IMO Independent Electricity Market Operator

IMO_REP_0038

CONNECTION ASSESSMENT & APPROVAL PROCESS

System Impact Assessment Report For Niagara-Nanticoke Area Cluster

273 MW New Generation at Thorold by Northland Power
CAA ID Number 2000-003

990 MW Interconnection Across Lake Erie by TransÉnergie US and HydroOne Inc.
CAA ID Number 2000-017

Final Report

Long Term Forecasts & Assessments Department & Consistent Information Set Department

March 13, 2002

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System Impact Assessment Report

Acknowledgement

The IMO wished to acknowledge the assistance of Hydro One Networks Inc. (HONI) in completing this assessment.

Disclaimers

IMO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the *IMO-controlled grid* would have an adverse impact on the reliability of the integrated power system and whether the IMO should issue a notice of approval or disapproval of the proposed connection under Chapter 4, section 6 of the *Market Rules*. This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. In particular, this report does not address any other Market-related, or any commercial, aspects of the connection proposal.

This report has been prepared solely for use by the connection applicant and the IMO in accordance with Chapter 4, section 6 of the *Market Rules*. The IMO assumes no responsibility to any third party for any use, which it makes of this report. Any liability which the IMO may have to the connection applicant in respect of this report is governed by Chapter 1, section 13 of the *Market Rules*.

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Special Notes and Limitations of Study Results

The Results reported in this System Impact Assessment are based on the information available to HONI, at the time of the study, suitable for a System Impact Assessment of a proposal for a new generation connection.

The short circuit and thermal loading levels have been computed based on the information provided by the connection applicant at the time of the assessment. 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 are available.

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

In this System Impact Assessment, 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 ampacity rating of Hydro One facilities are established based on assumptions used in Hydro One for transmission system planning studies and in accordance with the *Market Rules*. 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 that are required to incorporate the proposed connection have been identified to the extent permitted by a System Impact Assessment under the current IMO Connection Assessment and Approval process. At more advanced stages of the project development, additional studies may identify the need for other facilities or upgrades not covered under this system impact assessment. Further studies may also be required to confirm constructability and the time required for construction.

System Impact Assessment Report

Executive Summary

This assessment examined the combined impact, on the *IMO-controlled grid* and the Ontario *interconnections* of the generating project proposed by Northland Power at Thorold in the Niagara area and the Lake Erie HVdc Interconnection project proposed by TransÉnergie US and Hydro One Inc. which will connect at Nanticoke TGS in Ontario and Erie West TS in Pennsylvania and/or Ashtabula TS in Ohio. The two projects are:

• *Thorold GS*	Installed Capacity:	348 MVA
	Actual maximum capacity:	273 MW
	In service Date:	Q3 2003
• *Lake Erie Interconnection*	Installed Capacity:	990 MW
	In service Date:	Q2 2004

Projects Incorporation Requirements

Thorold GS

Thorold GS project is to be connected to the *IMO-controlled grid* via a 400 m line tap. The line will be equipped with a HV breaker with associated manually-operated disconnect switches at the generator HV bus end, and one motorized line disconnect at the other end. This arrangement in Figure 2 meets the requirements of the Transmission System Code.

It is required that the power injected into the 230 kV circuit Q10P does not exceed at any time the continuous rating of this circuit.

Lake Erie Interconnection

The connection of the three HVdc bipoles to the Nanticoke 230 kV switchyard is to be made via six 230 kV breakers and the associated bus and station diameter work as shown in Figure 3. It is required that the installation of the first 330 MW HVdc bipole will provide four 230 kV breakers at the 230 kV Nanticoke TGS. For the subsequent stages, a new breaker has to be added with the installation of each bipole.

It is necessary to obtain and forward to the IMO the thermal rating of the Nanticoke 230 kV station buswork. The IMO will assess whether or not for certain system scenarios the buswork is adequate to support the full output of the proposed HVdc Interconnection. If certain sections of the bus work or other station equipment are found to be overloaded for all station elements in service or one element out of service then, the applicants will be required to initiate and undertake work to replace these station equipment and coordinate this work with Hydro One Networks Inc.

Generation Rejection/Run-Back Requirements

Thorold GS

To address the possible overloading of the 230 kV circuits out of Beck2 GS under conditions of high QFW it is required that an automatic generation rejection or run-back scheme be installed at Thorold GS. The scheme is required to trip up to three units for a double contingency or for a single contingency under outage conditions.

