



REPORT

System Impact Assessment Report

15 MW Plant Expansion at Cardinal

CONNECTION ASSESSMENT & APPROVAL PROCESS

Final Report

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Applicant: Cardinal Power of Canada LP

Market Facilitation Department

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System Impact Assessment Report

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System Impact Assessment Report

15 MW Plant Expansion at Cardinal

Acknowledgement

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

Disclaimers

IESO

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

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

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

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Special Notes and Limitations of Study Results

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

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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 System Impact 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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Executive Summary

Description

Cardinal Power of Canada LP (the Connection Applicant) is proposing to install Cardinal Power G3 (the Project), a new 18.75 MVA gas turbine generator inside the existing Canada Starch Operating Company (CASCO) steam host located within its facility. The installation of the new generator will add up to 15 MW of generation alongside the existing 152 MVA gas and 71 MVA steam units at Cardinal Power. With load at the steam host typically at 12 MW, Cardinal Power expects the CASCO facility to export at most 3 MW with the new generator to the IESO-controlled grid.

The proposed in-service date for the new generation unit is July 2013.

This assessment examined the impact of injecting up to 3 MW from the CASCO facility as a result of 15 MW of additional gas generation from Cardinal Power via the 115 kV circuits L1MB and L2M on the reliability of the IESO-controlled grid.

The following conclusions and recommendations were derived from the study results:

Findings

The analysis concluded that:

- (1) The connection arrangement and equipment for the project are acceptable to the IESO.
- (2) The system fault levels after the incorporation of the Cardinal Power G3 will not exceed the interrupting capabilities of the existing breakers on the IESO-controlled grid near this facility.
- (3) No pre-contingency overloads were identified in the thermal analysis.
- (4) In summer conditions with light loads, when the Cardinal Power facility may reach a maximum output of 145 MW.

Under maximum Cardinal Power facility output and maximum embedded generation output at Morrisburg TS and Chesterville TS, the loss of L1MB resulted in L2M slightly exceeding its summer long term emergency rating post-cardinal power runback. A manual re-dispatch of generation at Morrisburg, Chesterville or Cardinal Power would be required to ensure L2M loadings are brought under summer long term emergency ratings within 15 minutes.

- (5) In winter conditions with light loads, when the Cardinal Power facility may reach a maximum winter output of 196 MW, the post-contingency thermal analysis resulted in potential violation of the short term emergency rating.

Under maximum Cardinal Power facility output and maximum embedded generation output at Morrisburg TS and Chesterville TS, the loss of L1MB resulted in L2M between St. Lawrence and Lunenburg exceeding its winter short term emergency rating by 26 A or about 5 MW. If these conditions occur, generation along L1MB and L2M may need to be curtailed pre-contingency to

respect the thermal ratings.

- (6) Cardinal Power G3 will need to be incorporated into the existing Cardinal Power runback scheme and the anti-islanding scheme at St. Lawrence TS.
- (7) Based on study results performed under all elements in service, it is anticipated that the Cardinal Power runback scheme is classified as a Type III Special Protection System
- (8) The maximum voltage changes for the loss of the Cardinal Power facility, or loss of L1MB, or loss of L2M were found to be within the 10% pre and post-ULTC action limit.

Under the studied light load conditions and maximum generation along L2M and L1MB, the St. Lawrence 115 kV bus may need to be maintained at 121 kV or less to ensure that voltages do not exceed 127 kV post-contingency in the event of the loss of Cardinal Power facility for a fault on the Cardinal A bus.

- (9) During outages to Morrisburg T3 or Morrisburg T4 transformer, pre-contingency generation curtailment may be required at both Cardinal Power and embedded generation at Morrisburg TS to prevent the potential over loading at the Dyno Nobel transformers due to circulating power as a result of the tripping of AL1 or AL2 breakers.
- (10) F
or the loss of either Cardinal AL1 or AL2 breakers, circulating flows exist at Morrisburg. Under maximum generation and minimum load conditions studied in this report, Cardinal Power output may need to be manually redispatched to 126 MW, post runback, to respect the level of reverse power at Morrisburg TS in the event of the loss of Cardinal AL1 or AL2 breakers.
- (11) Based on the information provided by the applicant, the excitation system and governor system meet Market Rule requirements.
- (12) The incorporation of Cardinal Power G3 does not cause any material adverse impact on the transient performance of the IESO-controlled grid.
- (13) The Protection Impact Assessment conducted by the transmitter identified the following:
 - (a) No Hydro One protection hardware changes are required as a result of the Cardinal G3 expansion.
 - (b) No Hydro One protection setting changes are required as a result of the Cardinal G3 expansion.
 - (c) No Hydro One telecommunication changes are required as a result the Cardinal G3 expansion.
- (13) The connection applicant will be connecting in the St. Lawrence area, an area of the power system that may experience congestion. At times, the connection applicant may be required to curtail the level of generation within its system for reliability purposes.

IESO's Requirements for Connection

Transmitter Requirements

The following requirements are applicable to Hydro One for the incorporation of Cardinal G3:

- (1) The transmitter is required to review the relay settings of the 115 kV circuits L1MB and L2M at St. Lawrence and any other circuits affected by the new generator.

Modifications to protection relays after this SIA is finalized must be submitted to IESO as soon as possible or at least six (6) months before any modifications are to be implemented on the existing protection systems. Mitigation solutions to address modifications resulting in adverse impact on reliability must be jointly developed with the applicant.

- (2) The transmitter is required to work with the connection applicant to produce a Facility Description Document for the Cardinal Power Runback Scheme. This document must be provided to the IESO during the Market Entry process.
- (3) The transmitter is required to work with the connection applicant to incorporate Cardinal G3 into the St. Lawrence anti-islanding scheme.

Connection Applicant Requirements

Specific Requirements: The following specific requirements are applicable to the applicant for the incorporation of Cardinal G3. Specific requirements pertain to the level of reactive compensation needed, operation restrictions, Special Protection Systems, upgrading of equipment and any project specific items not covered in the general requirements:

- (1) A directly connected generating facility must have the capability to inject or withdraw reactive power continuously at its connection point. The amount of reactive power required is up to 33% of its rated active power at all levels of active power output except where a lesser continually available capability is permitted by the IESO. Since the CASCO facility will inject a maximum active power of 3.0 MW, the CASCO facility would be required to have the capability to provide ± 1 Mvar of dynamic reactive power with Cardinal G3.

Based on simulations performed on data supplied by the applicant, the CASCO facility will be capable of providing ± 1 Mvar of dynamic reactive power with Cardinal G3 controlling the 115 kV voltage near the Cardinal Power H bus, and Casco T3 transformer controlling the 4.16 kV bus voltage.

- (2) The connection applicant is required to incorporate Cardinal G3 into the Cardinal Power runback scheme.
- (3) The connection applicant is required to work with Hydro One to incorporate Cardinal G3 into the St. Lawrence anti-islanding scheme.
- (4) The connection applicant is required to work with Hydro One in producing Facility Description Document containing the high level design functional description and timing for the Cardinal Power runback scheme. This document must be provided to the IESO during the Market Entry process.

- (4) Cardinal Power is required to provide real time telemetering of the Cardinal Power Runback Scheme arming status.
- (5) Under the studied system conditions, it has been recommended that the Cardinal Power Runback scheme is classified as Type III SPS. If NPCC classifies the scheme to be Type I or if in the future, changes in system conditions results in the SPS being classified as Type I, Cardinal Power will need to satisfy NPCC Type I SPS criteria.

General Requirements: The connection applicant shall satisfy the applicable requirements and standards specified in the Market Rules, Market Manuals and the Transmission System Code (TSC), North American Electric Reliability Corporation (NERC) and North East Power Coordinating Council (NPCC) standards. The following requirements summarize some of the general requirements that are applicable to the proposed project, and presented in detail in **section 2** of this report.

- (1) The generator shall regulate speed with an average droop based on maximum active power adjustable between 3% and 7% and set at 4%. Regulation deadband shall not be wider than $\pm 0.06\%$. A sustained 10% change of rated active power after 10 s in response to a constant rate of change of speed of 0.1%/s during interconnected operation shall be achievable.
- (2) The proposed generator shall inject or withdraw reactive power continuously as indicated in (1) under the Specific Connection Applicant requirements above.

The proposed generator shall have the capability to regulate automatically voltage within $\pm 0.5\%$ of any set point within $\pm 5\%$ of rated voltage at a point whose impedance (based on rated apparent power and rated voltage) is not more than 13% from the highest voltage terminal. If the AVR target voltage is a function of reactive output, the slope $\Delta V/\Delta Q_{\max}$ shall be adjustable to 0.5%. The equivalent time constants shall not be longer than 20 ms for voltage sensing and 10 ms for the forward path to the exciter output. AVR reference compensation shall be adjustable to within 10% of the unsaturated direct axis reactance on the unit side from a bus common to multiple units
- (3) The connection applicant shall ensure that the excitation system and power system stabilizer satisfy the requirements of Appendix 4.2 of the Market Rules.
- (4) The connection applicant shall ensure that the generator has the capability to provide short-time capabilities specified in IEEE/ANSI 50.13 and continuous capability determined by either field current, armature current, or core-end heating. More restrictive limiting functions, such as steady state stability limiters, shall not be enabled without IESO approval.
- (5) The generation shall have the capability to ride through routine switching events and design criteria contingencies assuming standard fault detection, auxiliary relaying, communication, and rated breaker interrupting times unless disconnected by configuration.
- (6) The connection applicant shall ensure that the 115 kV equipment is capable of continuously operating between 113 kV and 127 kV. Protective relaying must be set to ensure that transmission equipment remains in-service for voltages between 94% of the minimum continuous value and 105% of the maximum continuous value specified in Appendix 4.1 of the Market Rules.
- (7) The connection applicant shall ensure that the connection equipment is designed to be fully operational in all reasonably foreseeable ambient temperature conditions. The connection equipment must also be designed so that the adverse effects of its failure on the IESO-controlled grid are mitigated. This includes ensuring that all circuit breakers fail in the open position.
- (8) The connection applicant shall ensure that the new equipment at the facility be designed to sustain the fault levels in the area. 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 its own expense with higher rated equipment capable of sustaining the increased fault level, up to maximum fault level specified in Appendix 2 of the Transmission System Code.

Fault interrupting devices must be able to interrupt fault currents at the maximum continuous voltage of 127 kV.

- (9) Appendix 2 of the Transmission System Code states that the maximum rated interrupting time for the 115 kV breakers must be ≤ 5 cycles. Thus, the connection applicant shall ensure that the installed breakers meet the required interrupting time specified in the Transmission System Code.

- (10) The connection applicant shall ensure that the new protection systems at the facility are designed to satisfy all the requirements of the Transmission System Code and any additional requirements identified by the transmitter.

As currently assessed by the IESO, the facility *is not* part of the BPS and, therefore it is not designated as essential to the power system.

The protection systems within the generation facility must only trip the appropriate equipment required to isolate the fault.

The autoreclosure of the high voltage breakers at the connection point must be blocked. Upon its opening for a contingency, the high voltage breaker must be closed only after the IESO approval is granted.

- (11) The connection applicant shall ensure that the telemetry requirements are satisfied as per the applicable Market Rules requirements. The determination of telemetry quantities and telemetry testing will be conducted during the IESO Facility Registration/Market Entry process.
- (12) If revenue metering equipment is being installed as part of this project, the connection applicant should be aware that revenue metering installations must comply with Chapter 6 of the IESO Market Rules. For more details the connection applicant is encouraged to seek advice from their Metering Service Provider (MSP) or from the IESO metering group.
- (13) The proposed facility must be compliant with applicable reliability standards set by NERC and NPCC that are in effect in Ontario as mapped in the following link:
<http://www.ieso.ca/imoweb/ircp/orcp.asp>
- (14) Cardinal Power is currently a restoration participant. The connection applicant is required to update its restoration participant attachment to include details regarding its proposed project. For more details please refer to the Market Manual 7.8. Details regarding restoration participant requirements will be finalized at the Facility Registration/Market Entry Stage.
- (15) 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 at least seven months before energization to the IESO-controlled grid. This includes both PSS/E and DSA software compatible mathematical models representing the new equipment for further IESO, NPCC and NERC analytical studies.

The connection applicant must also 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. The evidence must be supplied to the IESO within 30 days after completion of commissioning tests. 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.

- (16) The Customer Impact Assessment (CIA) report for the proposed facility has not yet been finalized, and as such, this report does not include CIA requirements. Final connection of this project may also be subject to additional requirements specified in the CIA performed by Hydro One. If required, any additional requirements resulting from the CIA will be included in an Addendum to the Final SIA report.

Notification of Conditional Approval

The proposed connection of the 18.75 MVA Cardinal Power G3 generator, operating up to 15 MW is expected to have no material adverse impact on the reliability of the IESO-controlled grid, subject to the requirements specified in this report.

It is recommended that a *Notification of Conditional Approval for Connection* for the addition of the 18.75 MVA generation unit be issued to Cardinal Power of Canada LP, subject to the implementation of the requirements outlined in this report.

1. Project Description

Cardinal Power of Canada LP currently operates a combine cycle gas cogeneration facility that consists of a 152 MVA gas unit (G1), a 71 MVA steam unit (G2). A cogeneration steam host, Canada Starch Operating Company (CASCO) also exists within its site. CASCO is connected to the Cardinal Power H bus via a 115 kV/4.16 kV transformer, Casco T3. The load at CASCO load is relatively constant, typically at 12 MW. Under cold weather conditions, the load can be 13 MW.

Cardinal Power is proposing expand its generating facility by installing a new 18.75 MVA simple cycle generator unit within the CASCO load facility on the 4.16 kV bus. The summer maximum continuous rating (MCR) of this unit is expected to be 11.1 MW, while the winter maximum continuous rating (MCR) of this unit is expected to be about 15 MW.

The new generator will operate at base load or at relatively high capacity, while the existing G1 and G2 output will depend on market signals. Cardinal G3 will have a static excitation system and will operate under voltage control mode.

The proposed in service date for the generation unit is July 2013.

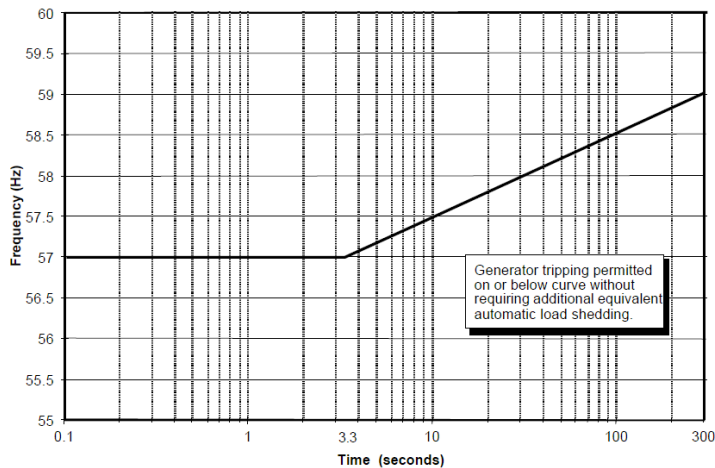
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2. General Requirements

The connection applicant shall satisfy the applicable requirements and standards specified in the Market Rules, Market Manuals and the Transmission System Code. The following sections highlight some of the general requirements that are applicable to the proposed project.

2.1 Frequency/Speed Requirements

As per Appendix 4.2 of the Market Rules, the connection applicant shall ensure that the generation facility has the capability to operate continuously between 59.4 Hz and 60.6 Hz and for a limited period of time in the region above straight lines on a log-linear scale defined by the points (0.0 s, 57.0 Hz), (3.3 s, 57.0 Hz), and (300 s, 59.0 Hz), as shown in the following figure.



The facility has to have the capability to regulate speed with an average droop based on maximum active power adjustable between 3% and 7% and set at 4% unless otherwise specified by the IESO. Regulation deadband shall not be wider than $\pm 0.06\%$. Speed shall be controlled in a stable fashion in both interconnected and island operation. A sustained 10% change of rated active power after 10 s in response to a constant rate of change of speed of 0.1%/s during interconnected operation shall be achievable. Due consideration will be given to inherent limitations such as mill points and gate limits when evaluating active power changes. Control systems that inhibit governor response shall not be enabled without IESO approval.

2.2 Reactive Power/Voltage Regulation Requirements

The generation facility is directly connected to the IESO-controlled grid, and thus, the connection applicant shall ensure that the facility has the capability to:

- Inject or withdraw reactive power continuously (i.e. dynamically) at a connection point up to 33% of its rated active power at all levels of active power output except where a lesser continually available capability is permitted by the IESO. 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, dynamic reactive compensation devices must be installed to make up the deficient reactive power;

- Regulate automatically voltage within $\pm 0.5\%$ of any set point within $\pm 5\%$ of rated voltage at a point whose impedance (based on rated apparent power and rated voltage) is not more than 13% from the highest voltage terminal. If the AVR target voltage is a function of reactive output, the slope $\Delta V/\Delta Q_{\max}$ shall be adjusted to not more than 0.5%. The equivalent time constants shall not be longer than 20 ms for voltage sensing and 10 ms for the forward path to the exciter output. AVR reference compensation shall be adjustable to within 10% of the unsaturated direct axis reactance on the unit side from a bus common to multiple units.

Please refer to **Section 6.6** of this report for specific reactive power and voltage regulation requirements for this project.

2.3 Control Systems Requirements

The connection applicant shall ensure that the generation facility has the capability to:

- Provide (a) Positive and negative ceilings not less than 200% and 140% of rated field voltage at rated terminal voltage and rated field current; (b) A positive ceiling not less than 170% of rated field voltage at rated terminal voltage and 160% of rated field current; (c) A voltage response time to either ceiling not more than 50 ms for a 5% step change from rated voltage under open-circuit conditions; and (d) A linear response between ceilings. Rated field current is defined at rated voltage, rated active power and required maximum continuous reactive power.
- Provide (a) A change of power and speed input configuration; (b) Positive and negative output limits not less than $\pm 5\%$ of rated AVR voltage; (c) Phase compensation adjustable to limit angle error to within 30° between 0.2 Hz and 2.0 Hz under conditions specified by the IESO, and (d) Gain adjustable up to an amount that either increases damping ratio above 0.1 or elicits exciter modes of oscillation at maximum active output unless otherwise specified by the IESO. Due consideration will be given to inherent limitations.

2.4 Short-time Capabilities Requirements

The connection applicant shall ensure that the facility has the capability to provide short-time capabilities specified in IEEE/ANSI 50.13 and continuous capability determined by either field current, armature current, or core-end heating. More restrictive limiting functions, such as steady state stability limiters, shall not be enabled without IESO approval.

2.5 Voltage Ride Through Requirements

The generation facility shall have the capability to ride through routine switching events and design criteria contingencies assuming standard fault detection, auxiliary relaying, communication, and rated breaker interrupting times, unless disconnected by configuration.

2.6 Voltage Requirements

Appendix 4.1 of the Market Rules states that under normal operating conditions, the voltages in the 115 kV system in southern Ontario are maintained within the range of 113 kV to 127 kV. Thus, the IESO requires that the 115 kV equipment in southern Ontario must have a maximum continuous voltage rating of at least 127 kV.

Protective relaying must be set to ensure that transmission equipment remains in-service for voltages between 94% of the minimum continuous

2.7 Connection Equipment Design Requirements

The connection applicant shall ensure that the connection equipment is designed to be fully operational in all reasonably foreseeable ambient temperature conditions. The connection equipment must also be designed so that the adverse effects of its failure on the IESO-controlled grid are mitigated. This includes ensuring that all circuit breakers fail in the open position.

2.8 Fault Levels Requirement

The Transmission System Code requires the new equipment to be designed to sustain the fault levels in the area where the equipment is installed. Thus, the connection applicant shall ensure that the new equipment at the facility is designed to sustain the fault levels in the area. 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 its own expense with higher rated equipment capable of sustaining the increased fault level, up to maximum fault level specified in the Transmission System Code. Appendix 2 of the Transmission System Code establishes the maximum fault levels for the transmission system. For the 115 kV system, the maximum 3 phase and single line to ground symmetrical fault levels are 50 kA.

Fault interrupting devices must be able to interrupt fault currents at the maximum continuous voltage of 127 kV.

2.9 Breaker Interrupting Time Requirement

Appendix 2 of the Transmission System Code states that the maximum rated interrupting time for the 115 kV breakers must be ≤ 5 cycles. Thus, the connection applicant shall ensure that the installed breakers meet the required interrupting time specified in the Transmission System Code.

2.10 Protection System Requirements

The connection applicant shall ensure that the protection systems are 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 the existing protection systems.

Facilities that are essential to the power system must be protected by two redundant protection systems according to section 8.2.1a of the TSC. These redundant protection systems must satisfy all requirements of the TSC, and in particular, they must not use common components, common battery banks or common secondary CT or PT windings. As currently assessed by the IESO, this facility is not on the current Bulk Power System list, and therefore, is not considered essential to the power system. In the future, as the electrical system evolves, this facility may be placed on the BPS list.

The 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 115 kV circuits L1MB or L2M 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.

The autoreclosure of the high voltage breakers at the connection point must be blocked. Upon its opening for a contingency, the high voltage breaker must be closed only after the IESO approval is granted.

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

2.11 Telemetry Requirements

If applicable according to Section 7.3 of Chapter 4 of the Market Rules, the connection applicant shall provide to the IESO the applicable telemetry data listed in Appendix 4.15 of the Market Rules on a continual basis. The data shall be provided in accordance with the performance standards set forth in Appendix 4.19, subject to Section 7.6A of Chapter 4 of the Market Rules. The data is to consist of certain equipment status and operating quantities which will be identified during the IESO Facility Registration/Market Entry Process.

To provide the required data, the connection applicant must install at this project monitoring equipment that meets the requirements set forth in Appendix 2.2 of Chapter 2 of the Market rules. 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.

