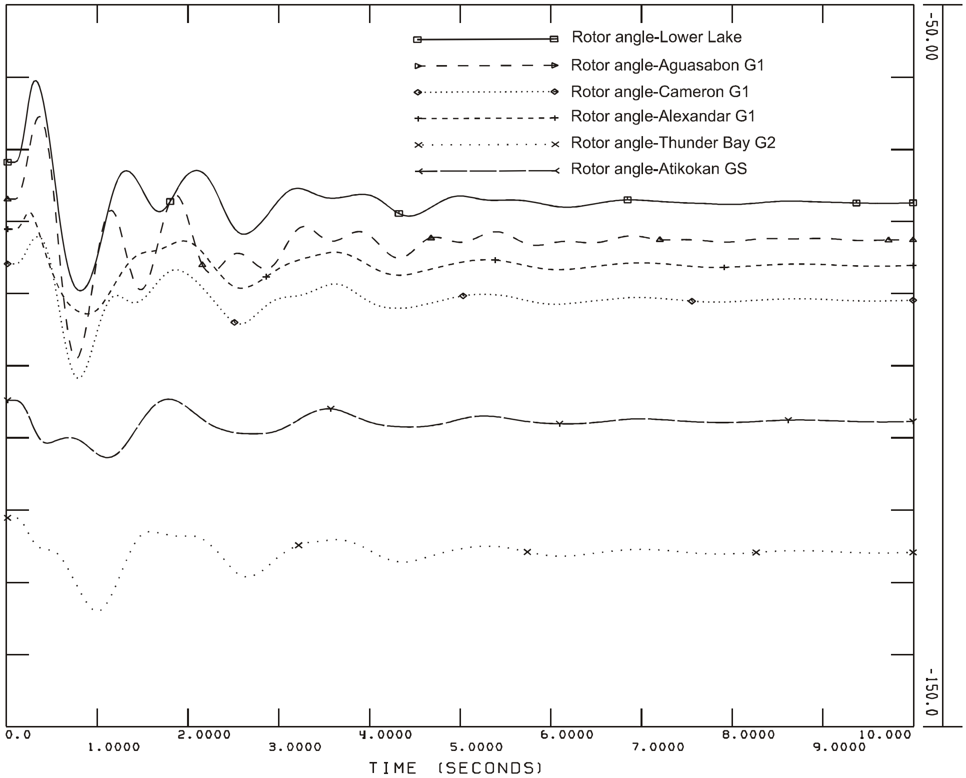


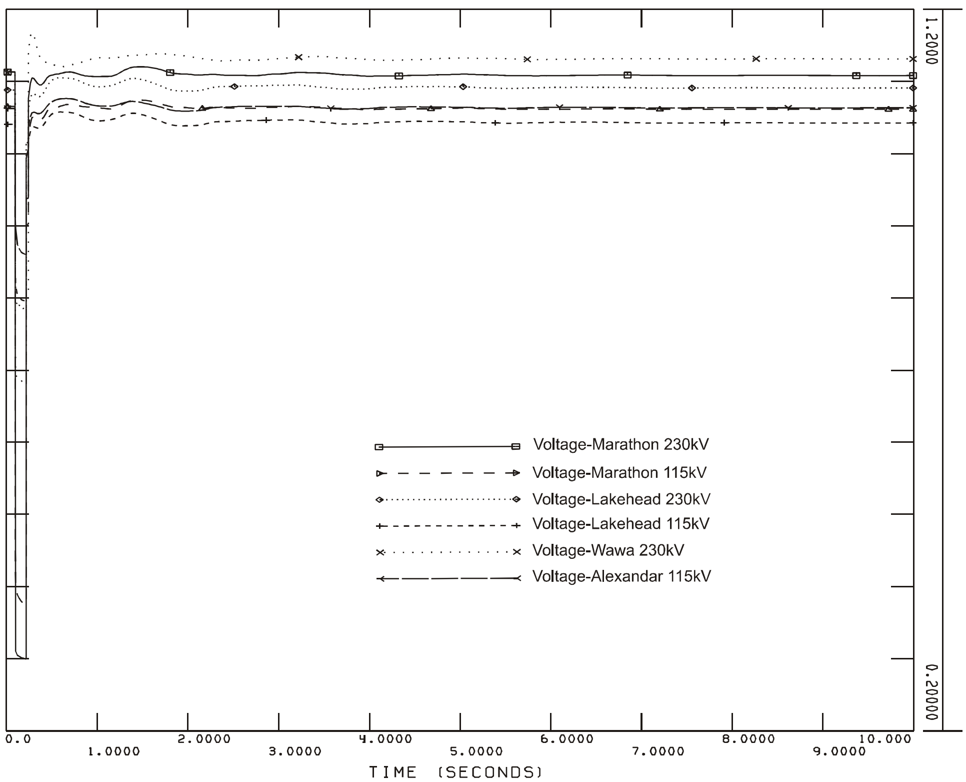
TW-SC1


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
-40.00
-160.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