Lake Erie Interconnection

To address the possible overloading of the 230 kV circuits into Burlington (for import case) and out of Beck2 GS (for export case), it is required that an automatic run-back scheme be installed on each of the three Lake Erie Interconnection HVdc bipoles.

Impact on Fault Levels

Thorold GS

Studies show that Thorold GS contributes up the 2.76 kA to the short circuit currents at Beck2 bus, thus bringing the fault currents very close to the interrupting capability of the existing breakers.

Because with Thorold GS, the fault levels at Beck2 GS are very close to the interrupting capability of the breakers it is required that Northland Power consider mitigating measures, such as ungrounding the step-up transformers or installing transformers with higher impedance. This will ensure that the Thorold GS development does not create fault levels exceeding equipment capability. It is required that the short circuit studies be repeated after test measurements for the transformers and generators at Thorold GS are available from Northland Power Inc..

Lake Erie Interconnection

Studies show that the Lake Erie HVdc Interconnection contributes up the 6.3 kA to the short circuit currents at the Nanticoke 230 kV bus, thus bringing the fault currents above the interrupting capability of the existing breakers.

It is required that TransÉnergie US Ltd. and Hydro One Inc., implement one of the following two options for reducing the line-to-ground fault currents at Nanticoke TGS:

- Install at least 5.0 ohms neutral reactors on the Nanticoke G2 step-up transformer T2 (this initiative is to be coordinated and approved by OPG) and on all three of the HVdc converter transformers, or
- Unground the 230 kV side of the converter transformers to eliminate the contribution of the interconnection to the fault levels in the area.

It is required that the short circuit studies be repeated after test measurements for the converter transformers are available from the applicants.

Requirement for Transient Performance

Thorold GS

The generator exciter model and data provided by Northland Power Inc. showed that the excitation system has a ceiling voltage of 428 V. The value of the exciter ceiling voltage is below the requirement of the *Market Rules* of 2.0 pu. It is therefore required that the excitation system ceiling voltage be raised.

Northland Power Inc. will be responsible for ensuring that the equipment that is eventually installed meets or exceeds the performance shown in the current transient stability studies, hence the equipment dynamic models and parameters should be close or better than those assumed in this report.

If Northland Power Inc. decides to change the station design or modify the connection point to the system, then they must submit detailed information about the proposed connectivity arrangement, all the data related to the connection facilities, generator and generator controls, to the IMO. The IMO will perform the necessary detailed system impact studies, report on the findings and any required measures for mitigating the system impact.

Lake Erie Interconnection

TransÉnergie US and Hydro One Inc. will be responsible for ensuring that the equipment that is eventually installed meets or exceeds the performance shown in the current transient stability studies, hence the equipment dynamic models and parameters should be close or better than those assumed in this report.

Requirement for Reactive Support

Lake Erie Interconnection

The study results indicate that each HVdc converter is required to have a reactive power producing capability of 130 MVars on the LV ac side to meet the steady state system performance requirements.

Requirements for Subsynchronous Resonance Studies

Lake Erie Interconnection

The IMO requires that TransÉnergie US and Hydro One Inc. initiate studies to identify whether or not subsynchronous torsional interactions would exist between the turbine and the HVdc controls. These studies should be performed after the design of the HVdc converter and control models is finalized. If these studies indicate the presence of subsynchronous interactions then, special controls must be designed to alleviate the problem.

Customer Impact Assessment (CIA) Findings

Thorold GS

The results of the CIA carried out by Hydro One networks Inc. concluded that:

- the plant does not adversely impact the local voltage performance in the Beck-Allanburg area under system disturbances,
- the plant contributes a 25% increase in the short circuit level at the customer connection points at Donohue CTS and,
- the plant is not expected to materially reduce the reliability of supply to the stations and the connected customers supplied from the circuits Q10P, Q26A, and Q32A.

Hydro One Networks Inc. believes that the increased short circuit levels are below the Donohue CTS breakers' interrupting capability, but strongly recommends that this equipment capability be verified.

Northland Power Inc. is required to initiate work needed to verify the short circuit rating of the interrupting equipment at Donohue CTS. If it is found that the breakers are inadequate, it is required that the Northalnd Power Inc. initiate and carry out the work for equipment upgrading.