2.12 Revenue Metering Requirement

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

2.13 Reliability Standards Requirements

Prior to connecting to the IESO controlled grid, the proposed facility must be compliant with the applicable reliability standards established by the North American Electric Reliability Corporation (NERC) and reliability criteria established by the Northeast Power Coordinating Council (NPCC) that

are in effect in Ontario. A mapping of applicable standards, based on the proponent's/connection applicant's market role/OEB license can be found here: <http://www.ieso.ca/imoweb/ircp/orcp.asp>

This mapping is updated periodically after new or revised standards become effective in Ontario.

The current versions of these NERC standards and NPCC criteria can be found at the following websites:

<http://www.nerc.com/page.php?cid=2|20>

<http://www.npcc.org/documents/regStandards/Directories.aspx>

The IESO monitors and assesses market participant compliance with a selection of applicable reliability standards each year as part of the Ontario Reliability Compliance Program. To find out more about this program, write to orcp@ieso.ca or visit the following webpage: <http://www.ieso.ca/imoweb/ircp/orcp.asp>

Also, to obtain a better understanding of the applicable reliability compliance obligations and 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 by contacting rssc@ieso.ca. The RSSC webpage is located at:

http://www.ieso.ca/imoweb/consult/consult_rssc.asp.

2.14 Restoration Participant Requirements

The connection applicant is currently a restoration participant. The connection applicant is required to update its restoration participant attachment to include details regarding its proposed project. For more details please refer to the Market Manual 7.8. Details regarding restoration participant requirements will be finalized at the Facility Registration/Market Entry Stage.

2.15 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 includes both PSS/E and DSA software compatible mathematical models representing the new equipment for further IESO, NPCC and NERC analytical studies. The connection applicant may need to contact the software manufacturers directly, in order to have the models included in their packages. 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 markets 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.

- End of Section -

3. Review of Connection Proposal

3.1 Proposed Connection Arrangement

The Cardinal Power facility is connected to the St. Lawrence 115 kV system through the 115 kV circuits L1MB and L2M. The transmission network in the vicinity of the Cardinal Power facility is shown in **Figure 1**.

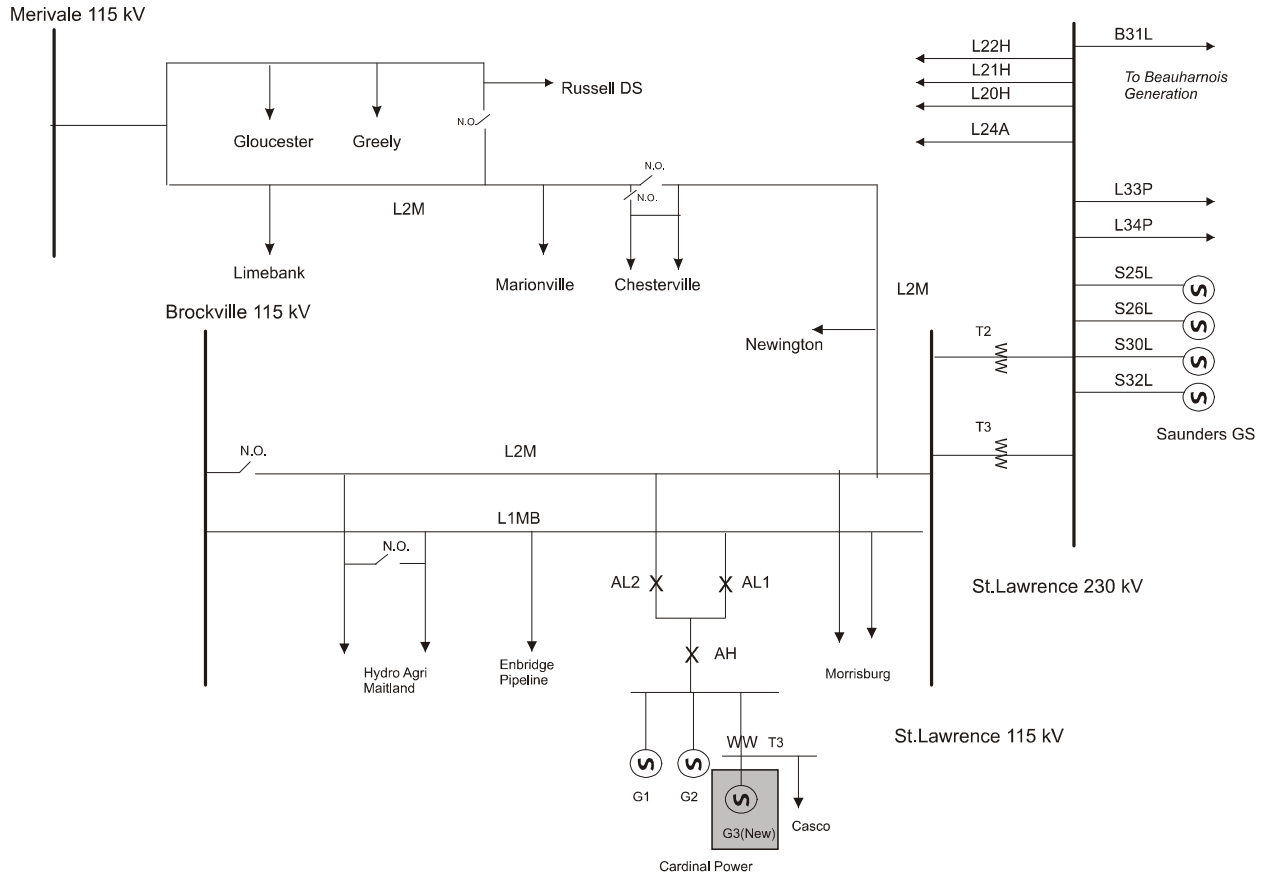


Figure 1: Proposed connection arrangement

3.2 Existing System

The 2010 hourly average historical power flows through the L1MB and L2M circuits, generation output at the Cardinal facility and voltage at St. Lawrence 115 kV bus are shown in **Figures 2 to 5**. Note positive power flows through the L1MB and L2M circuits represent flows out of the bus.

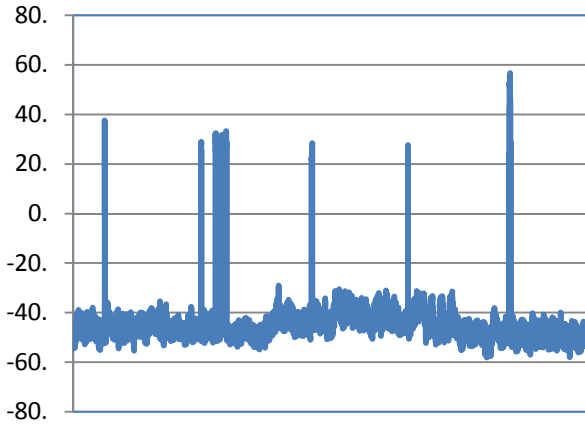


Figure 2: MW flow on L1MB at St. Lawrence

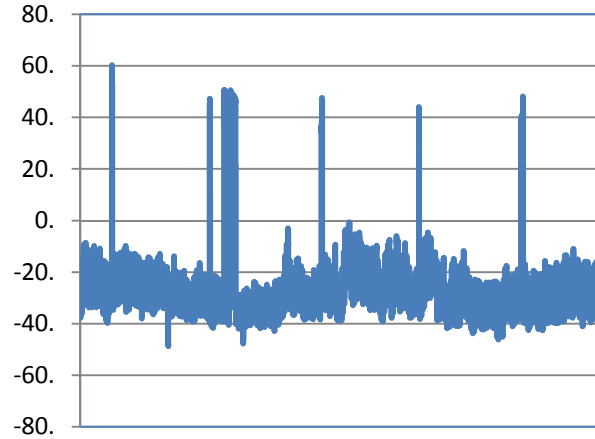


Figure 3: MW flow on L2M at St. Lawrence

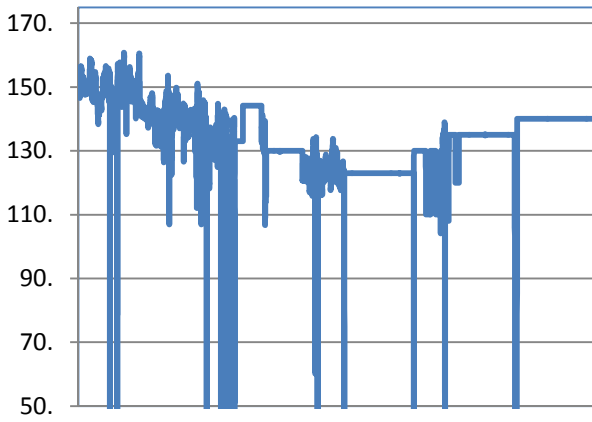


Figure 4: MW Output at Cardinal Facility

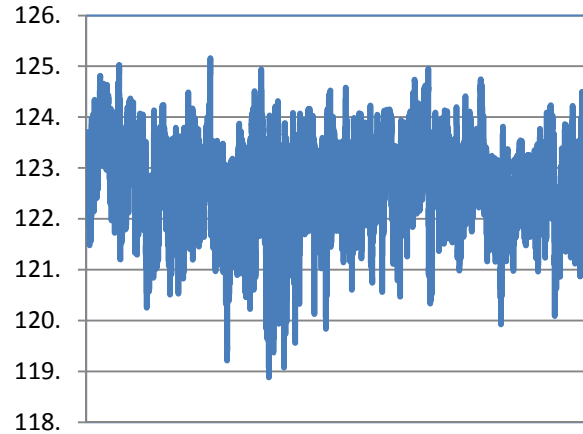


Figure 5: Voltage at St. Lawrence 115 kV bus

The following can be observed:

Station	Average voltage
St. Lawrence 115 kV	123 kV

Quantity	Maximum	Minimum
Flow on L1MB out of St. Lawrence	32 MW	-57 MW
Flow on L2M out of St. Lawrence	50 MW	-46 MW
MW Output at Cardinal Facility	156 MW	-

The above quantities were accounted for when determining the study scenarios and assumptions for the System Impact Assessment. For the list of assumptions, please refer to **Section 6.1** of this report.

- End of Section -

4. Data Verification

4.1 Generator

The following table presents the reactive capability of Cardinal Power G3 at 11.1 MW and 15.0 MW active power levels corresponding to its summer and winter Maximum Continuous Rating (MCR), respectively. Shown are the maximum and minimum reactive output at various ambient temperatures and the reactive power required to achieve 0.9 lagging power factor and 0.95 leading power factor at the specific active power output obtained from the reactive capability curve provided by Cardinal Power.

Table 1: Cardinal G3 Reactive Capability at various Ambient Temperatures and Active Power

Cardinal Power Output G3	Ambient Temp 40°C		Ambient Temp 25°C		Ambient Temp 5°C		0.9 lagging pf (Mvar)	0.95 leading pf (Mvar)
	Qmax (Mvar)	Qmin (Mvar)	Qmax (Mvar)	Qmin (Mvar)	Qmax (Mvar)	Qmin (Mvar)		
11.1 MW	14.00	-6.32	16.97	-6.32	20.71	-6.32	5.375	-3.64
15.0 MW	11.25	-6	15	-6	18.75	-6	7.26	-4.93

As shown, Cardinal Power G3 is capable of operating at a power factor range greater than 0.9 lagging and 0.95 leading.

4.2 Transformer

Specifications for the Casco T3 115/4.16 kV transformer according IESO Facility Registration documentation are listed below.

Transformation	120/4.16/4.16 kV
Rating	15 MVA(ONAN), 20 MVA (ONAF)
Impedance on 15 MVA base	11.98% (HL) ; 11.98% (HT); 2.16% (LT)
Configuration	3 phase, high side: wye, low side: wye, tertiary: delta
Tapping	On-load tap changers at HV (120 ± 15.4 kV in 16 steps)

Cardinal Power has indicated that the Casco T3 tap changer is presently set to maintain transformer secondary voltages between 4.13 kV and 4.2 kV.

4.3 Dynamic Models

The performance of the equipment proposed for the installation and their transient behavior was evaluated using the data provided by Cardinal Power; results are presented in **Sections 6.8 and 6.9**. The dynamic models of the generator, excitation systems, power system stabilizer and governor are given below.

1) GENERATOR

The Cardinal G3 generator is modeled with the Salient Pole Generator Model (GENSAL) with the following parameters and values:

Table 2: GENSAL Generator Parameters

MODEL : GENSAL – Generator Parameters		
CON's	Value	Description
J	6	T'_{D0} (>0) (sec)
J+1	0.04	T''_{D0} (>0) (sec)
J+2	0.11	T''_{Q0} (>0) (sec)
J+3	2.04	Inertia, H
J+4	0	Speed damping, D
J+5	2.73	X_D
J+6	1.39	X_Q
J+7	0.36	X'_D
J+8	0.31	$X''_D = X''_Q$
J+9	0.17	X_L
J+10	0.0280	S(1.0)
J+11	0.0450	S(1.2)

2) EXCITATION SYSTEM

The Cardinal G3 exciter is modeled with the IEEE Type ST4B Potential or Compounded Source-Controlled Rectifier Exciter (ESST4B) with the following parameters and values:

Table 3: ESST4B Exciter Parameters

MODEL : ESST4B– Exciter Parameters					
CON's	Value	Description	CON's	Value	Description
J	0.01	Tr (sec)	J+9	-9.04	Vmmin
J+1	200	Kpr	J+10	0	Kg
J+2	40	Kir	J+11	1	Kp
J+3	10.08	Vrmax	J+12	0	Ki
J+4	-9.04	Vrmin	J+13	1.25	Vbmax
J+5	0.01	Ta	J+14	0.125	Kc
J+6	1	Kpm	J+15	0	Kl
J+7	0	Kim	J+16	0	THETAP
J+8	10.08	Vmmax			

Note, the Market Rules requires that the equivalent exciter time constants shall not be longer than 20 ms for voltage sensing and 10 ms for the forward path to the exciter (ie. $T_r \leq 20$ ms and $T_a \leq 10$ ms). This model meets this requirement.

3) STABILIZER

The Cardinal G3 Power System Stabilizer is modeled with the IEEE Dual-Input Stabilizer Model (PSS2A) with the following parameters and values:

Table 4: PSS2A Stabilizer Parameters

MODEL : PSS2A– Stabilizer Parameters					
CON's	Value	Description	CON's	Value	Description
J	10	Tw1	J+9	0.1	T9
J+1	10	Tw2	J+10	10	Ks1
J+2	0	T6	J+11	0.08	T1
J+3	10	Tw3	J+12	0.02	T2
J+4	0	Tw4	J+13	0.08	T3
J+5	10	T7	J+14	0.02	T4
J+6	2.45	Ks2	J+15	0.1	Vstmax
J+7	1	Ks3	J+16	-0.1	Vstmin
J+8	0.5	T8			
ICONs	Value	Description	ICONs	Value	Description
M	1	ICS1	M+3	0	REMBUS2
M+1	0	REMBUS1	M+4	5	M
M+2	3	ICS2	M+5	1	N

4) GOVERNOR

The Cardinal G3 governor is modeled with the Gas Turbine-Governor (GAST) with the following parameters and values:

Table 5: GAST Governor Parameters

MODEL : GAST - Governor Parameters		
CON's	Value	Description
J	0.05	R(speed droop)
J+1	0.4	T1
J+2	0.2	T2
J+3	3	T3
J+4	0.8	Ambient temperature load limit, AT
J+5	2	KT
J+6	0.8	Vmax
J+7	-0.05	Vmin
J+8	0	Dturb

5. Fault Level Assessment

Fault level studies were completed by Hydro One to examine the effect of the additional Cardinal G3 unit on fault levels at existing facilities in the area. Studies were performed to analyze the fault levels with and without the new Cardinal G3 unit and other committed generation in the surrounding area. The short circuit study was carried out with the following facilities and system assumptions:

Niagara, South West, West Zones

- All hydraulic generation
- 6 Nanticoke
- 2 Lambton
- Brighton Beach (J20B/J1B)
- Greenfield Energy Centre (Lambton SS)
- St. Clair Energy Centre (L25N & L27N)
- East Windsor Cogen (E8F & E9F) + existing Ford generation
- TransAlta Sarnia (N6S/N7S)
- Imperial Oil (N6S/N7S)
- Thorold GS (Q10P)

Central, East Zones

- All hydraulic generation
- **6 Pickering units**
- **4 Darlington units**
- **4 Lennox units**
- GTAA (44 kV buses at Bramalea TS and Woodbridge TS)
- Sithe Goreway GS (V41H/V42H)
- Portlands GS (Hearn SS)
- Kingston Cogen
- TransAlta Douglas (44 kV buses at Bramalea TS)

Northwest, Northeast Zones

- All hydraulic generation
- 1 Atikokan
- 2 Thunder Bay
- NP Iroquois Falls
- AP Iroquois Falls
- Kirkland Lake
- 1 West Coast (G2)
- Lake Superior Power
- Terrace Bay Pulp STG1 (embedded in Neenah paper)

Bruce Zone

- 8 Bruce units (Bruce G1 and Bruce G2 maximum capacity @ 835 MW)
- 4 Bruce B Standby Generators

All constructed wind farms including

- Erie Shores WGS (WT1T)
- Kingsbridge WGS (embedded in Goderich TS)
- Amaranth WGS – Amaranth I (B4V) & Amaranth II (B5V)
- Ripley WGS (B22D/B23D)
- Prince I & II WGS (K24G)
- Underwood (B4V/B5V)
- Kruger Port Alma (C24Z)
- Wolf Island (injecting into X4H)

New Generation Facilities:*Committed generation*

- Greenwich Wind Farm (M23L and M24L)
- Gosfield Wind Project (K2Z)
- Kruger Energy Chatham Wind Project (C24Z)
- Raleigh Wind Energy Centre (C23Z)
- Talbot Wind Farm (W45LC)
- Greenfield South GS (R24C)
- Halton Hills GS (T38B/T39B)
- York Energy Centre (B82V/B83V)
- Island Falls (H9K)
- Becker Cogeneration (M2W)
- Wawatay G4 (M2W)
- Beck 1 G9: increase capacity to 68.5 MVA (Beck #1 115 kV bus)
- Lower Mattagami Expansion
- All renewable generation projects awarded FIT contracts were included

Transmission System Configuration

Existing system with the following upgrades:

- Bruce x Orangeville 230 kV circuits up-rated
- Burlington TS: Rebuild 115 kV switchyards
- Leaside TS to Birch JCT: Build new 115 kV circuit. Birch to Bayfield: Replace 115 kV cables.
- Uprate circuits D9HS, D10S and Q11S
- Hurontario SS in service with R19T+V41H open from R21T+V42H (230 kV circuits V41H and V42H extended and connected from Cardiff TS to Hurontario SS). Hurontario SS to Jim Yarrow 2x3km 230 kV circuits in-service
- Cherrywood TS to Claireville TS: Unbundle the two 500 kV super-circuits (C551VP & C550VP)
- Allanburg x Middleport 230 kV circuits (Q35M and Q26M) installed
- Claireville TS: Reterminate circuit 230 kV V1RP to Parkway V71P. Reterminate circuit 230 kV V72R to Cardiff(V41H)
- One 250 Mvar (@ 250 kV) shunt capacitor bank installed at Buchanan TS
- LV shunt capacitor banks installed at Meadowvale

- 1250 MW HVDC line ON-HQ in service
- Modeling of Michigan system with short circuit equivalent provided by International Transmission Company (ITC).
- Tilbury West DS second connection point for DESN arrangement using K2Z and K6Z
- Second 500kV Bruce-Milton double-circuit line in service. Double-circuit line from the Bruce Complex to Milton TS with one circuit originating from Bruce A and the other from Bruce B
- 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
- Woodstock Area transmission reinforcement:
 - Karn TS in service and connected to M31W & M32W at Ingersol TS
 - W7W/W12W terminated at LFarge CTS
 - Woodstock TS connected to Karn TS
- Nanticoke and Detweiler SVCs
- Series capacitors at Nobel SS in each of the 500 kV circuits X503 & X504E to provide 50% compensation for the line reactance
- Lakehead TS SVC
- Porcupine TS & Kirkland Lake TS SVC
- Porcupine TS: Install 2x125 Mvar shunt capacitors
- Essa TS : Install 250 Mvar shunt capacitor
- Hanmer TS: Install 149 Mvar shunt capacitor
- Pinard TS: Install 2x30 Mvar LV shunt capacitors
- Upper Mattagami expansion
- Fort Frances TS: Install 22 Mvar moveable shunt capacitor
- Dryden TS: Install shunt capacitors
- Lower Mattagami Expansion – H22D line extension from Harmon to Kipling.

System Assumptions

- Lambton 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
- Napanee TS 230 kV operated **open**
- Cherrywood TS north & south 230kV buses operated **open**
- Richview TS 230 kV bus 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 and asymmetrical fault levels near the Cardinal Generation Facility against the corresponding breaker ratings.

Table 6: Short Circuit Results with and without Cardinal G3 in Service

Bus	Cardinal G3 O/S				Cardinal G3 I/S				Breaker Ratings	
	Total Fault Current Symmetrical (kA)		Total Fault Current Asymmetrical (kA)		Total Fault Current Symmetrical (kA)		Total Fault Current Asymmetrical (kA)		Symmetrical (kA)	Asymmetrical (kA)
	3-ph fault	L-G	3-ph fault	L-G	3-ph fault	L-G	3-ph fault	L-G		
St. Lawrence 230 kV	26.148	27.61	32.702	36.18	26.17	27.62	32.729	36.200	40	42.1
St. Lawrence 115 kV	19.038	22.27	24.564	29.56	19.10	22.32	24.632	29.616	50	56.8
Cardinal Power H bus 115 kV	7.837	8.330	9.891	11.08	8.076	8.509	10.200	11.329	40	42.1
Cardinal Power A bus 115 kV	7.824	6.456	8.729	6.986	8.000	6.535	8.913	7.065	20	21

The results show that fault levels in the area surrounding the Cardinal Power Generation Facility are within the symmetrical and asymmetrical breaker ratings. Fault levels increase when all the proposed generators are in service with the highest increase at the Cardinal Power H bus of 0.309 kA (Asymmetrical current for 3 phase fault).