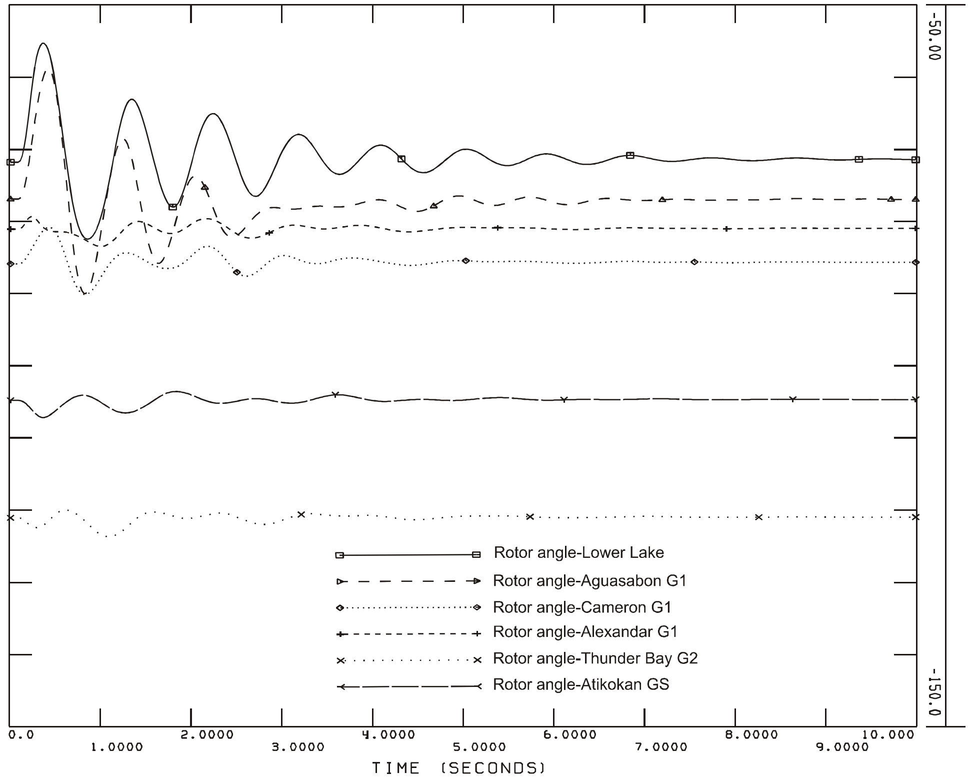

Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

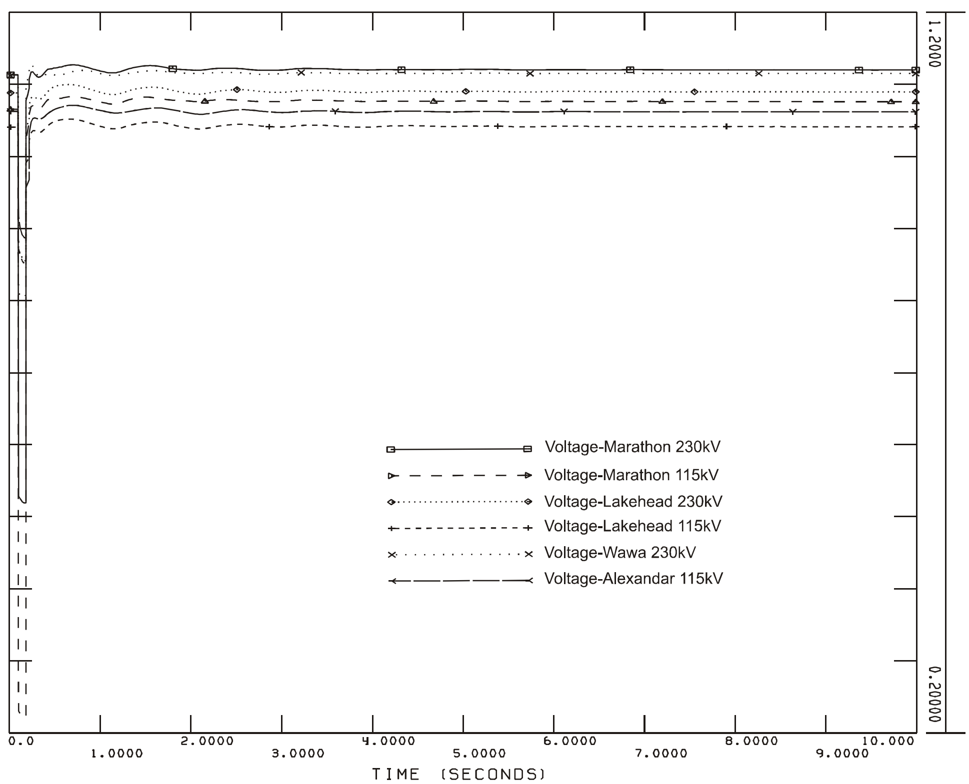
TW-SC2


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
-50.00
-150.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