Lake Erie Interconnection

Hydro One Networks Inc. provided verbal preliminary findings of the impact of the new proposed Interconnection on the existing connected customers in the Nanticoke area.
Hydro One Networks Inc. has indicated that the CIA study did not identify a major impact on customer voltages or significant increase in short circuit levels at the HV point of customer connection.

Cost Estimates

Hydro One has provided budgetary cost estimates for the facilities and the work that would be needed to connect each project to the *IMO-controlled grid*. These are detailed in section 14 of this report.

Identification of "Sole Beneficiary"

Those facilities that are triggered by, and deemed to be for the sole benefit of each project have been identified in section 15 of this report.

Notification of Approval

It is recommended that the *Notification of Approval* be granted to each of these projects, subject to the implementation of the respective requirements stipulated in this report.

1.0 Introduction

This report presents the results of the study performed to identify the combined impact on the *IMO-controlled grid* and the Ontario interconnections of the generating project proposed by Northland Power at Thorold in the Niagara area, and the Lake Erie HVdc Interconnection project proposed by TransÉnergie US and Hydro One Inc., which will connect Nanticoke TGS in Ontario and Erie West TS in Pennsylvania and/or Ashtabula TS in Ohio. The two projects are:

• Thorold GS	Installed Capacity:	348 MVA
	Actual maximum capacity:	273 MW
	In service Date:	Q1 2003
• Lake Erie Interconnection	Installed Capacity:	990 MW
	In service Date:	Q2 2004

2.0 Details of Each Project

The main details regarding the locations and connection arrangements of each project are provided in the sections below. The approximate geographical location of the new projects and a schematic diagram of the transmission system in the area of the proposed connections are shown in Figure 1.

2.1 Thorold GS

Northland Power Inc. proposes to construct a new generating facility of 348 MVA located on the Donahue site in Thorold. The generation facility will consist of two gas-turbine units and one steam turbine unit, each rated at 116 MVA. It is proposed to connect the new generating units to the transmission system via a 230 kV tap off the 230 kV circuit Q10P in the proximity of the Donahue complex. The proposed project will be connected to the single circuit line Q10P, which is normally supplied from the 230 kV line Q32A or alternatively supplied from the 230 kV line Q26A.

The proposal is to connect each generator unit through a step-up transformer, and a HV breaker to a new 230 kV bus. The new 230 kV bus will be connected to the existing system through a HV breaker, a 400 meter line and a disconnect switch designated as 89-LI-Q10P-X.

Northland Power provided with their SIA Application typical summer and winter capacity numbers for the proposed development. The information, which is summarized below in Table 1, indicates that the maximum net power output to the system for this development is estimated not to be higher than 273.2 MW.

Table 1. Typical Summer and Winter Operation of Thorold Co-generation Project

Summer and Winter Operation of Thorold GS				
	Summer (30^0 C)		Winter(-10^0 C)	
	Maximum	Normal	Maximum	Normal
Mill Load	0	46	0	46
Gas Turbine Output (MW)	148.7	148.7	189.8	189.8
Steam Turbine Output (MW)	81.4	99	89.5	100.9
In Plant Load (MW)	5.8	6.8	6.1	6.7
Net Power (MW)	**224.3**	**240.9**	**273.2**	**284**
Abitibi Mill Load (MW)	0	46	0	46
Net Output (MW)	**224.3**	**194.9**	**273.2**	**238**

Figure 2 shows the configuration of the proposed facilities the connection onto the circuits Q32A and Q26A and the data associated with the generators and the step-up transformers.

After the completion of this SIA study Northland Power indicated that they consider a second option for the generation project at Thorold. The second option is to install one gas-turbine generator rated 212 MVA instead of the two 116 MVA gas-turbine generators proposed in the original connection application. The steam turbine generator remains unchanged.

Northland Power Inc. has provided some information for the new connection including typical data for the step-up transformer and generator typical parameters and control models. A "back of the envelope" type comparison was carried out between the two connection options with respect to the impact on the system short circuit levels. It was concluded that the contributions of each of the two options to short circuit levels are comparable.

If Northland Power Inc. decides to install one larger gas-turbine generator, then they must submit detailed information about the proposed connectivity arrangement, all the data related to the connection facilities, generator and generator controls, to the IMO. The IMO will perform the necessary detailed system impact studies, report on the findings and any required system impact mitigating measures.