Therefore, it can be concluded that increases in fault levels, due to the Cardinal Facility 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, and the transient performance of the system.

6.1 Assumptions and Background

The following describes the study scenarios, system conditions and modeling assumptions.

Study Scenarios

The following table summarizes the net Maximum Continuous Rating of the Cardinal Power facility and maximum Cardinal+Casco net injection under summer and winter conditions as provided by Cardinal Power. As shown, the maximum facility output is less than the net maximum winter facility output.

Table 7: Total Cardinal Power Facility Output under Summer and Winter Conditions

	Cardinal Power Output			Cardinal Station Service Load	Cardinal Power MCR	Casco Load	Cardinal+Casco Total Net Injection
	G1	G2	G3				
Summer	90.5 MW	46 MW	11.1 MW	3 MW	144.6 MW	12.0 MW	132.6 MW
Winter	129 MW	55 MW	15 MW	3 MW	196 MW	13.0 MW	183 MW

Notes (1) Summer MCR provided under 35°C ambient temperature

(2) Winter MCR provided under 10°C ambient temperature

Accounting for the summer and winter facility net output, maximum and minimum load conditions along L1MB and L2M and various embedded generation output at Chesterville TS and Morrisburg TS, a total of six different scenarios were developed for the assessment. These scenarios include:

- S1 – Cardinal Power at Summer MCR with Cardinal G3 expansion. Minimum load conditions. 40 MW Solar + 30 MW of Wind embedded at Chesterville and Morrisburg.
- S2 – Cardinal Power at Winter MCR with Cardinal G3 expansion. Minimum load conditions. 40 MW Solar+0 MW of Wind embedded at Chesterville and Morrisburg.
- S3 – Cardinal Power at Winter MCR with Cardinal G3 expansion. Minimum load conditions. 40 MW Solar+30 MW of Wind embedded at Chesterville and Morrisburg.
- S4 – Cardinal Power at Winter MCR with Cardinal G3 expansion. Maximum load conditions. 0 MW Solar+0 MW of Wind embedded at Chesterville and Morrisburg.
- S5 – Cardinal at Winter MCR without Cardinal G3 expansion. Minimum load conditions. 0 MW of Solar+0 MW of Wind embedded at Chesterville and Morrisburg.
- S6 – Cardinal at Winter MCR without Cardinal G3 expansion. Minimum load conditions. 40 MW of Solar+30 MW of Wind embedded at Chesterville and Morrisburg.

Note, minimum load with maximum embedded generation were used as study assumptions to reveal potential thermal limitations. In reality, maximum solar generation is unlikely to be coincident with

minimum load conditions. In the event that these study assumptions yield overly conservative results, lower embedded coincident with minimum load may need to be further studied.

The following table summarizes the various flows, loads assumed for each of the scenarios:

Table 8: Summary of Study Scenario Conditions

	S1	S2	S3	S4	S5	S6
Total L2M+L1MB flows at St. Lawrence	160.2 MW	178 MW	206 MW	77 MW	124 MW	192.5 MW
Chesterville Load ²	12 MW	12 MW	12 MW	35 MW	12 MW	12 MW
Chesterville EG ¹	21 MW	21 MW	21 MW	0 MW	0 MW	21 MW
Newington DS Load	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW
Morrisburg Load ²	20.6 MW	20.6 MW	20.6 MW	60 MW	20.6 MW	20.6 MW
Morrisburg EG ¹	50.5 MW	20.5 MW	50.5 MW	0 MW	0 MW	50.5 MW
Enbridge Cardinal Load	1.0 MW	1.0 MW	1.0 MW	1.0 MW	1.0 MW	1.0 MW
Dyno Nobel Load	2.8 MW	2.8 MW	2.8 MW	2.8 MW	2.8 MW	2.8 MW
Cardinal Power Net Generation (G1+G2+G3- Station Service)	144.6 MW	196 MW	196 MW	196 MW	181 MW	181 MW
Casco Load	12 MW	13 MW	13 MW	13 MW	13 MW	13 MW
Cardinal Power G3 Output (MW)	11.1 MW	15 MW	15 MW	15 MW	0 MW	0 MW
Cardinal Power G3 Output (Mvar)	-5.2 Mvar	-5.2 Mvar	-5.2 Mvar	-5.2 Mvar	0 MW	0 MW
Imports on L33P+L34P at St. Lawrence	299.7 MW	299.7 MW	299.7 MW	299.7 MW	299.7 MW	299.7 MW
Saunders Output	1003.4 MW	1003.4 MW	1003.4 MW	1003.4 MW	1003.4 MW	1003.4 MW
Beauharnois Output; 4 Terminal Mode	800 MW	800 MW	800 MW	800 MW	800 MW	800 MW

Note: (1) Embedded Generation values obtained from Hydro One's list of embedded generation applications as of March 20, 2011.

(2) Maximum and minimum load values obtained from IESO 2010 hourly average historical data.

System Conditions

All transmission system elements were in service.

Load stations in the St. Lawrence area were set to operate at 0.9 power factor.

The Eastern Ontario demand was scaled to the 2013 extreme weather summer coincident peak of about 1401 MW and the Ottawa Ontario demand was scaled to the 2013 extreme weather summer coincident peak of about 1840 MW.

Modeling Assumptions

For both load flow and transient studies, the IESO 2010 summer base case was used as a starting point. The Eastern and Ottawa zone demand were first scaled to the 2013 extreme weather coincident peak. The loads along L2M and L1MB were then scaled to yield the various conditions outlined in **Scenarios S1 to S6**. The following other changes were implemented into the base case in the Eastern and Ottawa Zone:

- Loads were represented by constant MVA loads for thermal and voltage analysis and as voltage dependent loads with P being modeled as 50% constant current and 50% constant impedance ($P \propto V^{1.5}$) and Q being modeled as 100% constant impedance ($Q \propto V^2$) for transient analysis.
- Embedded generation at Morrisburg and Chesterville and St. Lawrence were assumed to operate at unity power factor at its point of common coupling.
- L2M assumed to be Normally Opened at Chesterville L2M-LC1 in span opener and L2M-6 switch. Brockville disconnect switch L2M-A was assumed to be Normally Opened.

6.2 Protection Impact Assessment

A Protection Impact Assessment (PIA) was completed by Hydro One to examine the impact of Cardinal G3 on existing transmission system protections. A copy of the Protection Impact Assessment summary can be found in **Appendix C** of this report.

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

6.3 Special Protection System (SPS)

Currently, there exists a runback scheme installed at the Cardinal Power facility that will reduce the Cardinal Power net generation output to 141 MW upon the detection of a loss of either AL1 or AL2 115 kV breaker. This scheme is known as the Cardinal Power Runback Scheme. By detecting the loss of breakers AL1 or AL2, this scheme will also runback for the loss of L1MB and L2M. Net generation accounts for the station service load at Cardinal Power. The existing gas unit, Cardinal G1, runs back at a rate of 2 MW/minute while the steam unit, Cardinal G2, runs back at a rate of 1 MW/minute. If the automatic runback is insufficient, the IESO can request that Cardinal Power manually reduce the output further to 102 MW. The existing runback scheme is illustrated in **Figure 6**.

Cardinal Power has indicated with the addition of Cardinal Power G3, the facility will maintain its runback capability to 141 MW. In the event of runback, Cardinal G3 will reduce its output to match the Casco load within a period of 1 or 2 minutes; if Cardinal G3 output is less than Casco load, Cardinal G3 output will remain unchanged. Cardinal Power G1 will still runback at a rate of 2 MW/minute and Cardinal G2 at a rate of 1 MW/minute such that the net facility output is 141 MW. The revised runback scheme is illustrated in **Figure 7**.

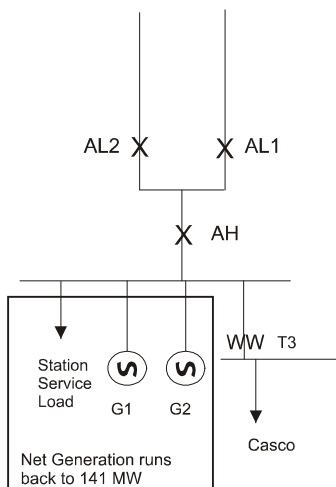


Figure 6: Diagram of Existing Runback Scheme

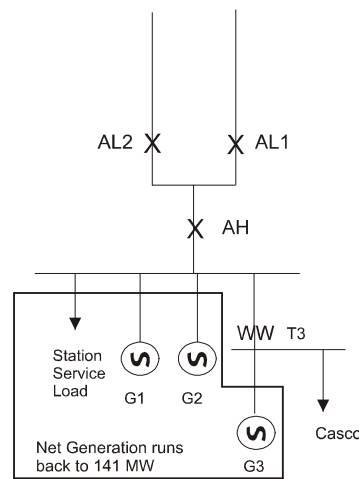


Figure 7: Diagram of Revised Runback Scheme

Under the given runback rates, Cardinal G1 would runback by 30 MW and Cardinal G2 would runback by 15 MW within a span of 15 minutes.

Preliminary studies were performed examining failure of the Cardinal Runback Scheme. It is expected that failed operation will not result in an adverse effect to the control areas outside of Ontario. Therefore it is anticipated that the Cardinal Power Runback Scheme be classified as a Type III Special Protection System.

6.4 St. Lawrence Anti-Islanding Schemes

An anti-island scheme is currently installed at St. Lawrence that sends transfer trip signals to Cardinal Power breakers AL1 and AL2 for the loss of both St. Lawrence T2 or T3 transformers (or the loss of one transformer with the other out-of-service pre-contingency). Subsequent to the opening of AL1 and AL2 breakers, transfer trip signals are sent to the generator breakers at Cardinal G1 and G2. The purpose of this scheme is to prevent island operation of the St. Lawrence 115 kV area. With the incorporation of Cardinal G3, a transfer trip signal will need to also be sent to Cardinal G3 subsequent to the opening of Cardinal AL1 and AL2 breakers.

6.5 Thermal Analysis

The assessment examined the effect the proposed facility would have on the thermal loadings of the 115 kV and 230 kV transmission area elements within its vicinity.

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 the Continuous, long term emergency and short term emergency planning thermal ratings for various circuits under summer weather conditions. The algorithm for deriving these ratings is as follows:

- *Ambient conditions*: 35°C temperature (summer ratings) , 10°C temperature (winter ratings), 4 km/hr wind speed, daytime
- *Continuous*: Rating obtained at the lesser of conductor temperature of 93 °C or sag temperature
- *Long Term Emergency (LTE)*: Rating obtained at the lesser conductor temperature of 127°C or sag temperature
- *Short Term Emergency (STE)*: Rating obtained at the sag temperature with a pre-contingency loading of 100% of the continuous rating.

Planning Ratings for transformers were obtained from the Hydro One secure website. Note, due to the terrain and sheltering of the circuits the transmitter does not allow the use of higher ratings associated with wind assumptions.

The following table summarizes the ratings for various circuits and transformers monitored for the thermal analysis. Unless indicated, the values provided are assumed to be planning ratings.

Table 9: Summary of Winter and Summer Thermal Ratings

Winter and Summer Thermal Ratings								
Element	Monitored Element		Rating (A)					
	From	To	Continuous		Long Term Emergency		Short Term Emergency	
			Sum	Wint	Sum	Wint	Sum	Wint
L2M	LUNENBRG_JL2118	ST_LAWRENCE 118	590	720	770	870	920	1020
	MORRISBG_JL2118	LUNENBRG_JL2118	680	840	860	970	920	1030
	CASCO_J_L2M 118	MORRISBG_JL2118	670	820	840	960	900	1010
	CASCO_J_L2M 118	BROCK_CH_JL2118	480	690	480	690	480	690
	CARD_PWR_CSS118	CASCO_J_L2M 118	810	1000	810	1000	810	1000
L1MB	LUNENBRG_JL1118	ST_LAWRENCE 118	660	800	830	950	890	1020
	MORRISBG_JL1118	LUNENBRG_JL1118	680	840	860	970	920	1030
	CASCO_J_L1MB118	MORRISBG_JL1118	680	840	860	970	920	1030
	CASCO_J_L1MB118	EN_CARDINALJ118	680	840	890	1000	1110	1200
	EN_CARDINALJ118	BROCK_CH_JL1118	480	690	480	690	480	690
	CARD_PWR_CSS118	CASCO_J_L1MB118	810	1000	810	1000	810	1000

The following table summarizes the pre-contingency loading as a percentage of the continuous rating for **Scenarios S1 to S3**. Circuit loadings for **Scenario S1** are given as a percentage of summer ratings, while circuit loadings for **Scenarios S2 and S3** are given as a percentage of winter ratings.

Table 10: Summary of Pre-Contingency Loading for Scenarios S1, S2 and S3

Pre-Contingency Loading					
Element	Monitored Element		% of Continuous Rating		
	From	To	S1	S2	S3
L2M	LUNENBRG_JL2118	ST_LAWRENCE 118	71.3	64.6	74.4
	MORRISBG_JL2118	LUNENBRG_JL2118	55.9	50.5	58.9
	CASCO_J_L2M 118	MORRISBG_JL2118	48.1	52.8	52.6
	CASCO_J_L2M 118	BROCK_CH_JL2118	1.6	1.1	1.1
	CARD_PWR_CSS118	CASCO_J_L2M 118	40.7	44.1	43.8
L1MB	LUNENBRG_JL1118	ST_LAWRENCE 118	58.1	53.4	62.1
	MORRISBG_JL1118	LUNENBRG_JL1118	56.7	51.1	59.3
	CASCO_J_L1MB118	MORRISBG_JL1118	47.9	52.0	51.7
	CASCO_J_L1MB118	EN_CARDINALJ118	1.7	1.4	1.4
	EN_CARDINALJ118	BROCK_CH_JL1118	1.7	1.2	1.2
	CARD_PWR_CSS118	CASCO_J_L1MB118	41.6	44.8	44.6

As shown, all pre-contingency loadings are within continuous ratings.

(a) Post-Contingency under Summer Conditions

The following table shows the post-contingency loading against LTE and STE ratings for the loss of L1MB and L2M under summer conditions (**Scenario S1**).

Table 11: Summary of Post-Contingency Loading for Loss of L1MB, Loss of L2M under Summer Conditions

Scenario S1								
Element	Monitored Element		Pre-Runback				Post-Runback	
			Cardinal G1= 90.5 MW Cardinal G2= 46 MW Cardinal G3 = 11.1 MW Station Service Load = 3 MW Total Net Cardinal Gen= 144.6 MW				Cardinal G1=88.5 MW Cardinal G2= 45 MW Cardinal G3=11.1 MW Station Service Load =3 MW Total Net Cardinal Gen= 141.6 MW	
			Loss of L1MB		Loss of L2M		Loss of L1MB	Loss of L2M
	From	To	% of LTE	% of STE	% of LTE	% of STE	% of LTE	% of LTE
L2M	LUNENBRG_JL2118	ST_LAWRENCE 118	103.4	86.5	0.0	0.0	101.5	0.0
	MORRISBG_JL2118	LUNENBRG_JL2118	87.8	82.0	0.0	0.0	86.1	0.0
	CASCO_J_L2M 118	MORRISBG_JL2118	74.9	69.9	0.0	0.0	73.2	0.0
	CASCO_J_L2M 118	BROCK_CH_JL2118	2.8	2.8	0.0	0.0	2.8	0.0
	CARD_PWR_CSS118	CASCO_J_L2M 118	79.2	79.2	0.0	0.0	77.5	0.0
L1MB	LUNENBRG_JL1118	ST_LAWRENCE 118	0.0	0.0	90.1	84.0	0.0	88.4
	MORRISBG_JL1118	LUNENBRG_JL1118	0.0	0.0	87.2	81.5	0.0	85.6
	CASCO_J_L1MB118	MORRISBG_JL1118	0.0	0.0	72.6	67.9	0.0	71.0
	CASCO_J_L1MB118	EN_CARDINALJ118	0.0	0.0	2.0	1.6	0.0	2.0
	EN_CARDINALJ118	BROCK_CH_JL1118	0.0	0.0	2.8	2.8	0.0	2.8
	CARD_PWR_CSS118	CASCO_J_L1MB118	0.0	0.0	79.3	79.3	0.0	77.6

As shown, for the loss of L1MB, L2M section between Lunenbrg x St. Lawrence will slightly exceed LTE values, but will be within STE values. Generation at either Morrisburg, Chesterville or Cardinal power will need to be re-dispatched within 15 minutes to help reduce the loading on L2M to within LTE ratings.

(b) Post-Contingency under Winter Conditions

The following table shows the post-contingency loading against LTE and STE ratings for the loss of L1MB and L2M under winter conditions (**Scenario S2**) pre and post- generation runback after 15 minutes.

Table 12: Scenario S2: Summary of Post-Contingency Loading for Loss of L1MB, Loss of L2M under Winter Conditions before and after Runback

Scenario S2								
Element	Monitored Element		Pre-Runback				Post-Runback	
			Cardinal G1= 129 MW Cardinal G2= 55 MW Cardinal G3 = 15 MW Station Service Load = 3 MW Total Net Cardinal Gen= 196 MW				Cardinal G1=99 MW Cardinal G2= 40 MW Cardinal G3=13 MW Station Service Load =3 MW Total Net Cardinal Gen= 149 MW ¹	
			Loss of L1MB		Loss of L2M		Loss of L1MB	Loss of L2M
	From	To	% of LTE	% of STE	% of LTE	% of STE	% of LTE	% of LTE
L2M	LUNENBRG_JL2118	ST_LAWRENCE 118	103.0	87.8	0.0	0.0	77.4	0.0
	MORRISBG_JL2118	LUNENBRG_JL2118	88.0	82.9	0.0	0.0	65.2	0.0
	CASCO_J_L2M 118	MORRISBG_JL2118	90.2	85.7	0.0	0.0	67.3	0.0
	CASCO_J_L2M 118	BROCK_CH_JL2118	1.9	1.9	0.0	0.0	1.9	0.0
	CARD_PWR_CSS118	CASCO_J_L2M 118	87.9	87.9	0.0	0.0	65.9	0.0
L1MB	LUNENBRG_JL1118	ST_LAWRENCE 118	0.0	0.0	89.1	83.0	0.0	65.8
	MORRISBG_JL1118	LUNENBRG_JL1118	0.0	0.0	87.5	82.4	0.0	64.7
	CASCO_J_L1MB118	MORRISBG_JL1118	0.0	0.0	88.8	83.6	0.0	66.2
	CASCO_J_L1MB118	EN_CARDINALJ118	0.0	0.0	1.8	1.5	0.0	1.8
	EN_CARDINALJ118	BROCK_CH_JL1118	0.0	0.0	1.9	1.9	0.0	1.9
	CARD_PWR_CSS118	CASCO_J_L1MB118	0.0	0.0	87.9	87.9	0.0	66.0

Note (1) Runback measured at 15 minutes. Runback to 141 MW would approximately be completed within 18 minutes.

As shown, for **Scenario S2**, the loss of L1MB or L2M will result in post-contingency loadings to be within STE ratings. Cardinal Power runback to 141 MW will help bring loadings to be within LTE rating.

The following table shows the post-contingency loading against LTE and STE ratings for the loss of L1MB and L2M under winter conditions (**Scenario S3**) pre and post- generation runback.

Table 13: Scenario S3 under 4 km/h Wind and Winter Conditions: Summary of Post-Contingency Loading for Loss of L1MB and Loss of L2M before and after Runback

Scenario S3: 4 km/hr ratings								
Element	Monitored Element		Pre-Runback				Post-Runback	
			Cardinal G1= 129 MW Cardinal G2= 55 MW Cardinal G3 = 15 MW Station Service Load = 3 MW Total Net Cardinal Gen= 196 MW				Cardinal G1=99 MW Cardinal G2= 40 MW Cardinal G3=13 MW Station Service Load =3 MW Total Net Cardinal Gen= 149 MW ¹	
	From	To	Loss of L1MB		Loss of L2M		Loss of L1MB	Loss of L2M
			% of LTE	% of STE	% of LTE	% of STE	% of LTE	% of LTE
L2M	LUNENBRG_JL2118	ST_LAWRENCE 118	120.2	102.5	0.0	0.0	Not a Practical Solution as Loading Exceeds STE	0.0
	MORRISBG_JL2118	LUNENBRG_JL2118	103.3	97.3	0.0	0.0		0.0
	CASCO_J_L2M 118	MORRISBG_JL2118	90.3	85.8	0.0	0.0		0.0
	CASCO_J_L2M 118	BROCK_CH_JL2118	2.0	2.0	0.0	0.0		0.0
	CARD_PWR_CSS118	CASCO_J_L2M 118	88.0	88.0	0.0	0.0		0.0
L1MB	LUNENBRG_JL1118	ST_LAWRENCE 118	0.0	0.0	104.8	97.6		80.6
	MORRISBG_JL1118	LUNENBRG_JL1118	0.0	0.0	102.8	96.8		79.2
	CASCO_J_L1MB118	MORRISBG_JL1118	0.0	0.0	88.8	83.7		65.7
	CASCO_J_L1MB118	EN_CARDINALJ118	0.0	0.0	1.8	1.5		1.8
	EN_CARDINALJ118	BROCK_CH_JL1118	0.0	0.0	2.0	2.0		1.9
	CARD_PWR_CSS118	CASCO_J_L1MB118	0.0	0.0	88.0	88.0	65.5	

For **Scenario S3**, the loss of L2M may result in the loading on L1MB to be within STE ratings and therefore runback is a possible control action. However, the loss of L1MB may result in the STE ratings of L2M being exceeded and therefore, the use of runback would not provide the instantaneous generation rejection that would be required. Studies show that the L2M section at Lunenbrg x St. Lawrence would be loaded beyond its STE rating by about 26 A or 5 MW. If these conditions occur, generation along L1MB and L2M may need to be curtailed pre-contingency to respect the thermal ratings. The probability of these coincident conditions for this scenario is considered low and does not warrant further system enhancements.