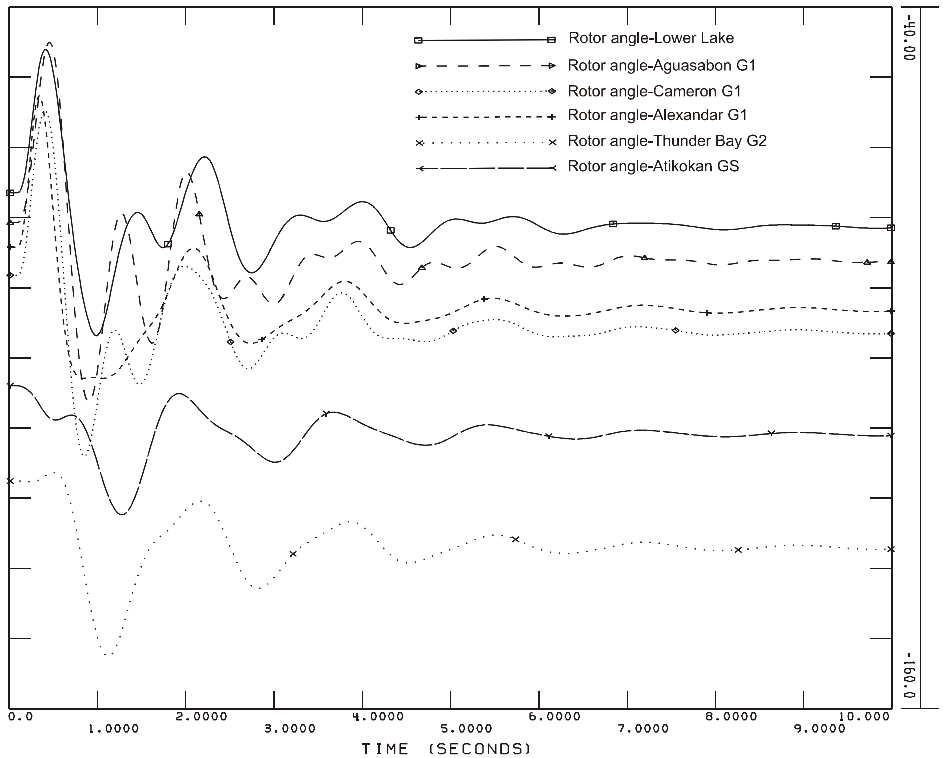

Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

TW-SC3

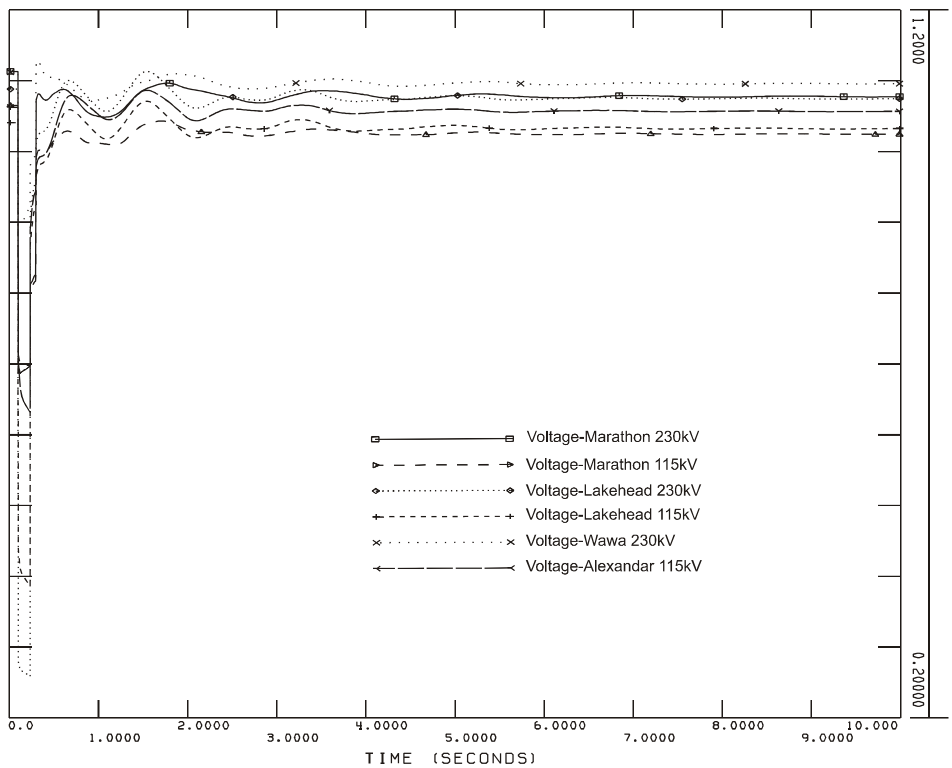

-50.00
-150.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)
Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS


1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)
Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV

TW-SC4

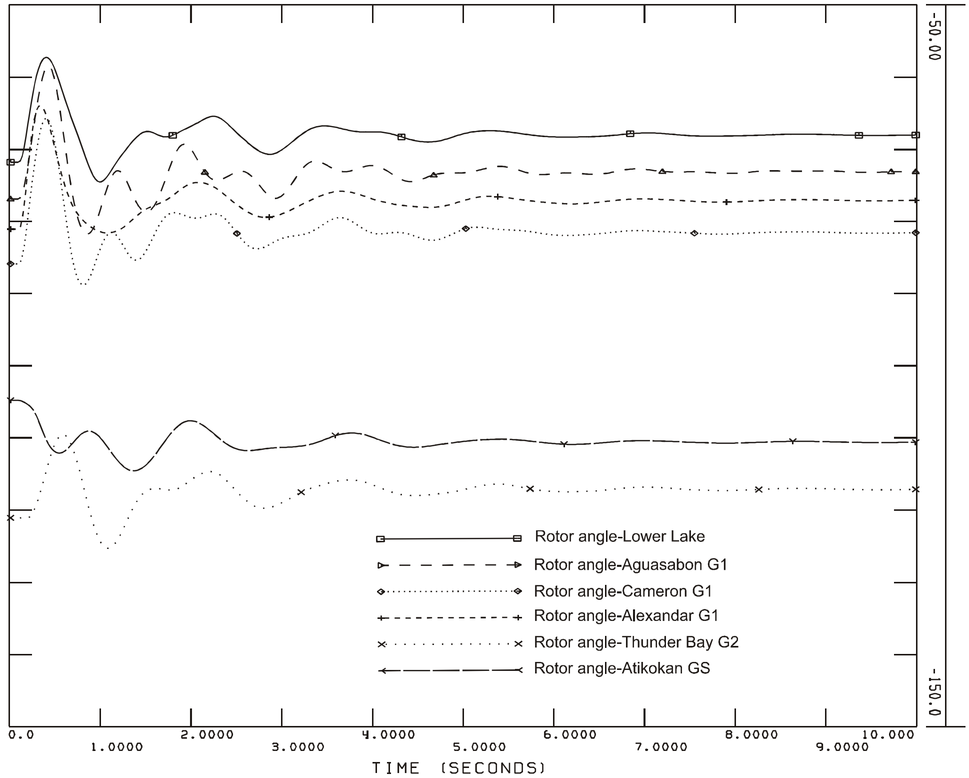


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
-40.00
-160.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