2.2 Lake Erie Interconnection

The proposed connection arrangement that was submitted by TransÉnergie US and Hydro One Inc. with their System Impact Assessment application is shown in Figure 3. In the initial stage a single 330 MW HVdc link will be connected via a 230 kV in-line breaker onto a *new diameter* at Nanticoke TGS. In the ultimate configuration a total of three HVdc bipoles are proposed to be connected in parallel to Nanticoke TGS. This arrangement means that each converter will be connected between two breakers onto the new station diameter. Any fault on one of the converter can be isolated while keeping the remaining two converters in service. The largest recognized contingency will be the loss of two bipoles for a stuck breaker condition on one of the new breakers.

3.0 Preliminary Assessments Summary

As a first step in the Connection Assessment and Approval Process both projects were the subject of Preliminary Assessments that were performed by the IMO. For each project a Preliminary Assessment Report was produced that identified the impact of the particular project on the reliability of the local area transmission system. Appendix A contains a summary of the recommendations included in each project's PA report.

4.0 System Impact Assessment - Study Assumptions

All studies were performed for the existing system configuration, together with any facilities that have already been approved by the IMO. However, for certain areas of this assessment, if it was found that the system capability was exceeded with the Thorold project incorporated and with selected mitigating measures implemented, sensitivity studies were performed to evaluate the impact of Pickering A generation, Sarnia-Windsor cluster of generators and Sithe cluster of generators. These sensitivity studies were necessary because the Thorold project CAA queue position places this project ahead of the projects included in the two above mentioned clusters.

The list below constitutes the "maximum facilities scenario" implemented in the basecase model used in this system impact assessment. All the IMO approved facilities listed below have been subject to a "project progress survey". The results of these surveys indicated that the projects are in progress. These projects are:

- Sithe Goreway generation project,
- Sithe Mississauga generation project,
- Pickering A generation in service and Bruce A out of service
- Ontario Quebec Interconnection at Hawthorne,
- Richmond Hill MTS #2,
- Vaughan MTS #3,
- TransAlta project in Sarnia,
- ENRON Project in Sarnia,
- AES Project near Leamington, and
- ATCO project in Windsor.

5.0 Local Impact Concerns

Following the Preliminary Assessment for the Lake Erie Interconnection, it became apparent that the addition of HVDC bipoles connected to Nanticoke 230 kV switchyard will result in an increase in the power flowing through the station equipment. An additional 990 MW of power will be flowing through the Nanticoke 230 kV station equipment. Using the available station equipment ratings, a verification was carried out to identify whether or not the possible maximum continuous power flow would exceed the continuous equipment rating.

Diagram A shows the maximum power that would be flowing through the station for one critical breaker out of service, with all generation and the HVdc bipoles in service. The calculations show that the continuous rating of the station breakers is high enough (4000 A) to sustain maximum power flows without any risk for damage.