6.5 Voltage Analysis

The assessment of the voltage performance in the St. Lawrence 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 study was done for minimum and maximum load conditions using a constant MVA model in both immediate pre-contingency state and in post-ULTC state.

A voltage decline analysis was performed with **Scenarios S3** (minimum load) and **S4** (maximum load), to observe the effect of the loss of L1MB and L2M. The pre-contingency active and reactive power output level at the Cardinal Power facility under these scenarios can be found in the "Assumptions and Background" section of this report (**Section 6.1**)

The study results under pre-ULTC and post-ULTC conditions are summarized in the following tables:

Table 14: Scenario S3: Post-Contingency Voltage Declines

S3: Minimum Load Conditions Voltage Declines (%)							
Bus Name	Pre-Contingency Voltage (kV)	Loss of Cardinal Power at A Bus		Loss of L1MB		Loss of L2M	
		Pre-ULTC	Post-ULTC	Pre-ULTC	Post-ULTC	Pre-ULTC	Post-ULTC
ST_LAWRENCE 230	242.9	-0.83	-0.94	0.45	0.44	0.27	0.24
ST_LAWRENCE 115	121.4	-2.42	-2.49	0.99	0.99	0.67	0.64
CHESTERVILLE115	120.8	-2.96	-2.99	1.93	1.92	N/A	N/A
EN_CARDINAL 115	121.5	-3.86	-3.77	N/A	N/A	1.52	1.51
MORRISBG_L1M115	121.5	-3.87	-3.77	N/A	N/A	2.06	2.04
MORRISBG_L2M115	121.5	-3.79	-3.69	2.13	2.13	0.55	0.53
DYNO_NOB_L2M115	121.5	-3.80	-3.71	1.64	1.64	2.88	2.87
DYNO_NOBL1MB115	121.5	-3.86	-3.78	N/A	N/A	1.60	1.59
CARD_PWR_CSS115	121.5	N/A	N/A	1.55	1.55	1.50	1.49

Table 15: Scenario S4: Post-Contingency Voltage Declines

S4: Maximum Load Conditions Voltage Declines (%)							
Bus Name	Pre-Contingency Voltage (kV)	Loss of Cardinal Power at A bus		Loss of L1MB		Loss of L2M	
		Pre-ULTC	Post-ULTC	Pre-ULTC	Post-ULTC	Pre-ULTC	Post-ULTC
ST_LAWRENCE 230	245.6	-0.58	-0.72	0.10	0.07	0.00	0.05
ST_LAWRENCE 115	124.0	-1.49	-0.44	0.21	0.16	-0.16	-0.14
CHESTERVILLE115	119.4	-1.64	-0.49	1.05	0.94	N/A	N/A
EN_CARDINAL 115	121.1	-2.00	-0.84	N/A	N/A	1.44	1.32
MORRISBG_L1M115	121.0	-2.01	-0.85	N/A	N/A	2.30	2.09
MORRISBG_L2M115	120.8	-1.78	-0.61	2.72	2.48	4.66	3.89
DYNO_NOB_L2M115	121.1	-1.61	-0.45	1.91	1.76	2.82	2.69
DYNO_NOBL1MB115	121.1	-1.98	-0.83	N/A	N/A	1.52	1.40
CARD_PWR_CSS115	121.1	N/A	N/A	1.82	1.67	1.43	1.31

As shown, all voltage changes are within IESO criteria. It should be noted that high voltages along L1MB and L2M can result due to the loss of Cardinal Power under minimum load conditions (**Scenario S3**). For pre-contingency voltages at St. Lawrence 115 kV bus of 121 kV, the post-contingency voltages at Cardinal

115kV, Morrisburg 115 kV, Enbridge Cardinal 115 kV and Dyno Nobel 115 kV buses were found to be as high as 126 kV. Therefore, the St. Lawrence 115 kV bus pre-contingency voltage may need to be reduced to 121 kV or below during high generation and minimum load conditions along L1MB and L2M.

6.6 Reactive Power Assessment

Currently, the CASCO facility is classified as a load facility. The IESO requires that load facilities should have the capability to operate at a power factor between 0.9 lagging and 0.9 leading.

After the installation of the new 18.75 MVA generation unit, the CASCO facility will inject active power into the grid and thus should be treated like a generation facility connecting to the IESO controlled grid. A directly connected generating facility must have the capability to inject and withdraw reactive power continuously at its connection point. The amount of reactive capability is up to 33% of its rated active power at all levels of active power output except where a lesser continually available capability is permitted by the IESO. Cardinal Power expects with the incorporation of Cardinal G3, the net injection at CASCO will be at most 3.0 MW. Therefore, the facility will be required to inject/withdraw 1 Mvar of dynamic reactive power

Load flow studies were performed to evaluate the reactive power capability in the lagging pf of the CASCO facility under the following assumptions:

- Typical voltage of 123 kV at St. Lawrence 115 kV
- Casco Load = 12 MW @ 0.88 pf lagging
- Casco T3 transformer regulates the 4.16 kV bus
- Cardinal Power G1 and G2 were assumed to be out of service
- Cardinal Power G3 controls the H bus voltage
- Maximum active power output from Cardinal Power G3 (at 15.0 MW)

Table 16: Evaluation of Reactive Power Capability of Casco Facility in the Lagging pf

Cardinal Power Active Power	Cardinal Power Reactive Power	4.16 kV bus voltage	Casco 115/4.16 kV transformer tap	Reactive Power injection at Connection Point	Cardinal Power H bus voltage
15.0 MW	7.9 Mvar	4.2 kV	120 kV	1.4 Mvar	125kV

Load flow studies were performed to evaluate the reactive power capability in the leading pf of the CASCO facility under the following assumptions:

- Typical voltage of 123 kV at St. Lawrence 115 kV
- Casco Load = 12 MW @ 0.88 pf lagging
- Casco T2 transformer regulates the 4.16 kV bus
- Cardinal Power G1 and G2 were assumed to be out of service
- Cardinal Power G3 controls the H bus voltage
- Maximum active power output from Cardinal Power G3 (at 15.0 MW)

Table 17: Evaluation of Reactive Power Capability of Casco Facility in the Leading pf

Cardinal Power Active Power	Cardinal Power Reactive Power	4.16 kV bus voltage	Casco 115/4.16 kV transformer tap	Reactive Power injection at Connection Point	Reactive Power injection at Connection Point
15 MW	4.7 Mvar	4.2 kV	121.925 kV	-1.9 Mvar	124.6 kV

As shown, the facility will be able to inject or withdraw 1 Mvar from the point of connection. This assumes Cardinal Power G3 controls the H bus voltage while Casco T3 controls the 4.16 kV voltage.

6.7 Dyno Nobel and Morrisburg TS Circulation Power Analysis

Under present conditions with Cardinal Power G1 and G2 in-service, the loss of Cardinal Power breakers AL1 or AL2 may result in circulating power at the Nitro Chemical station. Excessive circulating power is of concern as there is a possibility that the increased inflow on one of the Dyno Nobel transformer may exceed its long term emergency thermal rating.

As the Cardinal Power runback scheme will automatically initiate for the loss of either AL1 or AL2 breaker, the runback scheme to 141 MW may not be sufficient in reducing Dyno Nobel transformer loadings to within their continuous rating. In some cases, this may not be enough and further curtailment at Cardinal Power may be required.

Prior to incorporation of Cardinal Power G3, it is expected that there will be 50 MW of embedded generation to be incorporated at Morrisburg. It is expected that the addition of embedded generation at Morrisburg Cardinal Power may further aggravate the circulation power at Dyno Nobel.

Hydro One has indicated that there are reverse power limits at Morrisburg TS. Transformers at Morrisburg each have a reverse power flow limit of 40 MW (continuous), 60 MW (15 minutes) and 50 MW (1 hour 15 minutes).

An analysis of the circulation power at Dyno Nobel and Morrisburg TS was performed with the following scenarios:

- S5: Under present conditions with no Cardinal G3 expansion and no embedded generation
- S6: Under future conditions with no Cardinal G3 expansion and 50 MW of embedded generation at Morrisburg
- S3: Under future conditions with Cardinal G3 expansion and 50 MW of embedded generation at Morrisburg

The table below shows results under (i) pre-Cardinal Power runback conditions and (ii) post-Cardinal Power runback conditions (after 15 minutes). Results are also shown for instances in which a manual redispatch is required post Cardinal Power runback to respect continuous reverse power flow limit at Morrisburg TS:

Table 18: Summary Flows at Dyno Nobel TS and Morrisburg TS for various Cardinal Breaker AL1 and AL2 contingencies

	Flows (MW) ¹			
	Dyno Nobel		Morrisburg	
	T1 @ 115 kV bus	T2 @ 115 kV bus	T3 @ 115 kV bus	T4 @115 kV bus
Continuous Rating (MVA)	13.3	13.3	83	83
10 day Rating (MVA)	14.9	14.9	128	128
15 minute Rating (MVA)	N/A	N/A	174.2	174.2
(i) Loss of Breaker AL2				
S5: Existing (pre-runback)	10.3	-7.5	46.8	-26.2
S5: Existing+ Cardinal runback to 141 MW	8.4	-5.6	38.5	-17.7
S6: 50 MW of embedded generation (pre-runback)	10.0	-7.2	20.8	-50.5
S6 : 50 MW of embedded generation+ Cardinal runback to 141 MW	8.1	-5.3	12.3	-42.1
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW+ manual redispatch of Cardinal to 130 MW	7.5	-4.7	9.8	39.7
S3: Cardinal expansion+50 MW of embedded generation (pre-runback)	10.8	-8.0	24.1	-53.8
S3: Cardinal expansion+50 MW of embedded generation+ Cardinal runback to 141 MW	8.4	-5.6	13.8	-43.7
S3: Cardinal expansion+50 MW of embedded generation+ Cardinal runback to 141 MW+ manual redispatch of Cardinal to 130 MW	7.5	-4.7	10.1	-39.8
(ii) Loss of Breaker AL1				
S5: Existing (pre-runback)	-7.4	10.2	-24.8	46.5
S5: Existing+ Cardinal runback to 141 MW	-5.4	8.2	-16.5	37.2
S6: 50 MW of embedded generation (pre-runback)	-7.4	10.2	-51.7	21.8
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW	-5.5	8.3	-43.1	13.4
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW+ manual redispatch of Cardinal to 126 MW	-4.7	7.5	-39.9	10.1
S3: Cardinal expansion +50 MW of embedded generation (pre-runback)	-8.2	11.0	-54.7	25.1
S3: Cardinal expansion+50 MW of embedded generation+ runback to 141 MW	-5.8	8.6	-44.7	14.8
S3: Cardinal expansion+50 MW of embedded generation+ Cardinal runback to 141 MW+ manual redispatch of Cardinal facility to 126 MW	-4.7	7.5	-39.8	10.1
(iii) Loss of Breaker AL1, Morrisburg T3 O/S				
S5: Existing (pre-runback)	-10.2	13.0	0	20.7
S5: Existing+ Cardinal runback to 141 MW	-7.4	10.1	0	20.7
S6: 50 MW of embedded generation (pre-runback)	-13.1	15.9	0	29.9
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW	-10.3	13.1	0	29.9
S3: Cardinal expansion +50 MW of embedded generation (pre-runback)	-14.3	17.0	0	-29.8
S3: Cardinal expansion +50 MW of embedded generation+ Cardinal runback to 141 MW	-10.8	13.6	0	-29.8
Note (1) Positive flow represents an inflow of power. Negative flow represents an outflow of power.				

(iv) Loss of Breaker AL1, Morrisburg T4 O/S				
S5: Existing (pre-runback)	-12.7	15.6	20.7	0
S5: Existing+ Cardinal runback to 141 MW	-9.8	12.6	-20.7	0
S6: 50 MW of embedded generation (pre-runback)	-10.2	13.0	-29.8	0
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW	-7.3	10.1	-29.8	0
S3: Cardinal expansion +50 MW of embedded generation (pre-runback)	-11.3	14.2	-29.8	0
S3: Cardinal expansion +50 MW of embedded generation+ Cardinal runback to 141 MW	-7.8	10.6	-29.8	0
(v) Loss of Breaker AL2, Morrisburg T3 O/S				
S5: Existing (pre-runback)	15.8	-12.9	0	20.7
S5: Existing+ Cardinal runback to 141 MW	12.9	-10.1	0	20.7
S6: 50 MW of embedded generation (pre-runback)	12.7	-9.9	0	-29.8
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW	9.7	7.0	0	-29.8
S3: Cardinal expansion +50 MW of embedded generation (pre-runback)	13.9	-11.0	0	-29.8
S3: Cardinal expansion +50 MW of embedded generation+ Cardinal runback to 141 MW	10.3	-7.5	0	-29.8
(vi) Loss of Breaker AL2, Morrisburg T4 O/S				
S5: Existing (pre-runback)	13.3	-10.4	20.7	0
S5: Existing+ Cardinal runback to 141 MW	10.4	7.6	20.7	0
S6: 50 MW of embedded generation (pre-runback)	15.6	-12.8	-29.8	0
S6: 50 MW of embedded generation+ Cardinal runback to 141 MW	12.8	-10	-29.8	0
S3: 15 MW at Cardinal+50 MW of embedded generation	16.8	-14.0	-29.8	0
S3: 15 MW at Cardinal+50 MW of embedded generation+ Cardinal runback to 141 MW	13.3	-10.5	-29.8	0

Note (1) Positive flow represents an inflow of power. Negative flow represents an outflow of power.

As shown in **Scenarios S3, S6 and S5**, the loss of either Cardinal AL2 or Cardinal AL1 will result in circulation power at Dyno Nobel. The loading on either Dyno Nobel T1 or T2 transformers, however, will be within their limited timed rating of 14.9 MVA, pre-Cardinal Power runback. Subsequent operation of the Cardinal Power runback scheme will help reduce the transformer loading to be within its continuous rating after 15 minutes of operation. Note, this study assumes a Dyno Nobel load of about 2.8 MW. Sensitivity studies repeated with **Scenario S3** (15 MW at Cardinal+50 MW of embedded generation), indicate that the Dyno Nobel load would have to be greater than 11.5 MW at 0.9 power factor in order for either transformer to be loaded over its long term emergency rating for the loss of either Cardinal AL1 or AL2 breaker.

If Morrisburg T4 and breaker AL1 is lost or Morrisburg T3 is out of service and breaker AL2 is lost, it can be observed that embedded generation at Morrisburg will help reduce the level of circulating power while Cardinal G3 would help to increase the level of circulating power. On the other hand, if Morrisburg T4 is out of service and breaker AL2 is lost or Morrisburg T3 is out of service and AL1 is lost, both the embedded generation at Morrisburg and Cardinal G3 will increase the level of circulating power at Dyno Nobel. As such, it is expected that pre-contingency curtailment may be required at both Cardinal Power and embedded generation at Morrisburg TS to prevent the potential over loading at the Dyno Nobel transformers due to the excessive transformer power inflows as a result of the loss of AL1 or AL2 breakers during outages to Morrisburg T3 or Morrisburg T4 transformer.

Circulating power also exists at Morrisburg TS. With 50 MW of Morrisburg embedded generation and no Cardinal G3 expansion, as much as 52 MW and 43 MW of transformer outflow may exist at either Morrisburg TS transformer for the IBO of Cardinal AL1 or AL2 breaker pre Cardinal Power runback scheme initiation and 15 minutes of post Cardinal Power runback scheme operation, respectively. These flows are within the Morrisburg 15 minute reverse power capability of 60 MW. In order to respect the continuous reverse power flow of 40 MW, study results indicate that Cardinal Power net generation will need to be manually redispatched to 130 MW within about an hour after runback.

With 50 MW of Morrisburg embedded generation and the Cardinal G3 expansion, as much as 55 MW and 45 MW of transformer outflow may exist at either Morrisburg TS transformer for the IBO of the Cardinal AL1 or AL2 breaker pre the Cardinal Power runback scheme initiation and 15 minutes of post Cardinal Power runback scheme operation, respectively. These flows are within the Morrisburg 15 minute reverse power capability of 60 MW. In order to respect the continuous reverse power flow of 40 MW, study results indicate that Cardinal Power net generation will need to be manually redispatched to 126 MW within about an hour after runback.

6.8 Control Systems Assessment

6.8.1 GOVERNOR SYSTEM PERFORMANCE TESTING

The proposed generator at Cardinal G3 is to be equipped with a Gas Turbine-Governor modeled by GAST PTI model.

As per appendix 4.2 of Market Rules, a generation unit greater than 10 MW shall have the capability to:

- Regulate speed with an average droop based on maximum active power adjustable between 3% and 7% and set at 4% unless otherwise specified by the IESO.

To evaluate governor performance, the Governor Droop test was performed with an initial loading of 50% of the machine MVA (0.5 * 18.75 MVA = 9.375 MVA) and zero speed with a step change of 1%. The response of this test is shown in **Figure 8**.

From the graphs the governor droop was calculated to be 4 % which meets the Market Rule requirements.

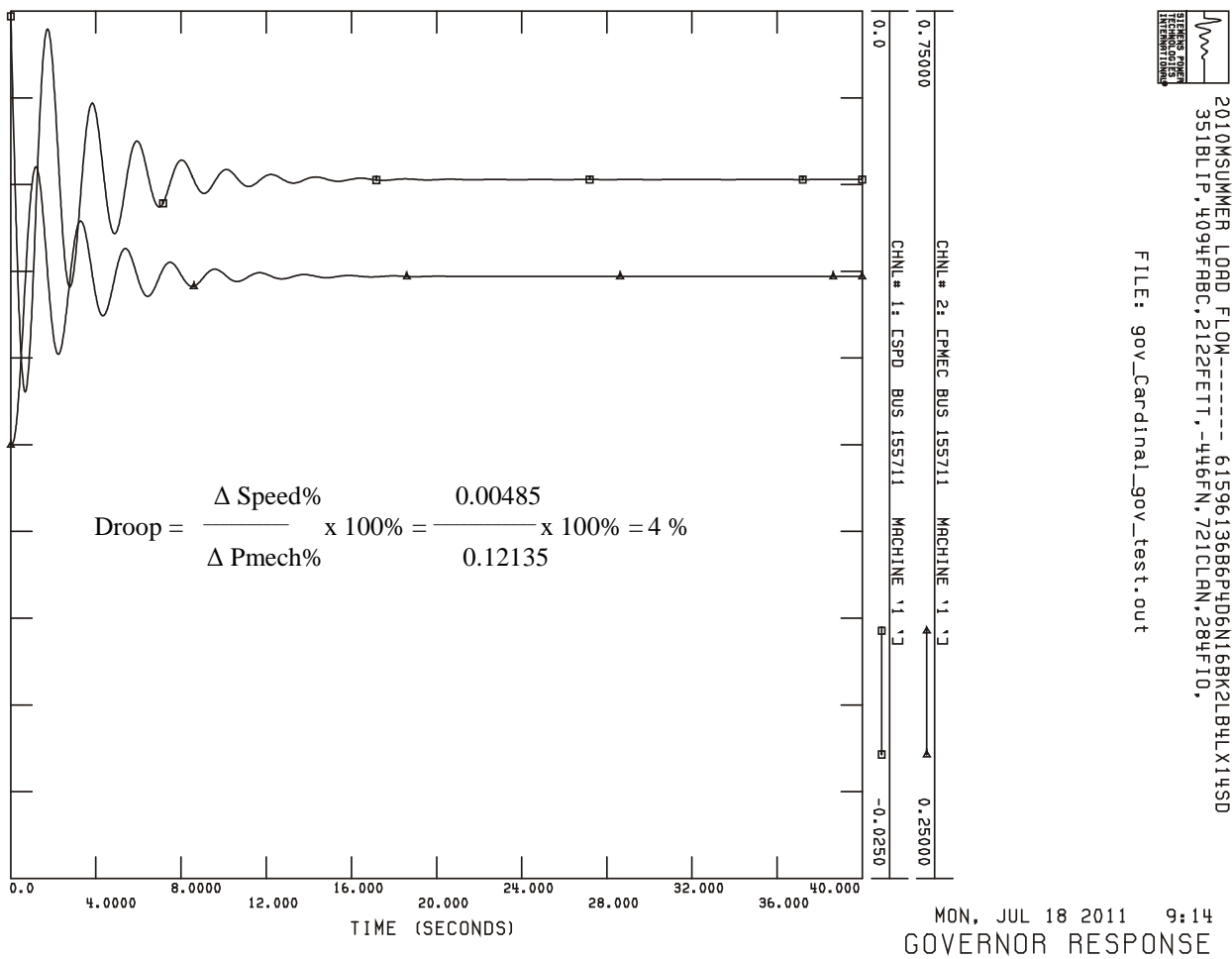


Figure 8: Governor Response

6.8.2 EXCITATION SYSTEM PERFORMANCE TESTING

The proposed generator at Cardinal G3 is to be equipped with an IEEE Type ST4B Potential Source-Controlled Rectifier Exciter by the ESST4B PTI model. The excitation system test was performed with a generator output of 15 MW.

EXCITATION SYSTEM CEILING CAPABILITY TEST

As per appendix 4.2 of Market Rules, each generation facility directly connected to the IESO-controlled grid shall have an Excitation System with the capability to:

- Provide positive and negative ceilings not less than 200% and 140% of rated field voltage at rated terminal voltage and rated field current

To evaluate the positive and negative ceilings, response ratio tests were performed.