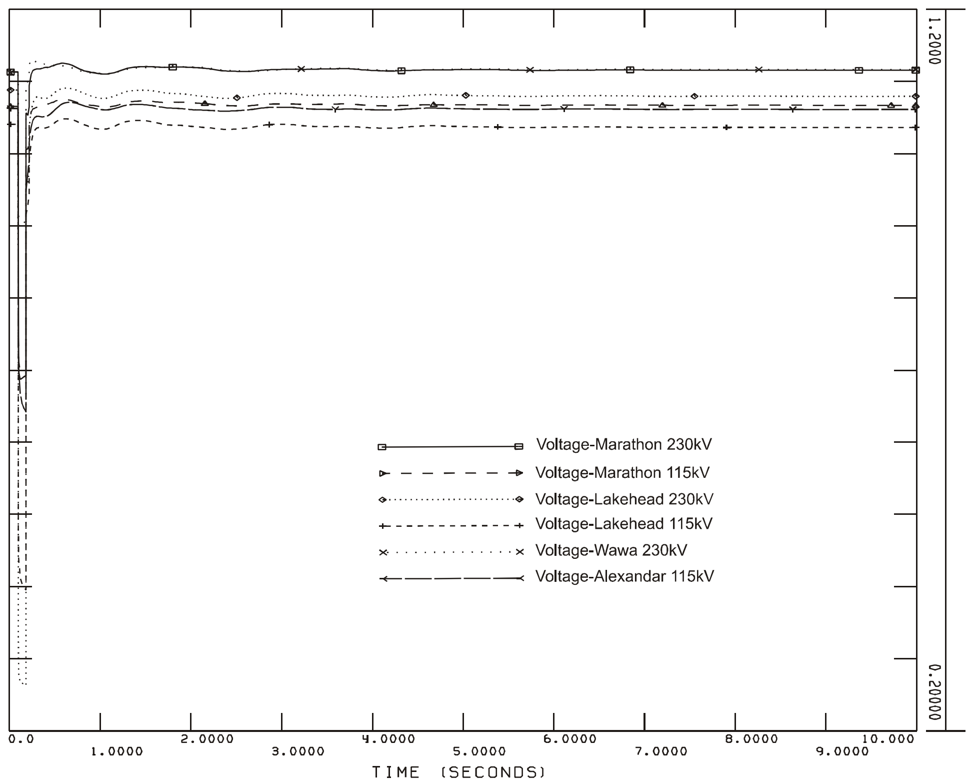


Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

TW-SC5

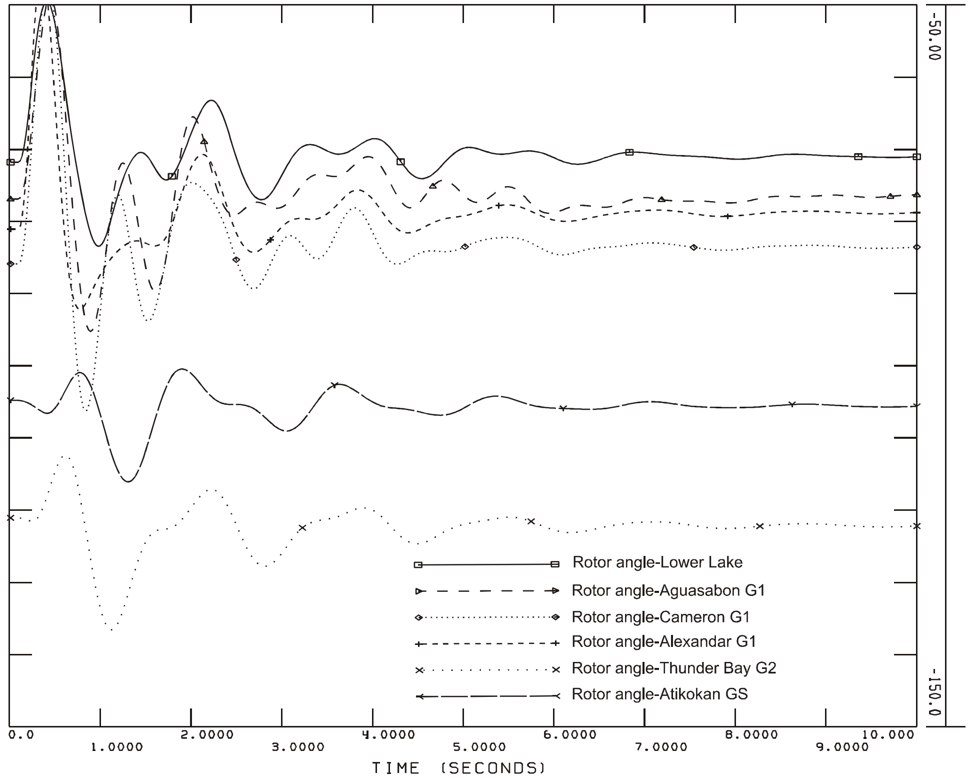


Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS
-50.00
-150.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

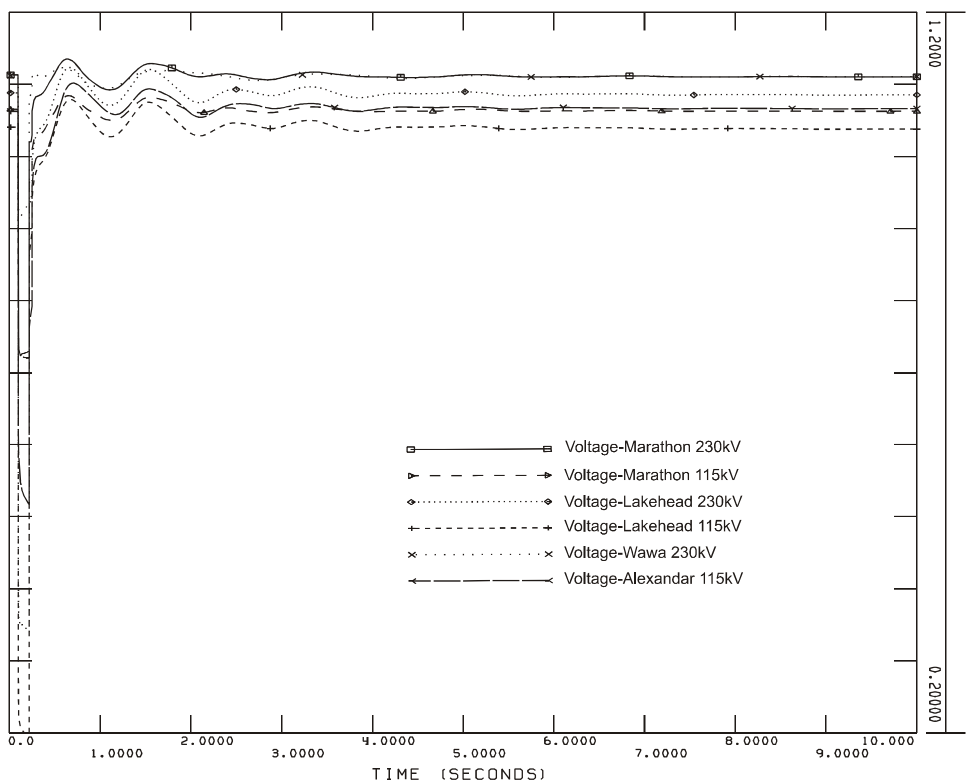


Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV
1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)

TW-SC6



-50.00
-150.0
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)
Rotor angle-Lower Lake
Rotor angle-Aguasabon G1
Rotor angle-Cameron G1
Rotor angle-Alexandar G1
Rotor angle-Thunder Bay G2
Rotor angle-Atikokan GS



1.2000
0.20000
0.0
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
7.0000
8.0000
9.0000
10.000
TIME (SECONDS)
Voltage-Marathon 230kV
Voltage-Marathon 115kV
Voltage-Lakehead 230kV
Voltage-Lakehead 115kV
Voltage-Wawa 230kV
Voltage-Alexandar 115kV

TW-Terminal voltage of Greenwich units