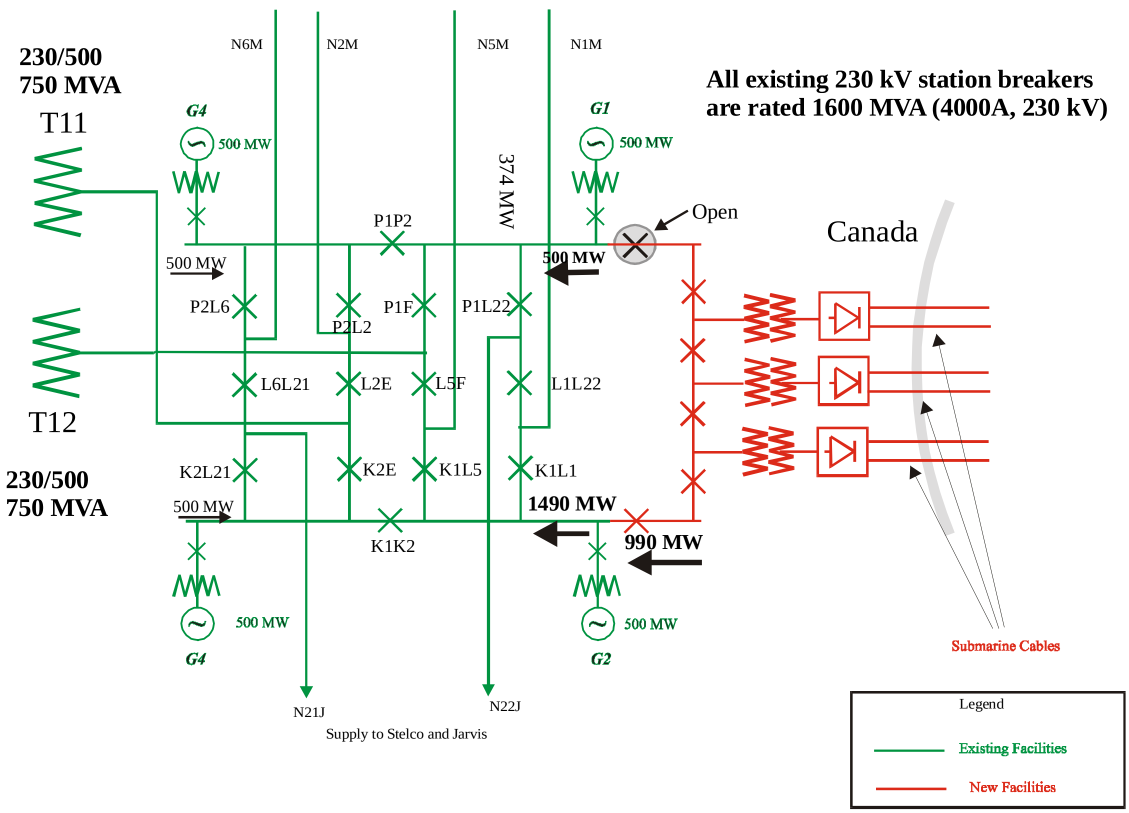


Diagram A. Nanticoke 230 kV - Power Flows Maximum Import & Generation

At this time, the rating of the station bus work is not available, hence an assessment of its thermal adequacy could not be made.

The applicant is required to obtain and forward to the IMO the thermal rating of the Nanticoke 230 kV station bus work. The IMO will assess whether or not for certain system scenarios it is adequate to support the full output of the proposed HVdc Interconnection. If certain sections of the bus work or other station equipment are found to be overloaded for all station elements in service or one element out of service then, the applicants will be required to initiate and undertake work to replace these station equipment and coordinate this work with Hydro One Networks Inc.

6.0 Impact on System Power Transfer Capability

It should be noted that the Preliminary Assessments (PA) carried out for each project included results of linear power flow analysis performed to identify the impact of the proposed project on the power transfer capability in the local area, the main transmission interfaces and interconnections in Ontario. The Preliminary Assessments concluded that each of the proposed developments does not reduce the power system transfer capability, but contributes to the increase in congestion over particular transmission interfaces.

This SIA focussed on the cumulative impact of the two projects on the transfer capability of the affected transmission interfaces and the Ontario interconnections.

6.1 Assumptions

6.1.1 Circuits Thermal Capability

The assumptions used in arriving at the thermal limits for the 230 kV circuits in the area surrounding the proposed projects and a table of thermal limits for these circuits are included in Appendix B attached at the end of this report.

6.1.2 Interface Power Transfer Capabilities

When in full operation, the two new projects influence the power transfers on a number of transmission interfaces. The interfaces that have been monitored in the studies and the associated power transfer limits are described below and are shown in Figure 4.

6.1.2.1 Queenston Flow West (QFW)

The QFW interface consists of five 230 kV circuits, namely Q30M, Q29HM, Q25BM, Q24HM and Q23BM. It is assumed for this assessment that the power transfer on this interface is limited to the present planning limit of about ***2000*** MW in the winter and ***1800*** MW in the summer due to post-contingency thermal ratings of the circuits.

However, in real-time operations the QFW limit is established on the basis of real-time readings of temperature, wind, illumination and status of critical transmission elements (i/s or o/s). QFW can vary, as indicated by historical records shown in Diagram 2, between 2600 MW and as low as 1500 MW or 1000 MW. It should be noted that the same records indicate that the QFW limit was between 2200 MW and 1400 MW for 95% of the summer time.

6.1.2.2 Flow into Middleport 230 kV (FIM)

FIM is the flow from Nanticoke TGS on N1M, N2M, N5M and N6M into the Middleport 230 kV station. The PA studies determined that the power flow on this interface with all elements in service is limited to around ***2047*** MW for the summer months. Again, in real-time operating this limit may vary with weather and system conditions.