The positive ceiling test automatically raises the reference setting of the voltage regulator by a large amount at time equal zero, with the generator initialized to at rated voltage, rated active power and required maximum continuous reactive power.

Figure 9 shows that for the positive ceiling capability test, the exciter field voltage is increased from the rated value of 2.9845 pu. to the ceiling voltage of 7.71 pu which is 258% of the rated field voltage. Therefore, the exciter at Cardinal G3 has a positive ceiling capability of at least 200%.

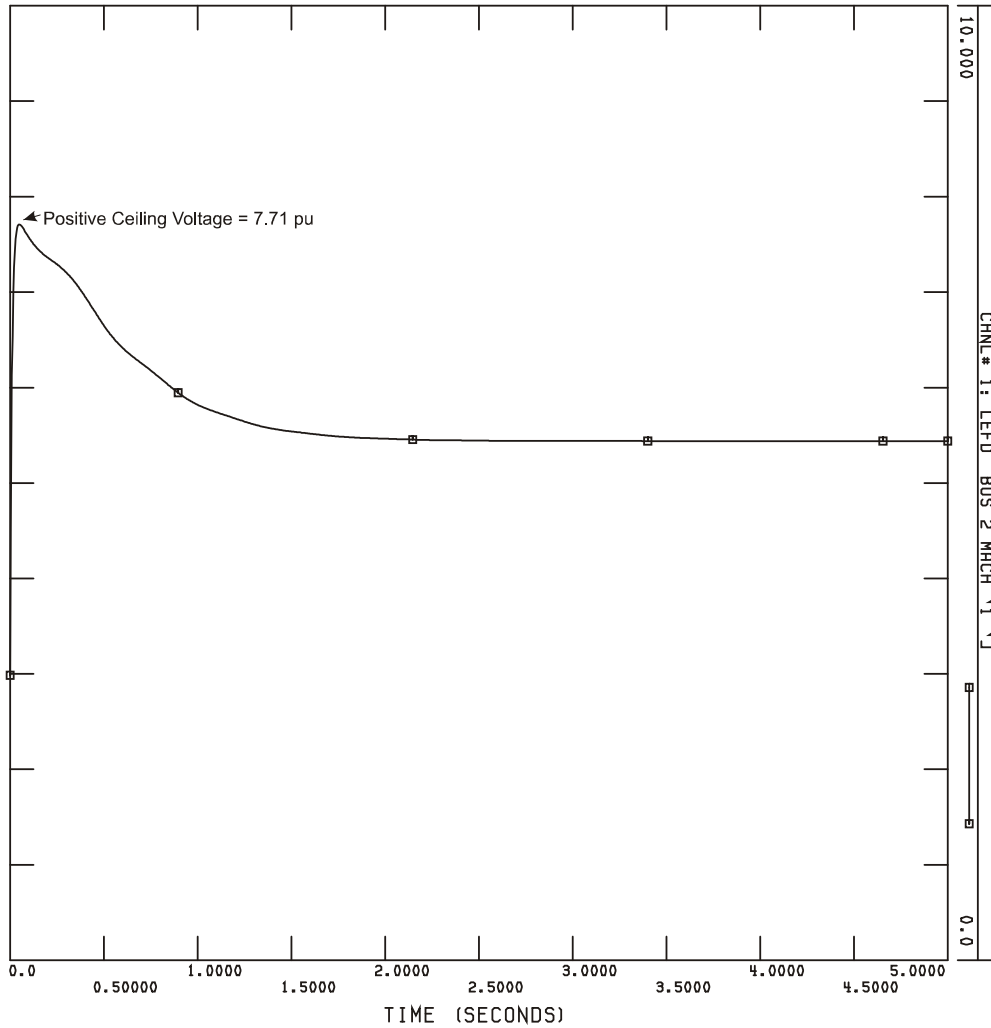


Figure 9: Positive Ceiling Capability Test Response

The negative ceiling test automatically lowers the reference setting of the voltage regulator by a large amount at time equal zero, with the generator initialized to at rated voltage, rated active power and required maximum continuous reactive power.

Figure 10 shows that for the negative ceiling capability test, the exciter field voltage is increased from the rated value of 2.9845 pu. to the ceiling voltage of 9.080 pu which is 304% of the rated field voltage. Therefore, the exciter at Cardinal G3 has a positive ceiling requirement of at least 140% .

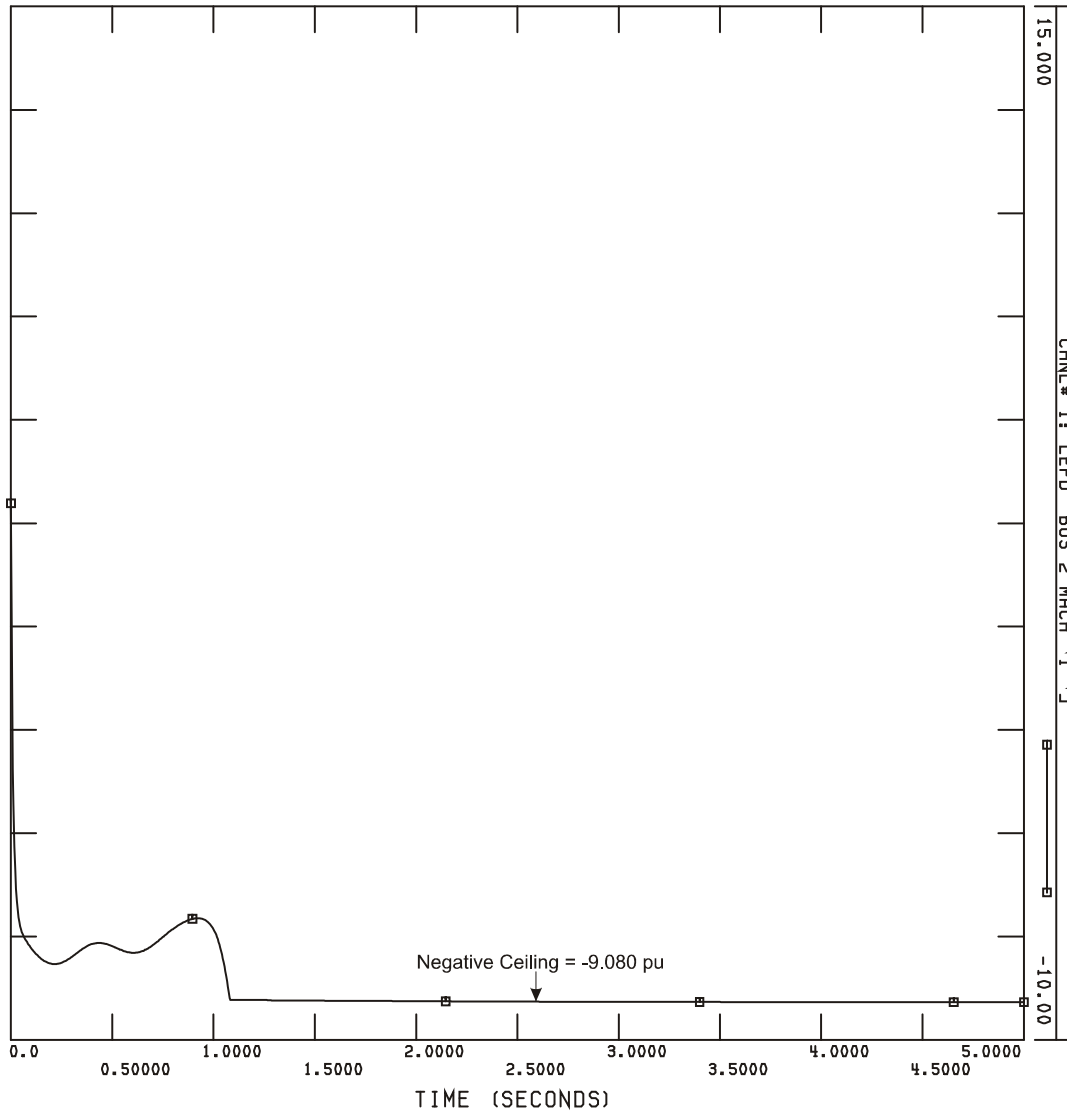


Figure 10: Negative Ceiling Capability Test Response

EXCITATION SYSTEM OPEN CIRCUIT RESPONSE TEST

As per appendix 4.2 of Market Rules, each generation facility directly connected to the IESO-controlled grid shall have an Excitation System with the capability to:

- Provide a voltage response time to either ceiling not more than 50 ms for a 5% step change from rated voltage under open-circuit conditions

Open circuit test for +5% step change in reference voltage was performed to verify if the exciter has the capability of reaching $1.95 * E_{fd_{rated}}$ starting from $E_{fd} = E_{fd_{rated}}$ within 50 ms.

Figure 11 shows the open circuit test results for a +5% step change in reference voltage

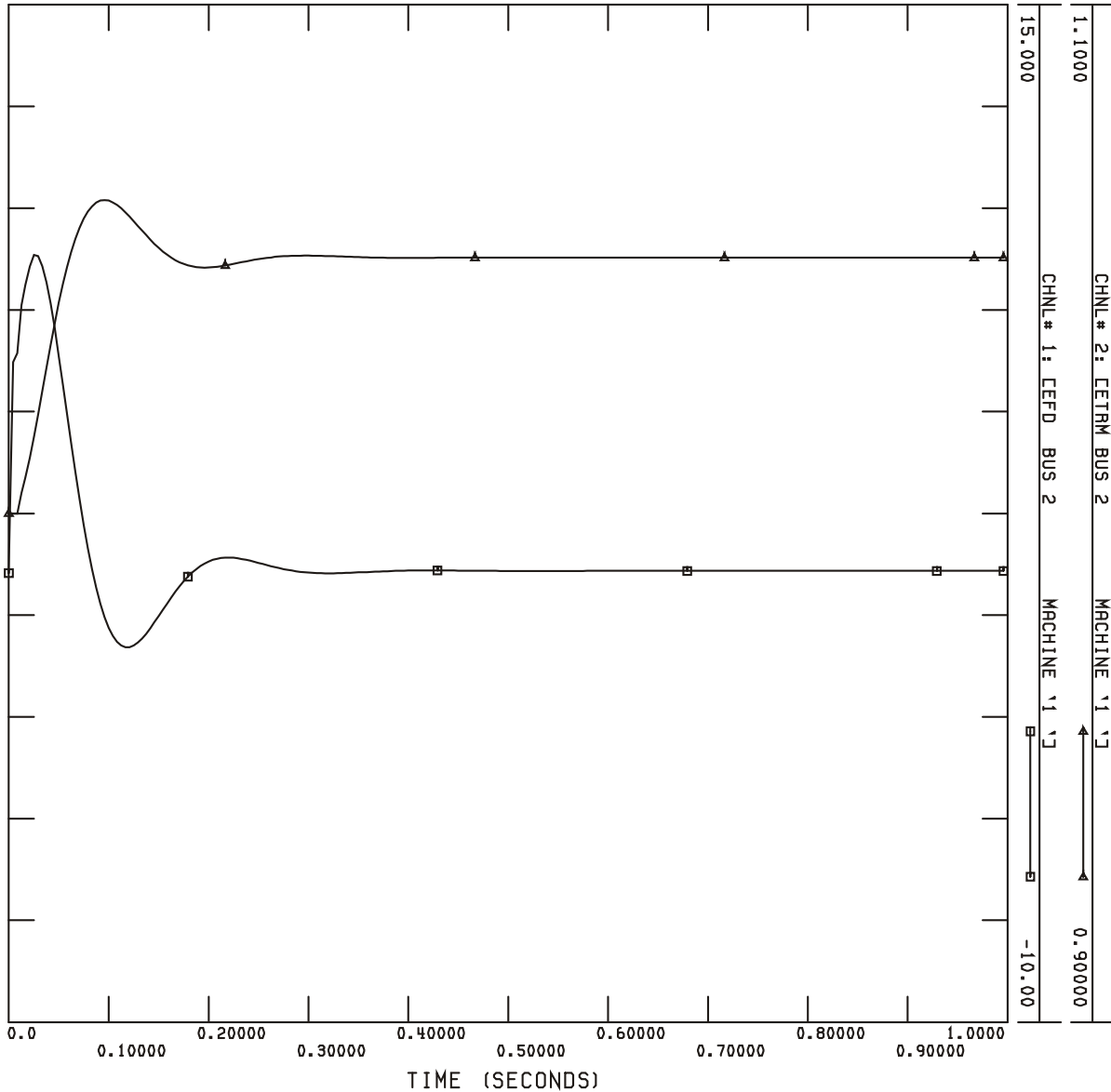


Figure 11: Open Circuit Test for +5% Reference Voltage Change

From the graph it was observed that $Efd_{initial}(t=0) = 1.0280 = Efd_{oc}$. $Efd_{rated} = 2.9845$ p.u

Therefore the required time to reach $1.95 * Efd_{rated} = 5.82$ p.u is:

$$RT_{OC_pos} = 50 * \frac{1.95 Efd_{rated} - Efd_{oc}}{1.95 Efd_{rated} - Efd_{rated}} = 84.5ms$$

From the graph it was observed that Efd reaches this value at approximately 4.7 ms.

Open circuit test for -5% step change in reference voltage was performed to verify if the exciter has the capability of reaching $-1.28 * Efd_{rated}$ starting from $Efd = Efd_{rated}$ within 50 ms.

Figure 12 shows the open circuit test results for a -5% step change in reference voltage

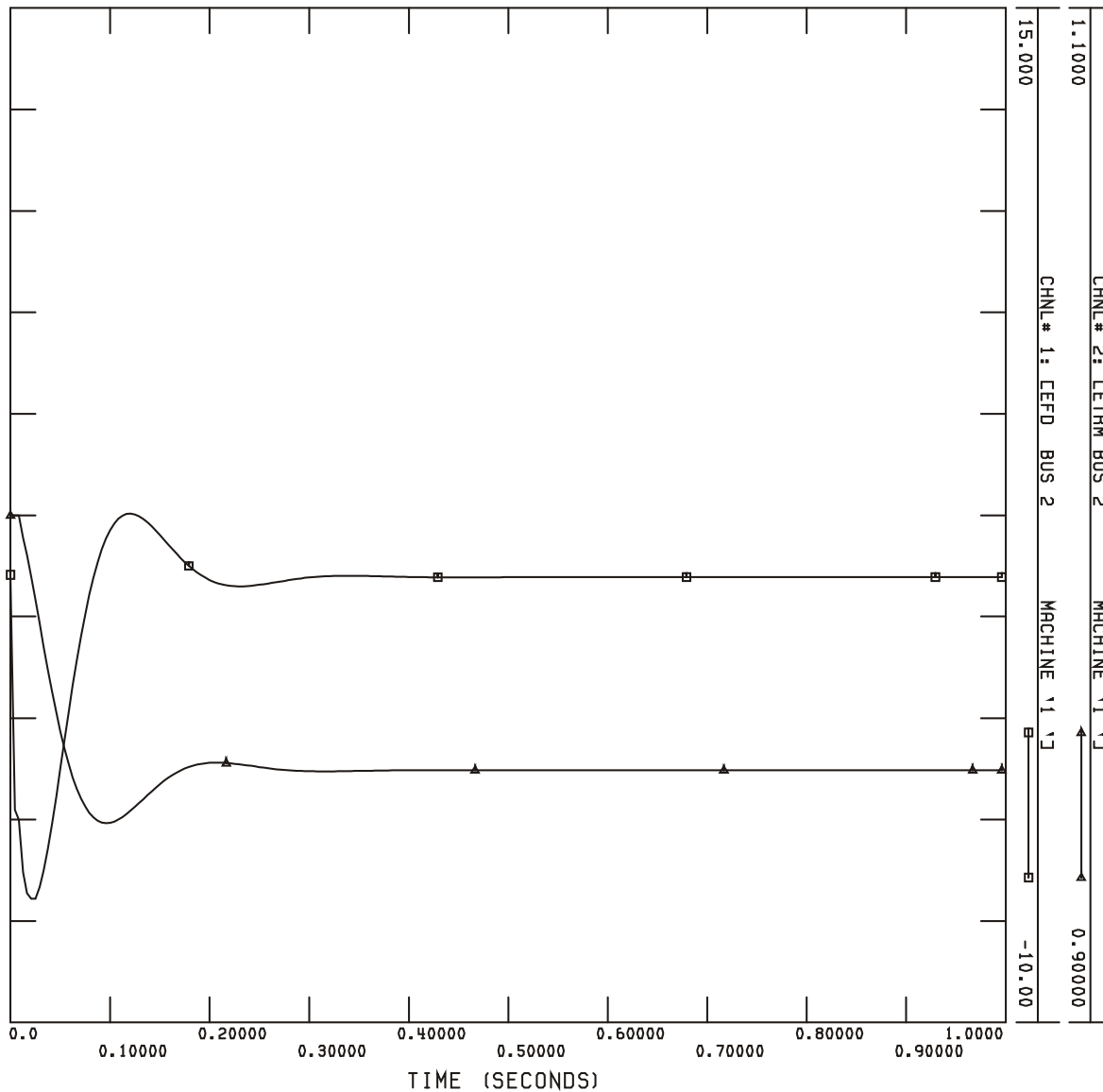


Figure 12: Open Circuit Test for -5% Reference Voltage Change

From the graph it was observed that $Efd_{initial}(t=0) = 1.0280 = Efd_{oc}$. $Efd_{rated} = 2.9845$ p.u

Therefore the required time to reach $-1.28 * Efd_{rated} = -3.82$ p.u is:

$$RT_{OC_neg} = 50 * \frac{1.28 Efd_{rated} + Efd_{oc}}{1.28 Efd_{rated} + Efd_{rated}} = 37.6 \text{ ms}$$

From the graph it was observed that Efd reaches this value at approximately 2.6 ms.

Therefore Cardinal G3 can provide a voltage response time to either ceiling for a 5% step change from rated voltage under open-circuit conditions that is within 50 ms.

EXCITATION SYSTEM POSITIVE CEILING CAPABILITY AT 160% OF RATED FIELD CURRENT

As per appendix 4.2 of Market Rules, each generation facility directly connected to the IESO-controlled grid shall have an excitation system with the capability to:

- Provide a positive ceiling not less than 170% of rated field voltage at rated terminal voltage and 160% of rated field current

The above requirement was performed by modelling Cardinal G3 connected to an infinite bus system at rated terminal voltage. The reference voltage was raised to 1.00081 p.u. in order to achieve a steady state where field current and field voltage were equal to 160% of rated values. The reference voltage was then raised to 1.04 pu. **Figure 13** shows this test.

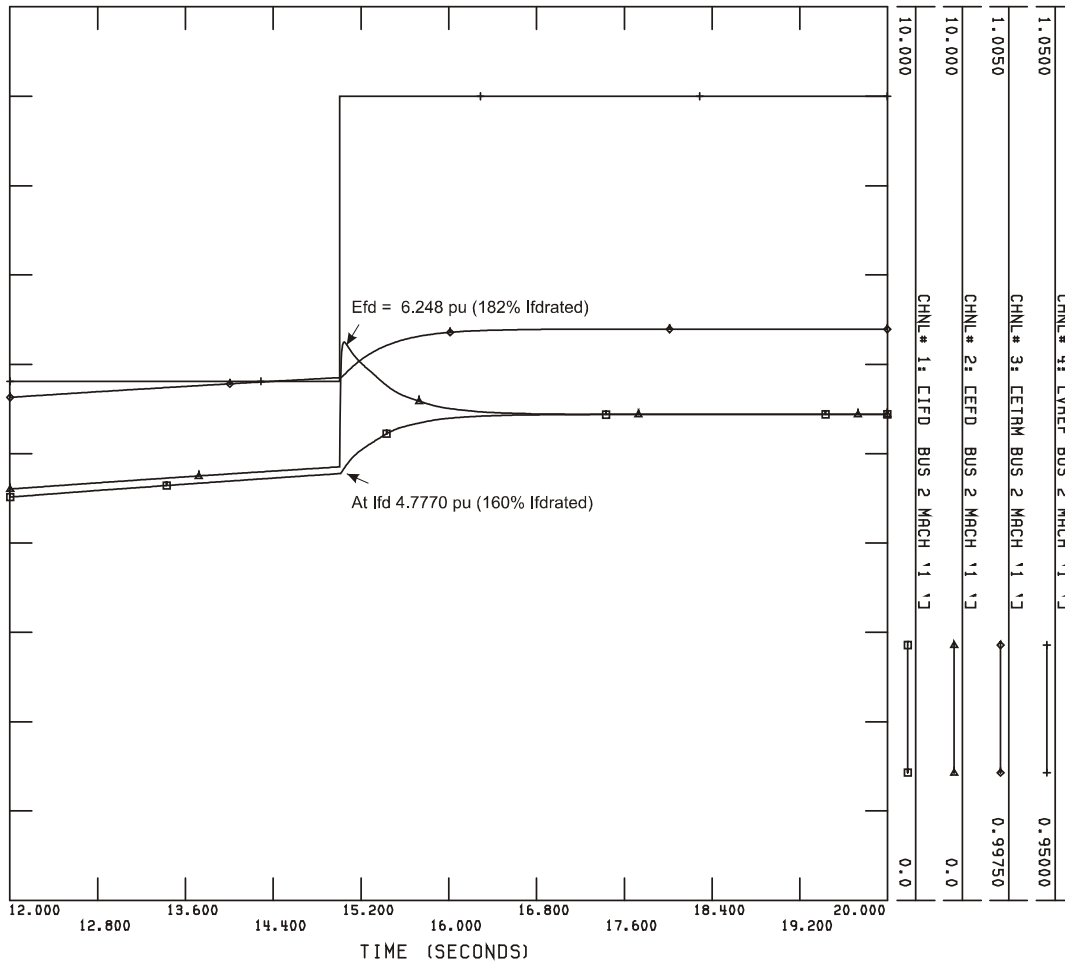


Figure 13: Cardinal Power G3 Voltage Response under rated terminal voltage and 160% of rated field current conditions for 4% change in reference voltage

From the above graph, it was noticed that field voltage reached 182% of rated field voltage at rated terminal voltage and 160% of rated field current for a reference voltage step change of 4%. Therefore, Cardinal G3 can provide a positive ceiling no less than 170% of rated field voltage at rated terminal voltage and 160% of rated field current.

6.9 Transient Analysis

Transient stability analysis was performed considering faults in the St. Lawrence area using **Scenario S3**. For the specific pre-contingency output level of the Cardinal facility, please refer to **Section 6.1** of the report.

The following eight contingencies were tested:

Table 19: Summary of Contingencies and Fault Clearing Time Performed for Transient Analysis

ID	Contingency	Voltage (kV)	Location	Fault Clearing Time (ms) ¹	
				Near	Remote
SC1	3 ph fault on L1MB	115 kV	St. Lawrence	183 ms at St. Lawrence	208 ms at Cardinal SS 208 ms at Morrisburg 2.1 s at Dyno Nobel
SC2	3 ph fault on L1MB	115 kV	Brockville	233 ms at Cardinal SS ²	258 ms at St. Lawrence 258 at Morrisburg 2.1 s at Dyno Nobel
SC3	3 ph fault on L1MB	115 kV	Cardinal Power RSS	183 ms at Cardinal SS	208 ms at St. Lawrence 208 ms at Morrisburg 2.1 s at Dyno Nobel
SC4	3 ph fault on L2M	115 kV	St. Lawrence	183 ms at St. Lawrence	208 ms at Cardinal SS 208 ms at Morrisburg 2.1 s at Dyno Nobel
SC5	3 ph fault on L2M	115 kV	Brockville	233 ms at Cardinal SS ²	258 ms at St. Lawrence 258 at Morrisburg 2.1 s at Dyno Nobel
SC6	3 ph fault on L2M	115 kV	Cardinal Power RSS	183 ms at Cardinal SS	208 ms at St Lawrence 208 ms at Morrisburg 2.1 s at Dyno Nobel
SC7	3 ph fault on L24A	230 kV	St. Lawrence	183 ms at St. Lawrence	216 ms at Hawthorne
SC8	3 ph fault on L20H	230 kV	St. Lawrence	183 ms at St Lawrence	216 ms at Hinchinbrook 2.1 s at Brockville

Note: (1) Fault applied at t=100 ms

(1) Fault seen by zone two at Cardinal Power RSS. Cleared after 50 ms due to no blocking signal received.

The transient responses are shown in **Appendix B**.

As a sensitivity test, contingency SC1 and SC7 were repeated with Cardinal Power G3 out of service to examine transient responses under current conditions. The total Cardinal Power facility output was 196 MW and the CASCO load was 13 MW. The rotor angle and voltage responses are shown in **Figures 14 and 15**. A comparison of the responses with and without Cardinal Power G3 in service show that the responses are similar and thus, the incorporation of Cardinal G3 does not adversely impact to the transient performance of the system for existing conditions.

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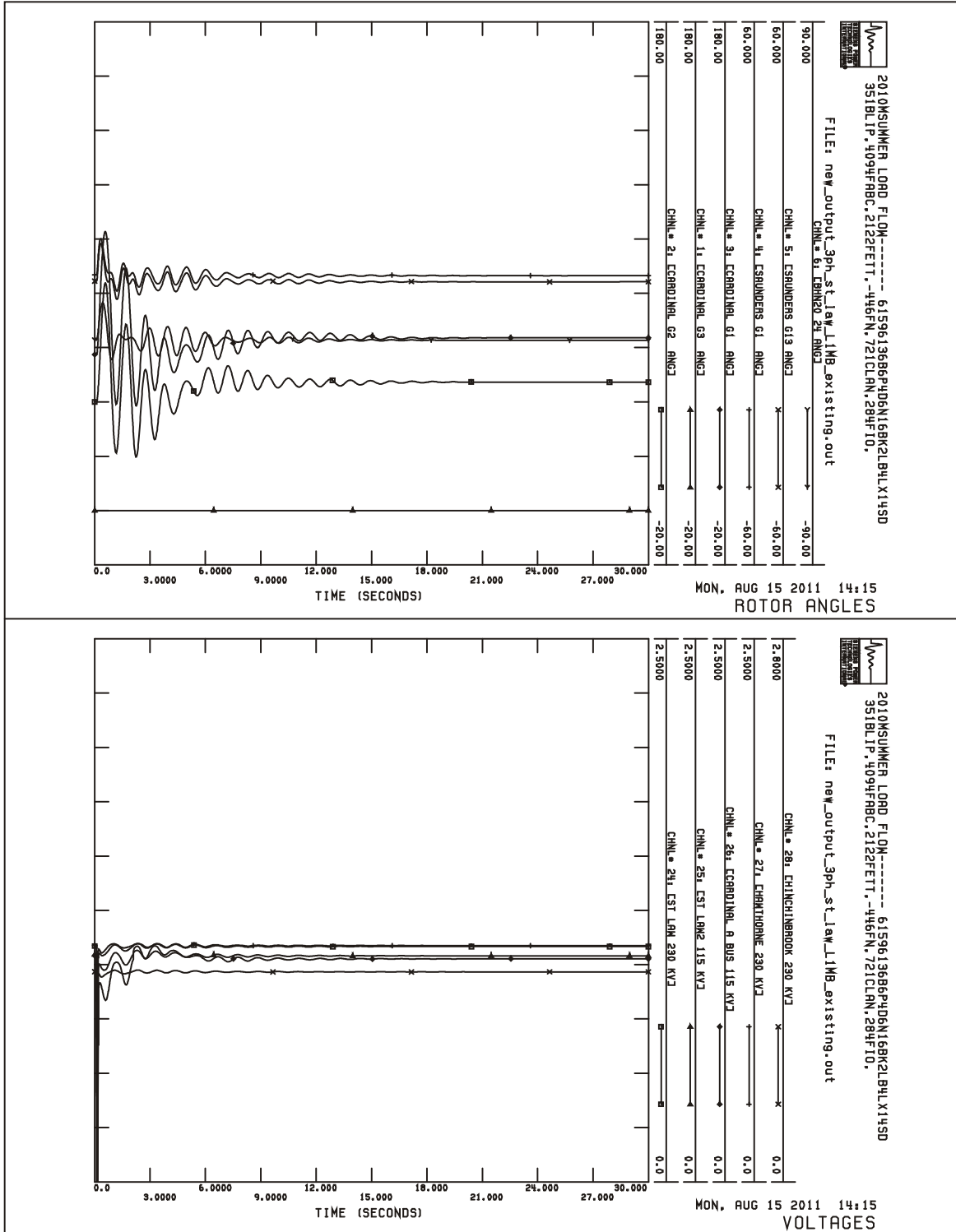


Figure 14: 3 ph fault on L1MB at St. Lawrence (Cardinal G3 O/S)

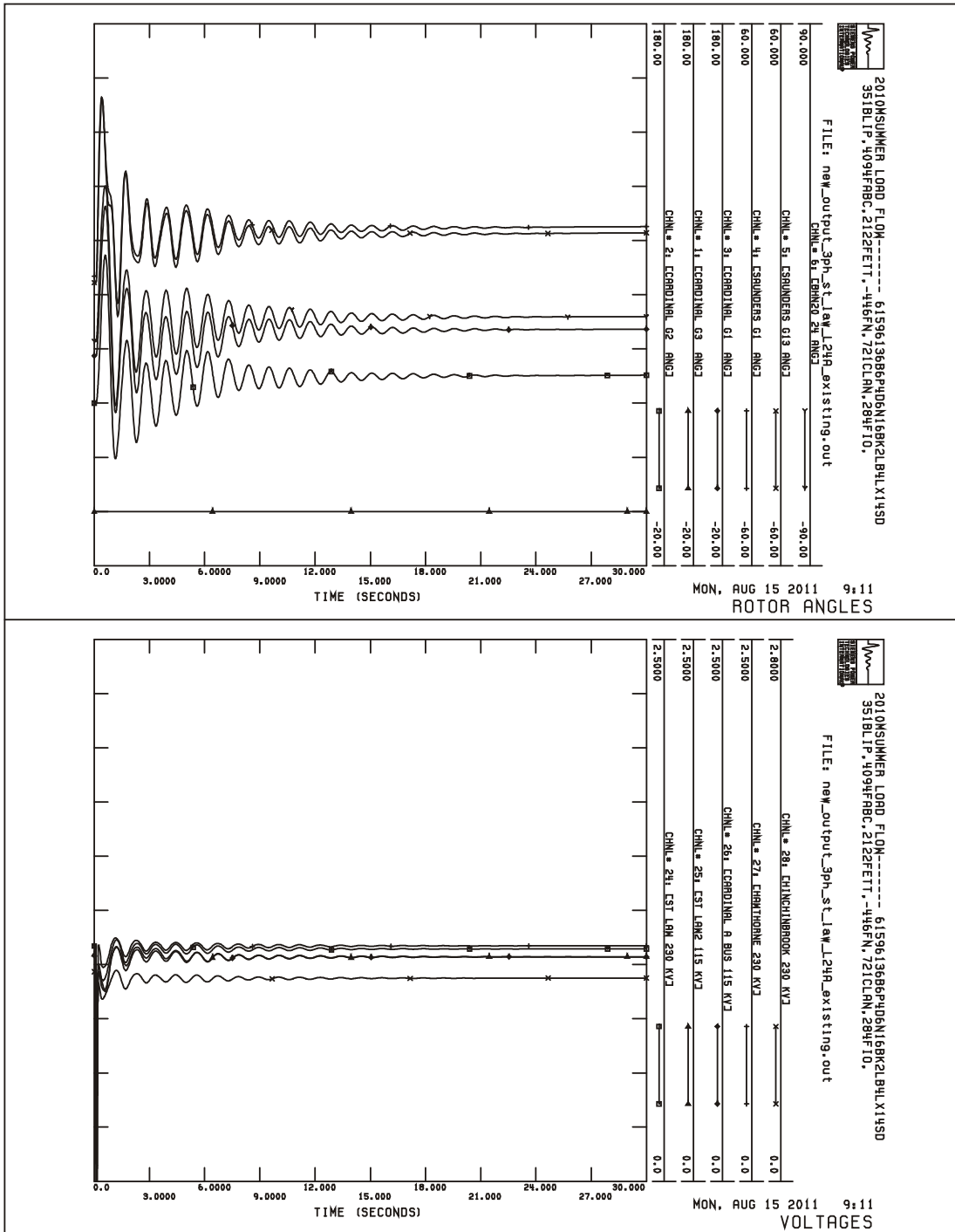


Figure 15: 3 ph fault on L24A at St. Lawrence (Cardinal G3 O/S)

It can be concluded from the results that with the new 18.75 MVA generator at Cardinal Power in-service, none of the simulated contingencies caused transient instability or undamped oscillations.

- End of Report -

Appendix A: Market Rules – Appendix 4.2

Appendix 4.2 – Generation Facility Requirements

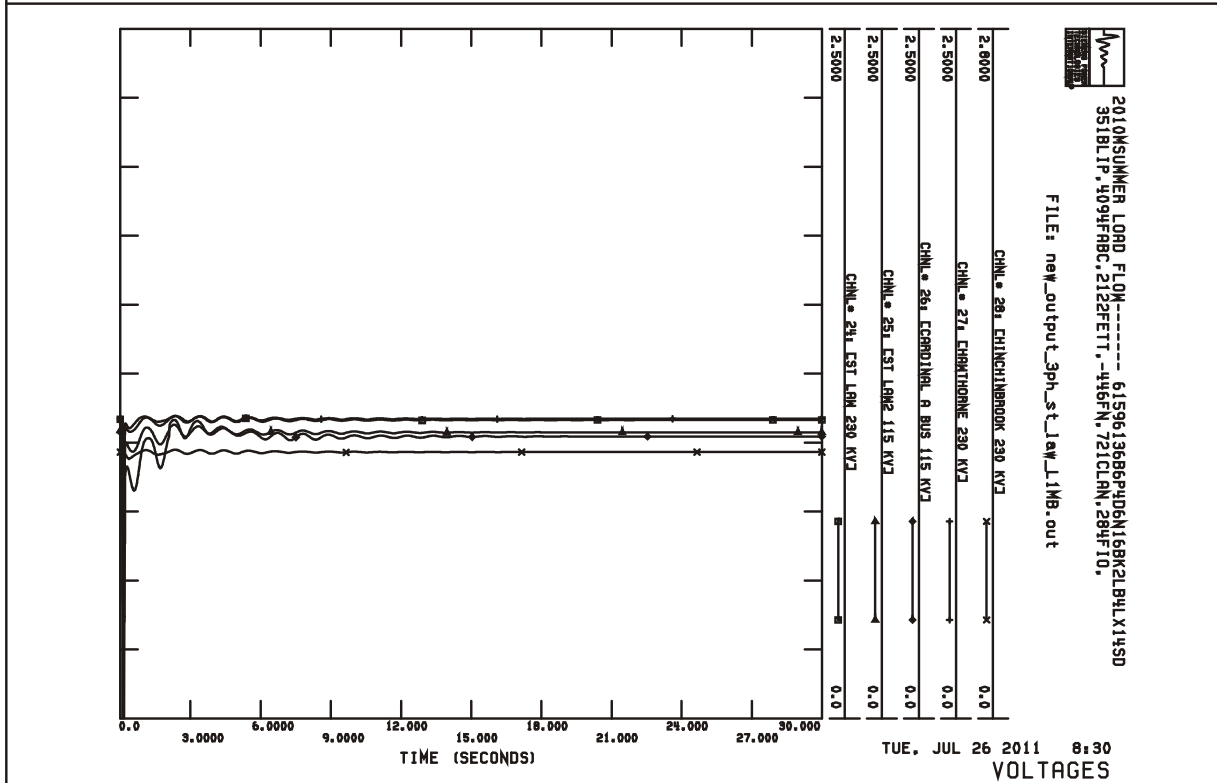
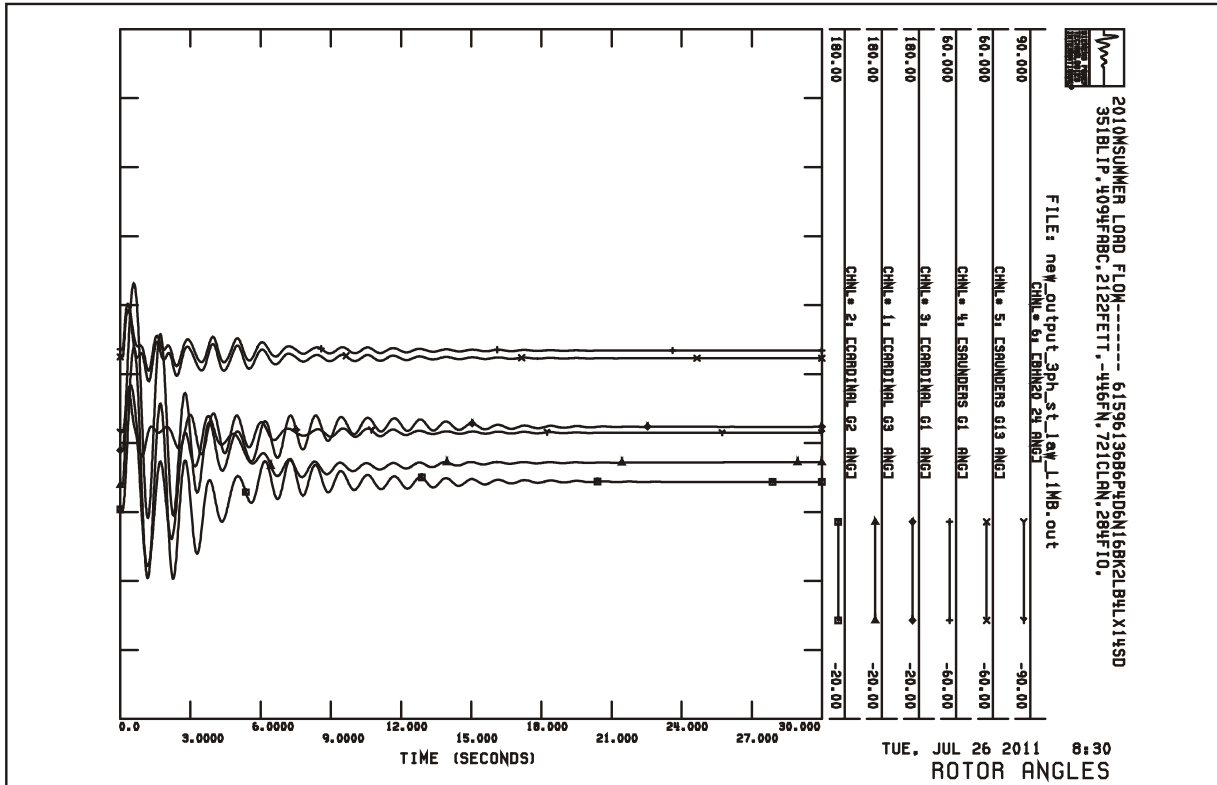
The performance requirements set out below shall apply to *generation facilities* subject to a *connection assessment* finalized after March 6, 2010. Performance of alternative technologies will be compared at the point of connection to the *IESO-controlled grid* with that of a conforming conventional synchronous *generation unit* with an equal apparent power rating to determine whether a requirement is satisfied.

Each *generation facility* that was authorized to connect to the *IESO-controlled grid* prior to March 6, 2010 shall remain subject to the performance requirements in effect for each system at the time of its authorization to connect to the *IESO-controlled grid* was granted or as agreed to by the *market participant* and the *IESO* (i.e. the “original performance requirements”). These requirements shall prevail until the main elements of an associated system (e.g. governor control mechanism, main exciter) are replaced or substantially modified. At that time, the replaced or substantially modified system shall meet the applicable performance requirements set out below. All other systems, not affected by replacement or substantial modification, shall remain subject to the original performance requirements.

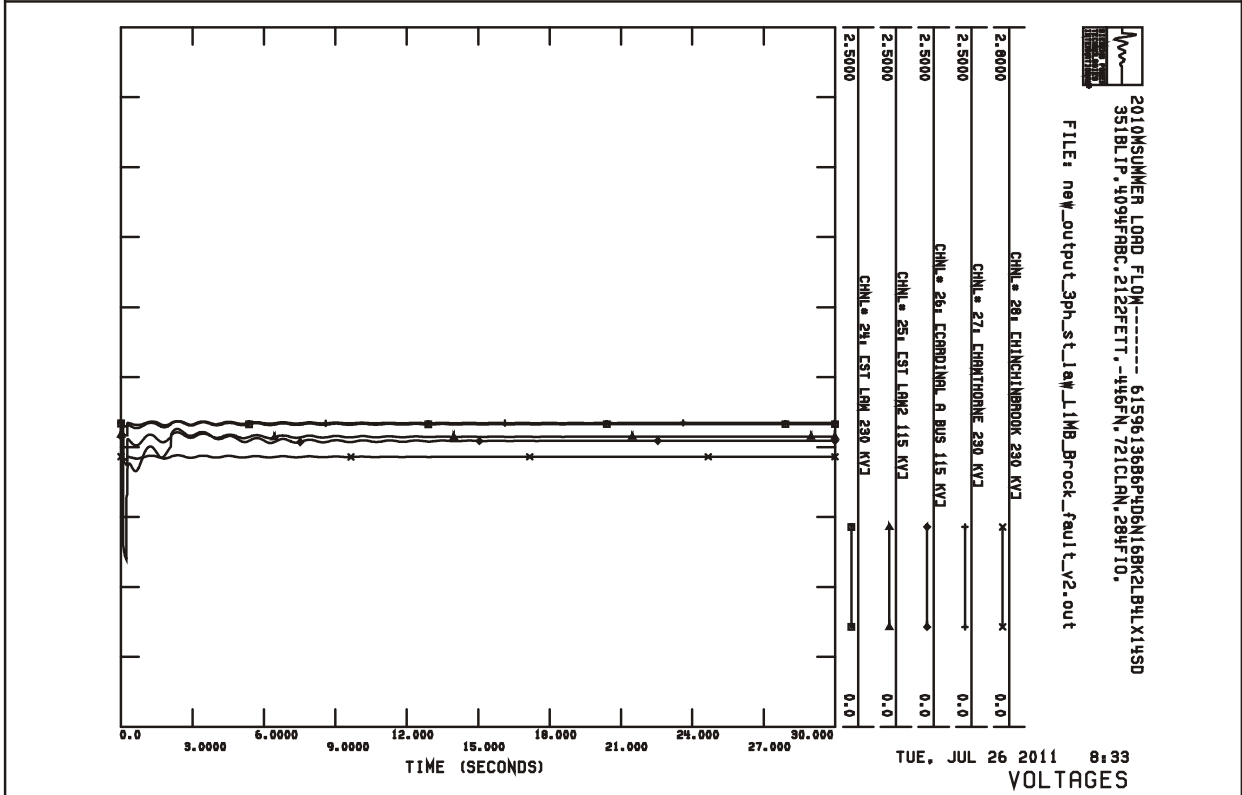
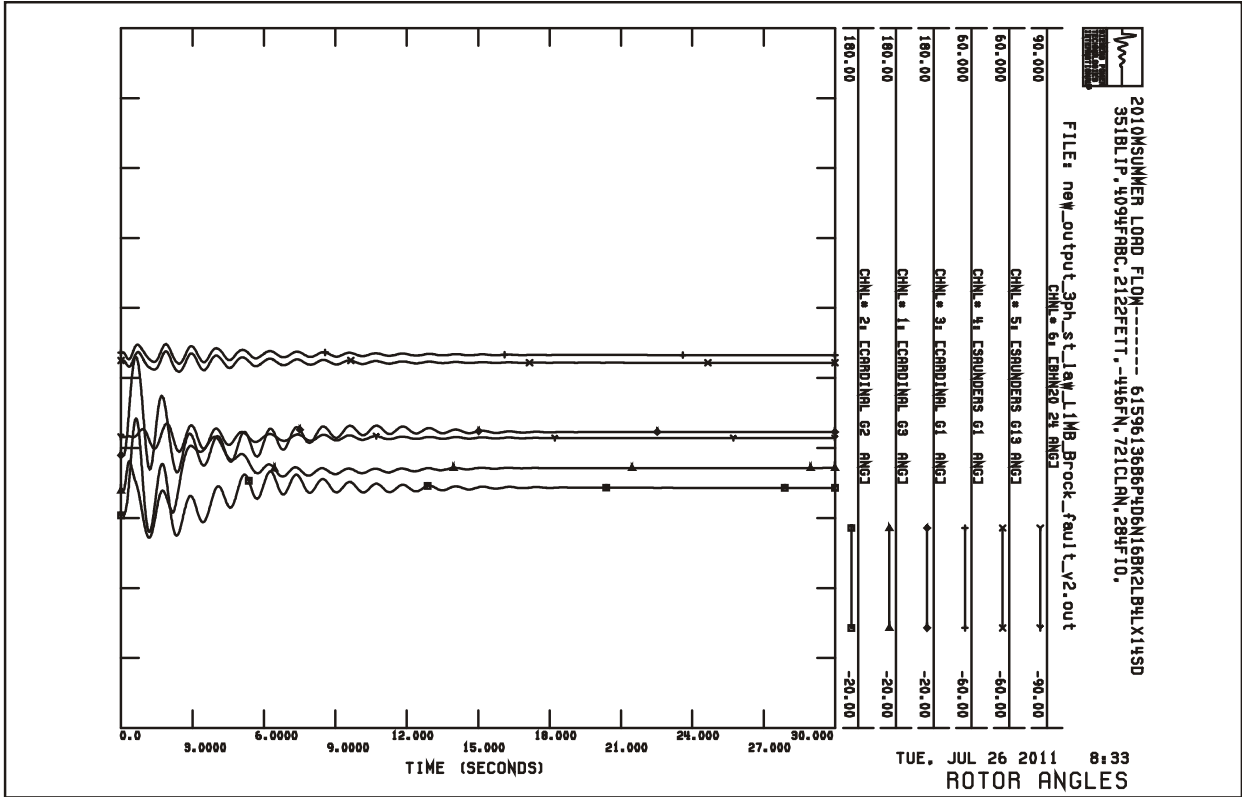
Category	Generation facility directly connected to the IESO-controlled grid, generation facility greater than 50 MW, or generation unit greater than 10 MW shall have the capability to:
1. Off-Nominal Frequency	Operate continuously between 59.4 Hz and 60.6 Hz and for a limited period of time in the region above straight lines on a log-linear scale defined by the points (0.0 s, 57.0 Hz), (3.3 s, 57.0 Hz), and (300 s, 59.0 Hz).
2. Speed/Frequency Regulation	Regulate speed with an average droop based on maximum active power adjustable between 3% and 7% and set at 4% unless otherwise specified by the <i>IESO</i> . Regulation deadband shall not be wider than $\pm 0.06\%$. Speed shall be controlled in a stable fashion in both interconnected and island operation. A sustained 10% change of rated active power after 10 s in response to a constant rate of change of speed of 0.1%/s during interconnected operation shall be achievable. Due consideration will be given to inherent limitations such as mill points and gate limits when evaluating active power changes. Control systems that inhibit governor response shall not be enabled without <i>IESO</i> approval.
3. Low Voltage Ride Through	Ride through routine switching events and design criteria contingencies assuming standard fault detection, auxiliary relaying, communication, and rated breaker interrupting times unless disconnected by configuration.
Category	Generation facility directly connected to the IESO-controlled grid shall have the capability to:
4. Active Power	Supply continuously all levels of active power output for 5% deviations in terminal voltage. Rated active power is the smaller output at either rated ambient conditions (e.g. temperature, head, wind speed, solar radiation) or 90% of rated apparent power. To satisfy steady-state reactive power requirements, active power reductions to rated active power are permitted.
5. Reactive Power	Inject or withdraw reactive power continuously (i.e. dynamically) at a <i>connection point</i> up to 33% of its rated active power at all levels of active power output except where a lesser continually available capability is permitted by the <i>IESO</i> . A conventional synchronous unit with a power factor range of 0.90 lagging and 0.95 leading at rated active power connected via a main output transformer impedance not greater than 13% based on generator rated apparent power is acceptable.
6. Automatic Voltage Regulator (AVR)	Regulate automatically voltage within $\pm 0.5\%$ of any set point within $\pm 5\%$ of rated voltage at a point whose impedance (based on rated apparent power and rated voltage) is not more than 13% from the highest voltage terminal. If the AVR target voltage is a function of reactive output, the slope $\Delta V / \Delta Q_{max}$ shall be adjustable to 0.5%. The equivalent time constants shall not be longer than 20 ms for voltage sensing and 10 ms for the forward path to the exciter output. AVR reference compensation shall be adjustable to within 10% of the unsaturated direct axis reactance on the unit side from a bus common to multiple units.

7. Excitation System	Provide (a) Positive and negative ceilings not less than 200% and 140% of rated field voltage at rated terminal voltage and rated field current; (b) A positive ceiling not less than 170% of rated field voltage at rated terminal voltage and 160% of rated field current; (c) A voltage response time to either ceiling not more than 50 ms for a 5% step change from rated voltage under open-circuit conditions; and (d) A linear response between ceilings. Rated field current is defined at rated voltage, rated active power and required maximum continuous reactive power.
8. Power System Stabilizer (PSS)	Provide (a) A change of power and speed input configuration; (b) Positive and negative output limits not less than $\pm 5\%$ of rated AVR voltage; (c) Phase compensation adjustable to limit angle error to within 30° between 0.2 and 2.0 Hz under conditions specified by the IESO, and (d) Gain adjustable up to an amount that either increases damping ratio above 0.1 or elicits exciter modes of oscillation at maximum active output unless otherwise specified by the IESO. Due consideration will be given to inherent limitations.
9. Phase Unbalance	Provide an open circuit phase voltage unbalance not more than 1% at a <i>connection point</i> and operate continuously with a phase unbalance as high as 2%.
10. Armature and Field Limiters	Provide short-time capabilities specified in IEEE/ANSI 50.13 and continuous capability determined by either field current, armature current, or core-end heating. More restrictive limiting functions, such as steady state stability limiters, shall not be enabled without IESO approval.
11. Performance Characteristics	Exhibit <i>connection point</i> performance comparable to an equivalent synchronous <i>generation unit</i> with characteristic parameters within typical ranges. Inertia, unsaturated transient impedance, transient time constants and saturation coefficients shall be within typical ranges (e.g. $H > 1.2$ Aero-derivative, $H > 1.2$ Hydraulic less than 20 MVA, $H > 2.0$ Hydraulic 20 MVA or larger, $H > 4.0$ Other synchronized units, $X'd < 0.5$, $T'do > 2.0$, and $S1.2 < 0.5$) except where permitted by the IESO.

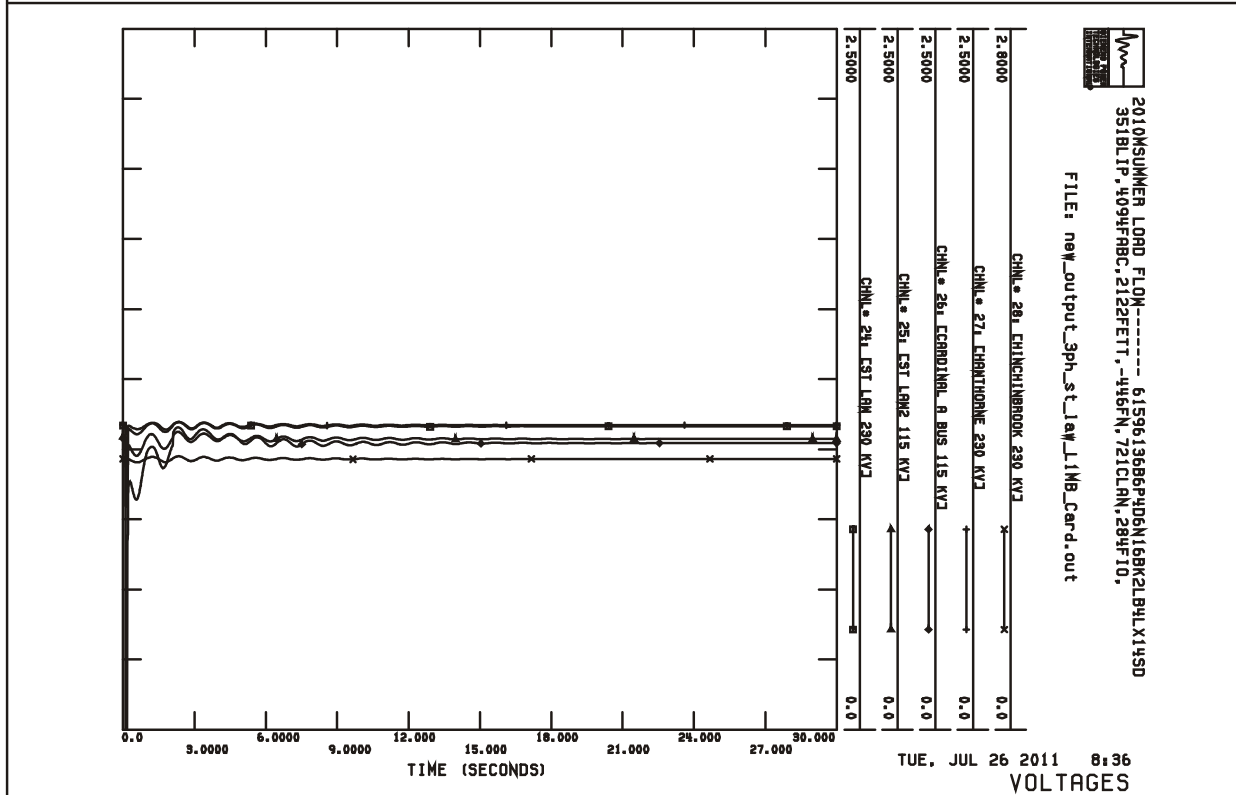
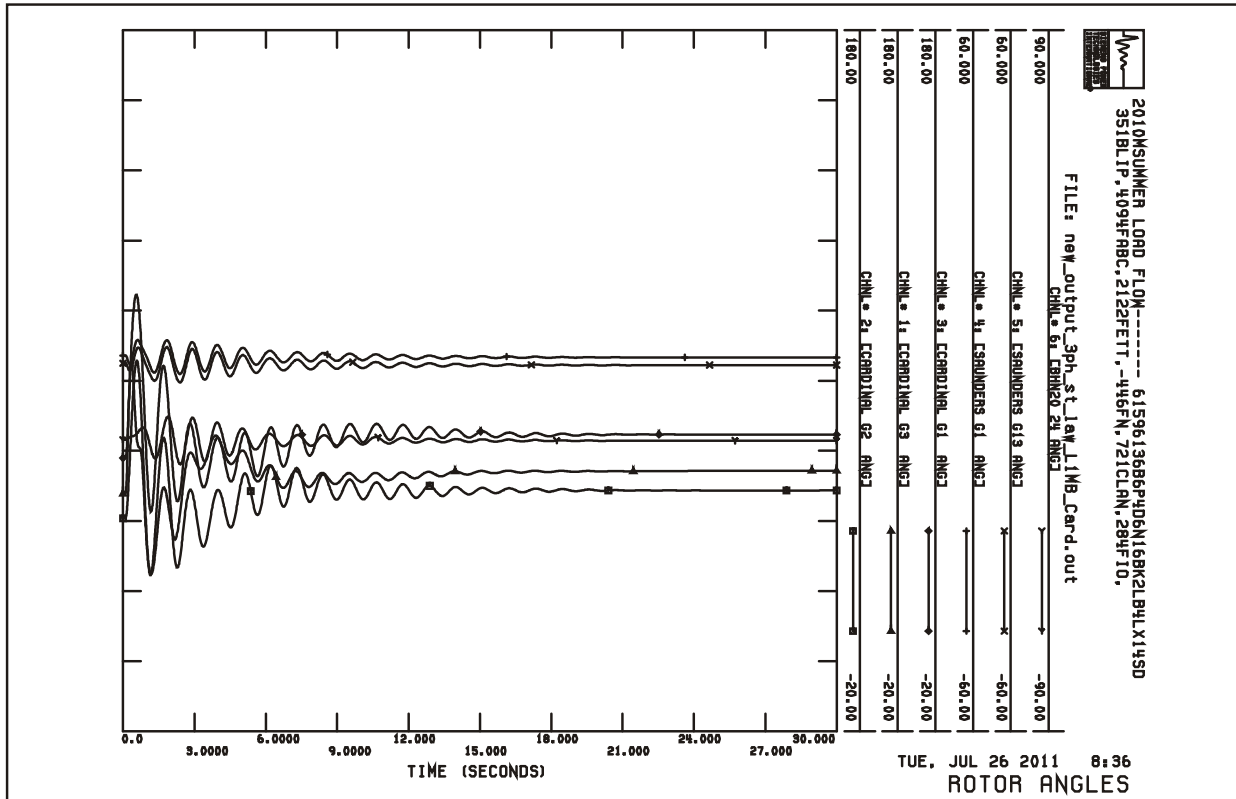
Appendix B: Diagrams for Transient Simulations



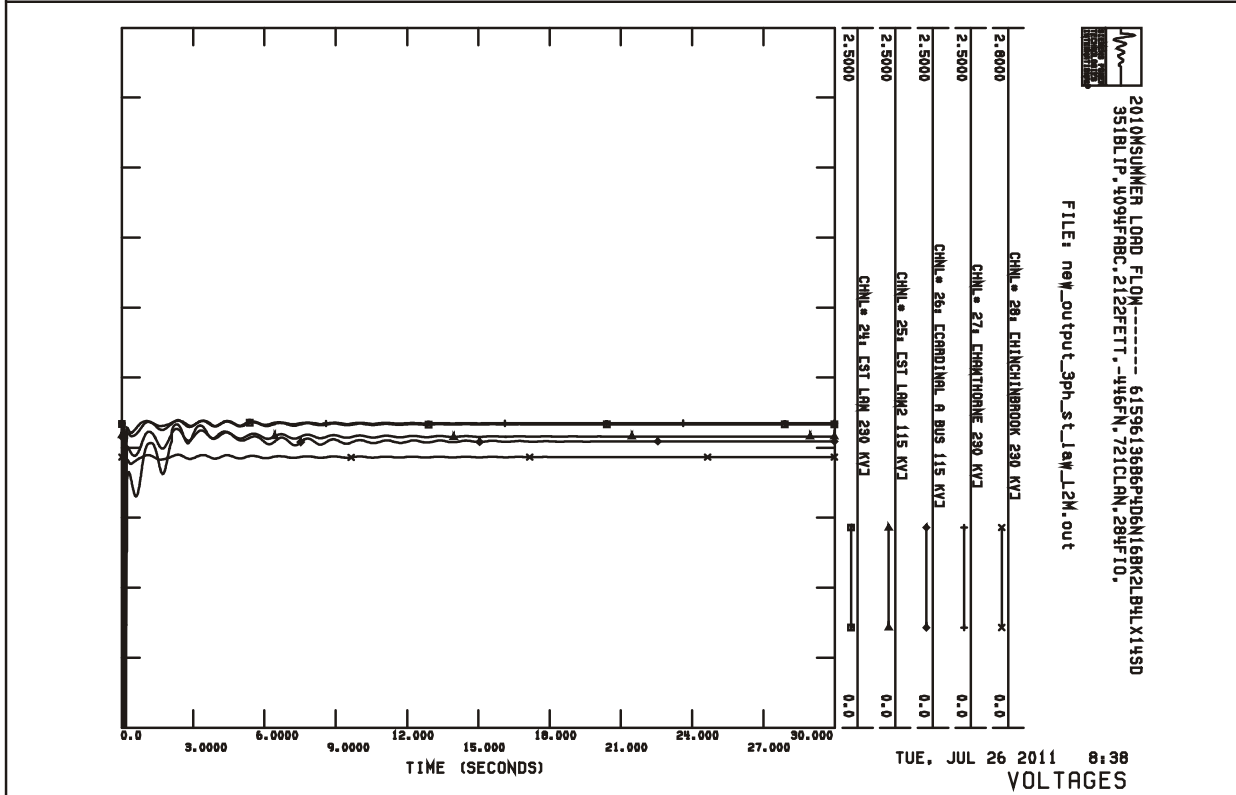
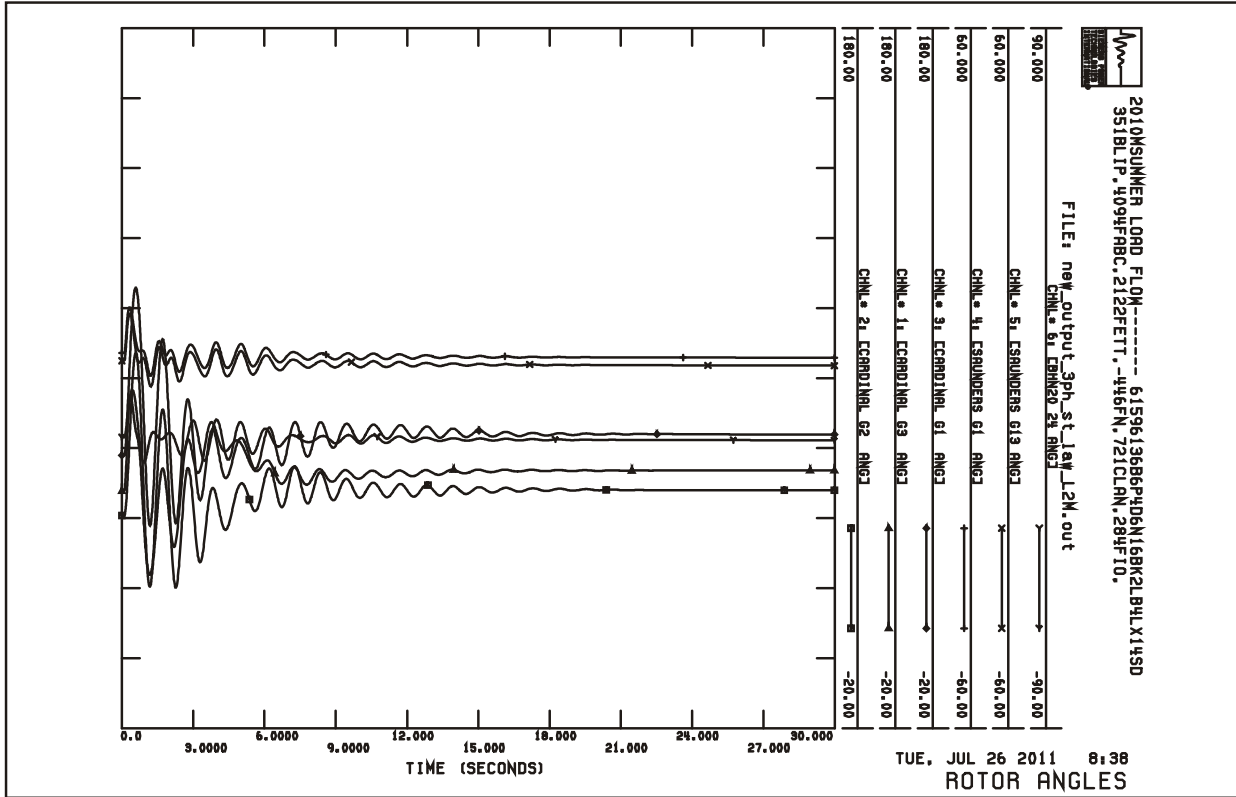
SC1- 3 phase fault on L1MB at St. Lawrence



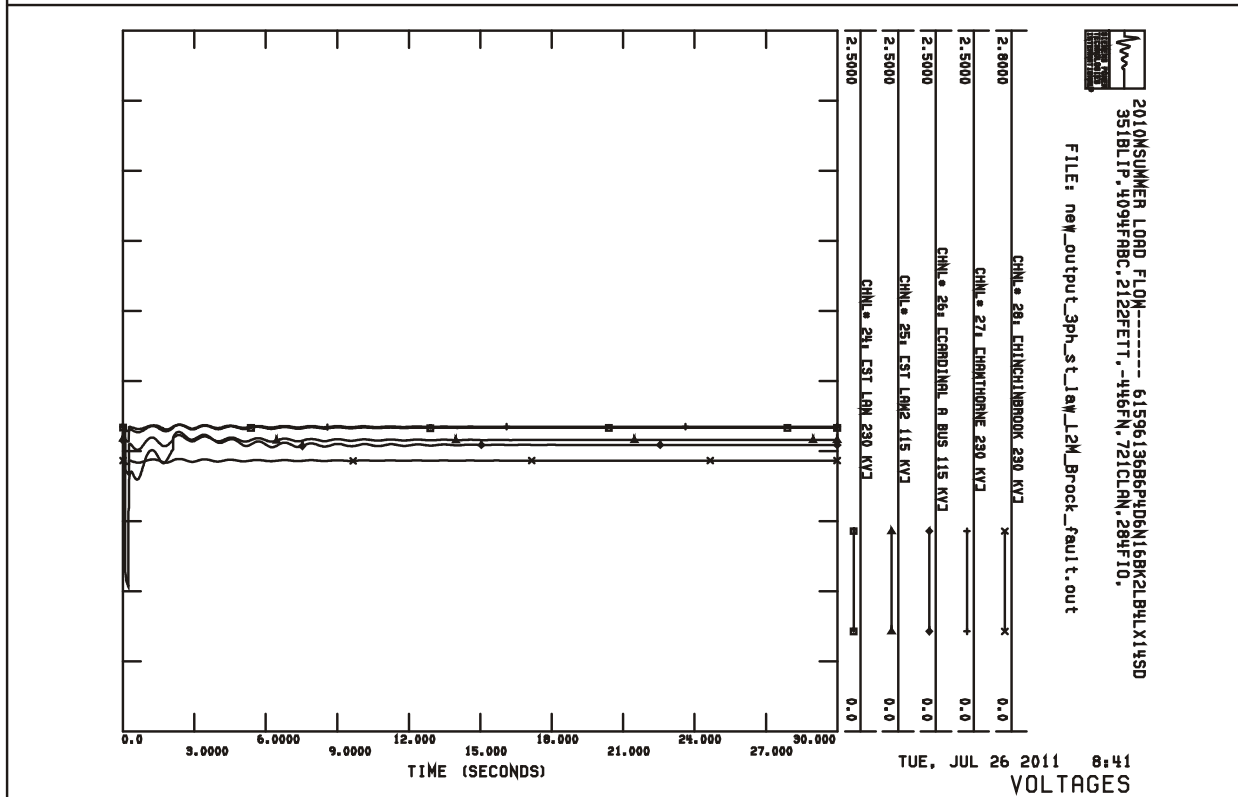
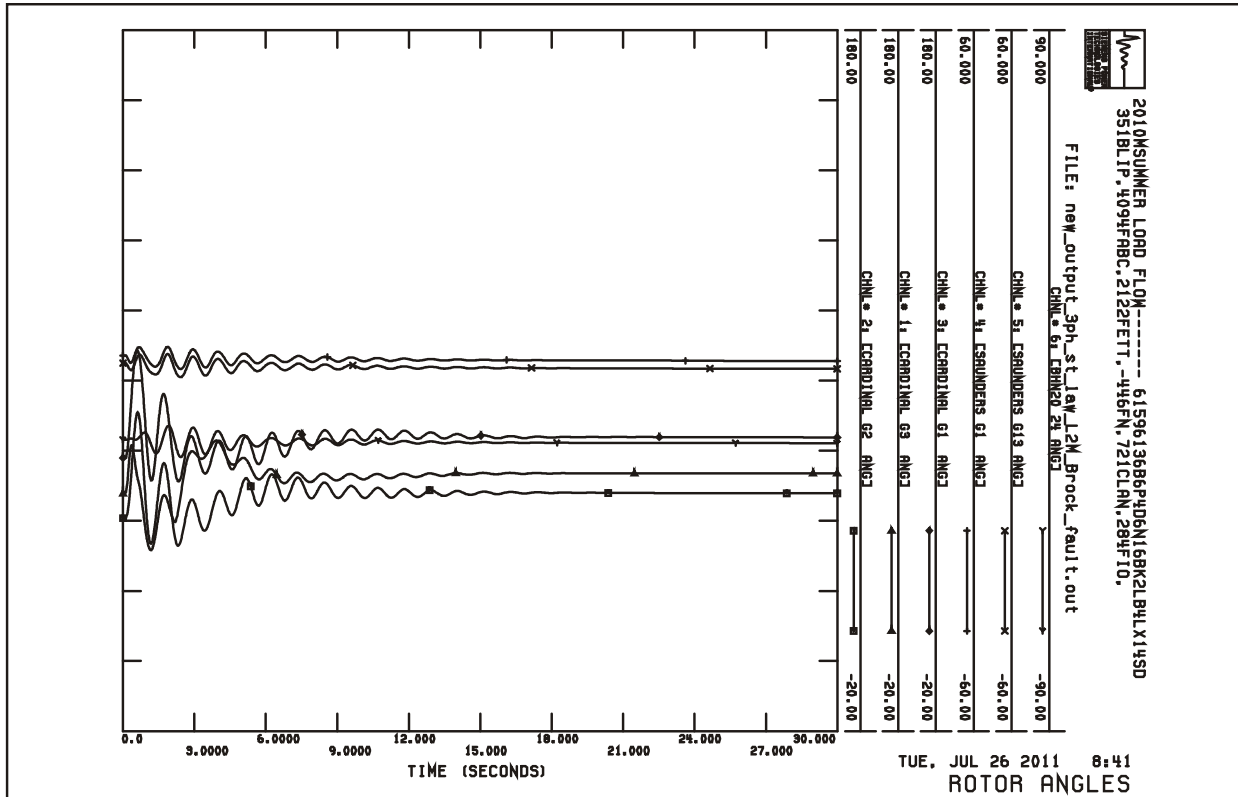
SC2- 3 phase fault on L1MB at St. Lawrence



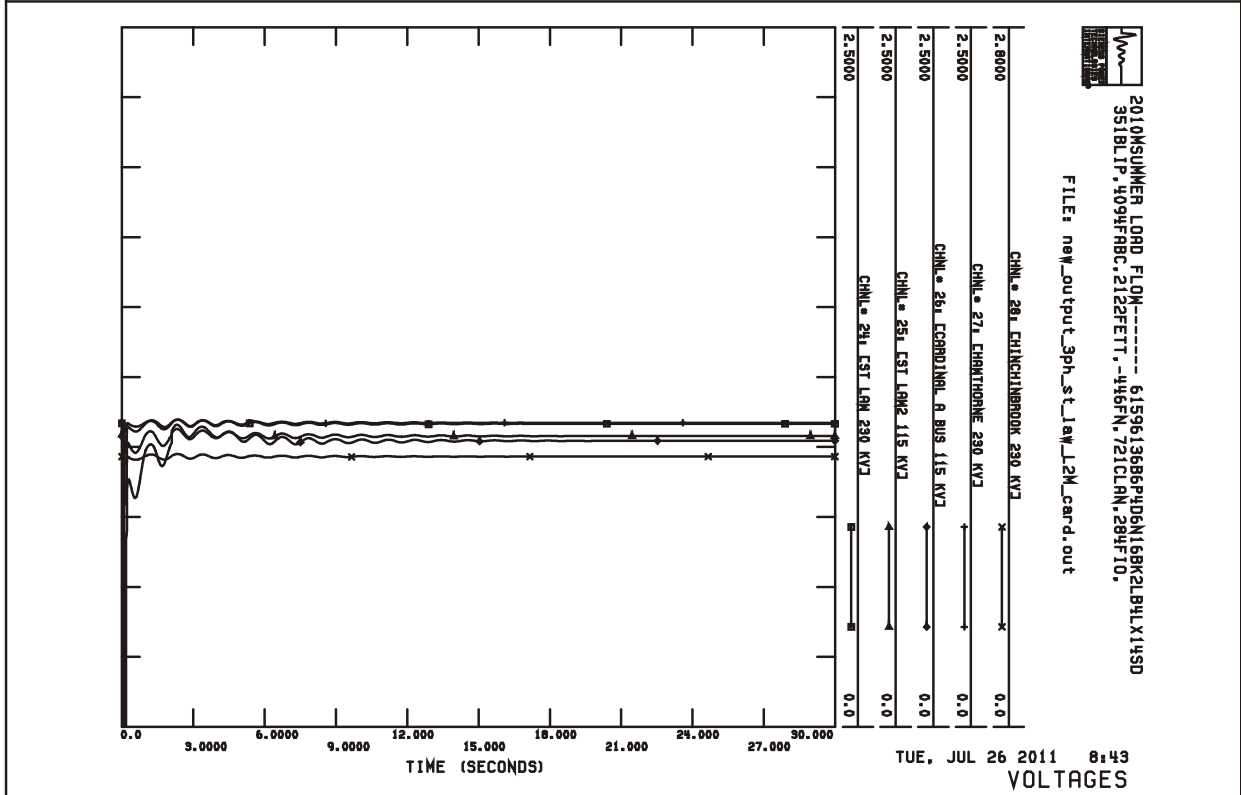
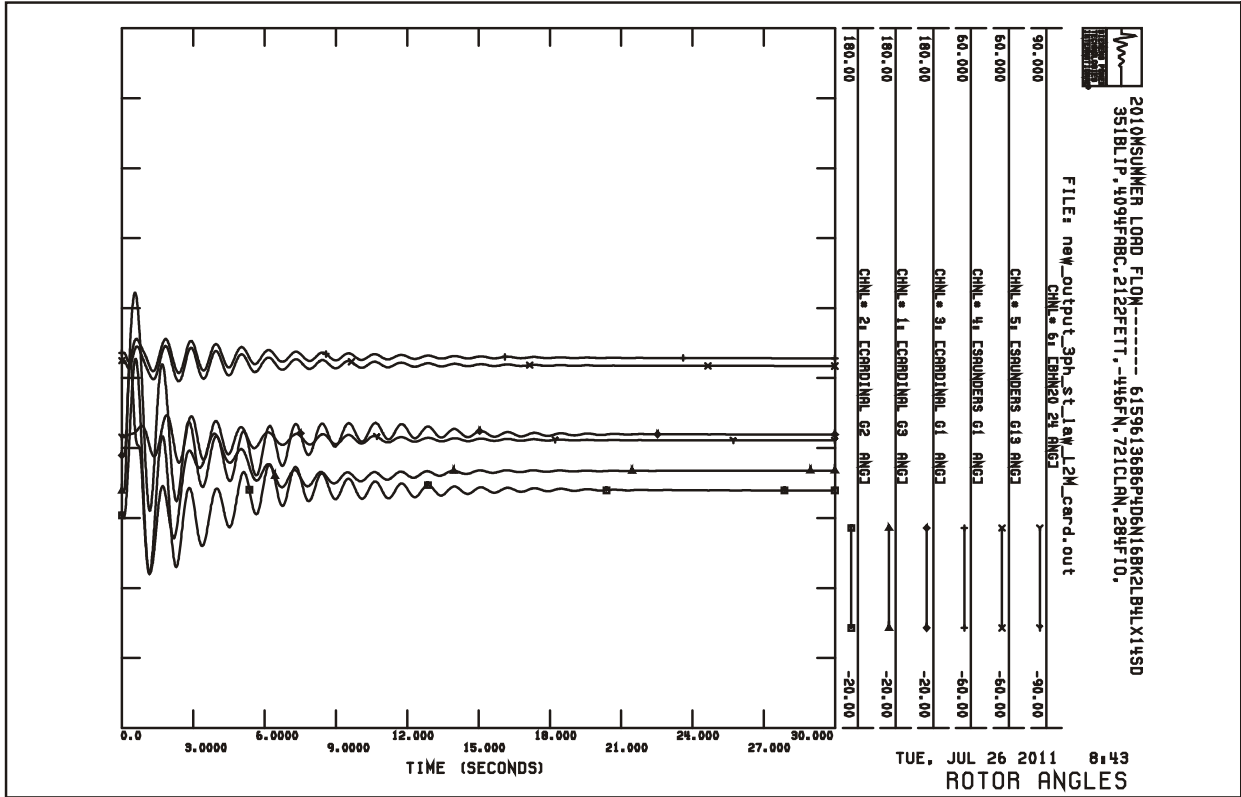
SC3- 3 phase fault on L1MB at Cardinal RSS



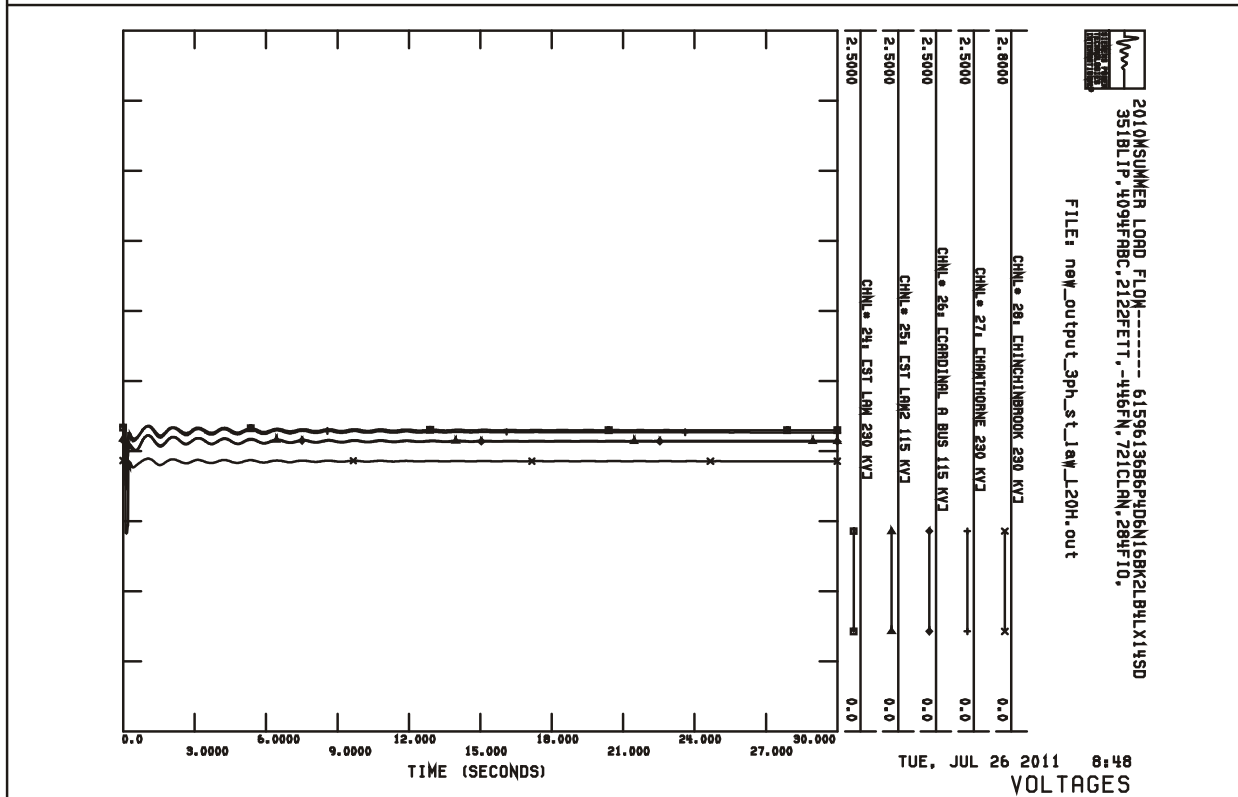
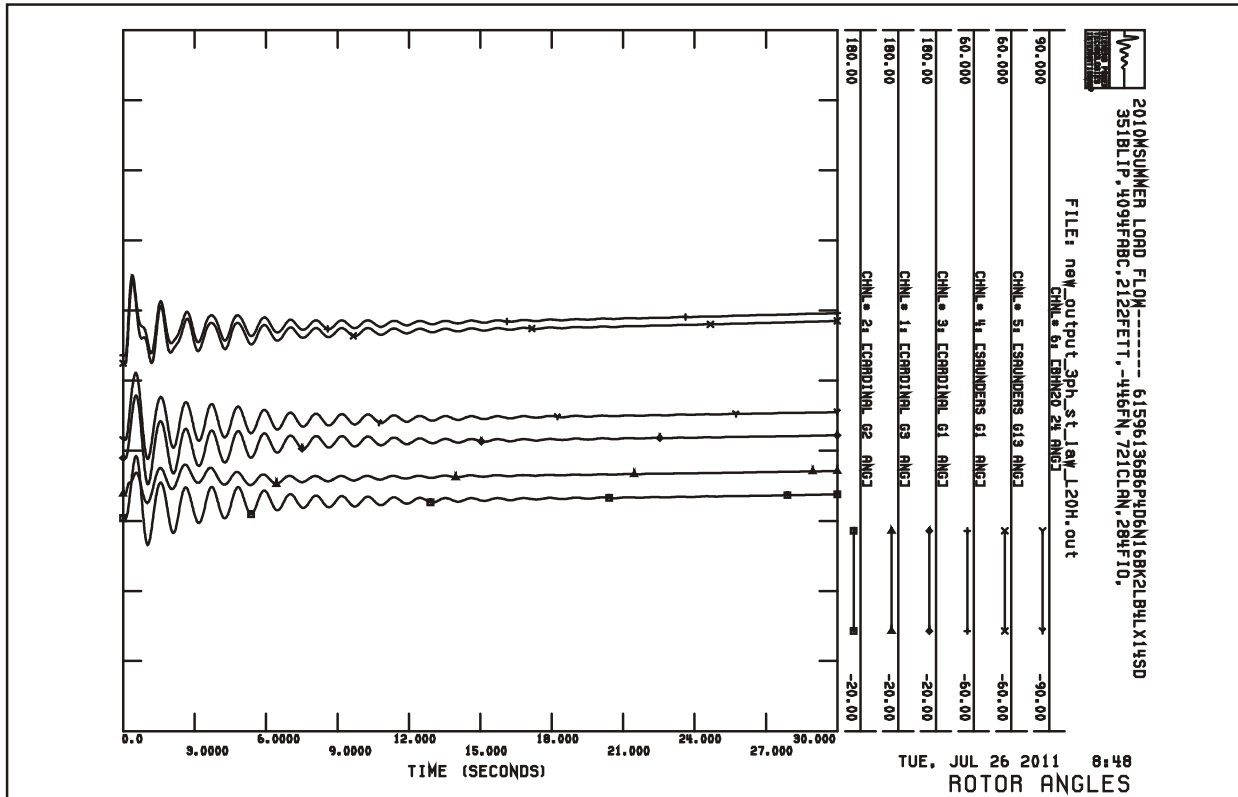
SC4- 3 phase fault on L2M at St. Lawrence



SC5- 3 phase fault on L2M at Brockville



SC6- 3 phase fault on L2M at Cardinal



SC8- 3 phase fault on L20H at St. Lawrence

Appendix C: Protection Impact Assessment



Hydro One Networks Inc.
483 Bay Street
Toronto, Ontario
M5G 2P5

PROTECTION IMPACT ASSESSMENT
CARDINAL POWER PLANT EXPANSION
15 MW GAS TURBINE
GENERATION CONNECTION

Date: June 23, 2011

Prepared by:

Hydro One Networks Inc.

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Disclaimer

This Protection Impact Assessment has been prepared solely for the IESO for the purpose of assisting the IESO in preparing the System Impact Assessment for the proposed connection of the proposed generation facility to the IESO-controlled grid. This report has not been prepared for any other purpose and should not be used or relied upon by any person, including the connection applicant, for any other purpose.

This Protection Impact Assessment was prepared based on information provided to the IESO and Hydro One by the connection applicant in the application to request a connection assessment at the time the assessment was carried out. It is intended to highlight significant impacts, if any, to affected transmission protections early in the project development process. The results of this Protection Impact Assessment are also subject to change to accommodate the requirements of the IESO and other regulatory or legal requirements. In addition, further issues or concerns may be identified by Hydro One during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with the Transmission System Code legal requirements, and any applicable reliability standards, or to accommodate any changes to the IESO-controlled grid that may have occurred in the meantime.

Hydro One shall not be liable to any third party, including the connection applicant, which uses the results of the Protection Impact Assessment under any circumstances, whether any of the said liability, loss or damages arises in contract, tort or otherwise.

EXECUTIVE SUMMARY

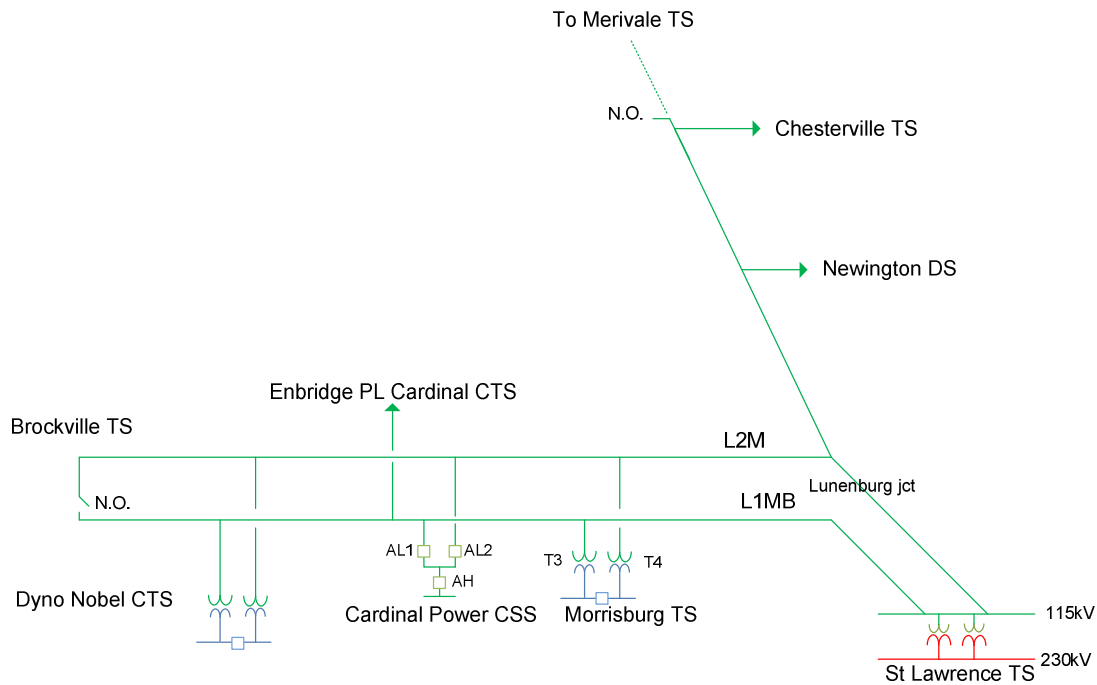


Figure 1: Cardinal Power CSS Connection to HONI Transmission System

It is feasible for Cardinal Power to expand its facility by connecting the proposed 15 MW gas turbine at the location shown in Figure 1 without modifications to Hydro One infrastructure.

PROTECTION HARDWARE

- No changes required.

PROTECTION SETTING

- No changes required.

TELECOMMUNICATIONS

- No changes required.