6.1.2.3 Flow East into Burlington 230 kV (FEIB)

FEIB is the flow into Burlington TS on the 230 kV circuits M27B, M28B, Q25BM, Q23BM B18H and B20H from Middleport TS. The PA studies determined that the power flow on this interface with all elements in service is limited to around ***1654*** MW for the summer months.

6.2 Contribution of Each New Development to the Interface Flows

A PTI linear analysis study was performed to determine the distribution of the power over the main Ontario transmission interfaces and interconnections when the power injected by the proposed developments is displaced with generation from various parts of the interconnected system. Table 3 below summarizes the Transmission Distribution Factors for the generation shifts indicated in the first row of the table.

Table 3. Generation Shift Factors with all elements in service for each Project

Interface	***Location of generation displaced by the Thorold GS (224.3 MW)***						
	Beck 1	Pickering	Nanticoke	Lambton	Lennox	NY-Roseton	Michigan
BLIP	Negligible	-0.11	-0.117	0.65	0.086	0.2	0.52
NY@Niag		0.24	0.20	0.36	0.273	0.65	0.41
Mi-Ont		-0.107	-0.12	-0.34	-0.086	0.2	0.52
FETT		0.87	-0.086	-0.020	0.813	0.153	0.026
QFW		0.76	0.79	0.63	0.727	0.35	0.544
FIM		-0.09	-0.583	-0.071	-0.09	-0.042	-0.066
FEIB		0.39	0.111	0.155	0.338	0.119	0.147
Interface	***Location of generation displaced by the Lake Erie Interconnection***						
	Beck 1	Pickering	Nanticoke	Lambton	Lennox	NY-Roseton	Michigan
BLIP	0.119	0.011	Negligible	0.772	0.116	0.326	0.701
NY@Niag	-0.207	0.03		0.16	0.221	0.438	0.207
Mi-Ont	0.119	0.011		-0.228	0.116	0.326	0.701
FETT	0.088	0.956		0.072	0.662	0.237	0.095
QFW	-0.793	-0.03		-0.16	-0.221	-0.438	-0.207
FIM	0.583	0.491	1.0	0.512	0.511	0.541	0.517
FEIB	-0.111	0.282	Negligible	0.044	0.151	0.008	0.036

6.3 Analysis of the Cumulative Effect of the Two Projects

The results of the Preliminary Assessments of these two projects indicate that under summer peak load and generation dispatch conditions, both developments would contribute to power flow congestion.

The purpose of the present analysis is to assess the cumulative effect of these projects on the power flowing on the selected transmission interfaces and give the connection applicants an indication of system conditions under which congestion may appear.

Two scenarios were chosen for this analysis. The first scenario (**A**) assumed Thorold generation at full summer output (224.3 MW), Abitibi Mill load off and maximum *import* over the Lake Erie Interconnection (990 MW). The second scenario (**B**) considered Thorold generation at full summer output (224.3 MW), Abitibi Mill load off and maximum *export* over the Lake Erie Interconnection (990 MW). The results of this analysis are included in Table 4 below.

Table 4. Congestion Analysis

Interface	Gen Shift for Thorold	Gen Shift for Lake Erie	Thorold Contribution (MW)	Lake Erie Contribution (MW)	Total Contribution (MW)
Lake Erie IMPORT CASE					
BLIP	Lambton	Lambton	148	764	**912**
Ont-NY	Roseton	Roseton	146	434	**580**
Mi-Ont	Michigan	Michigan	116	694	**810**
FETT	Pickering	Pickering	196	946	**1142**
QFW	Nanticoke	Lambton	177	-158	**19**
FIM	-	Beck	-	574	**574**
FEIB	Pickering	Pickering	87	279	**366**
Lake Erie EXPORT CASE					
Neg.BLIP	Nanticoke	Lambton	26	768	**790(east)**
Mi-Ont	-	Michigan	0	694	**694(east)**
QFW	Nanticoke	Roseton	177	433	**610**

For situations of import over the proposed Lake Erie Interconnection, significant flow congestion would appear on the Flow East Towards Toronto Interface when Pickering generation is reduced. The calculation that was performed to determine an approximate percentage of time when congestion could occur on FETT interface, used year 2001 actual distribution of the FETT power flow and transfer limit. The results show that the FETT interface could experience congestion, over the year, *for up to 15% of the time* with both projects in service and at full output. FETT records for year 2001 are shown below in Diagram B.

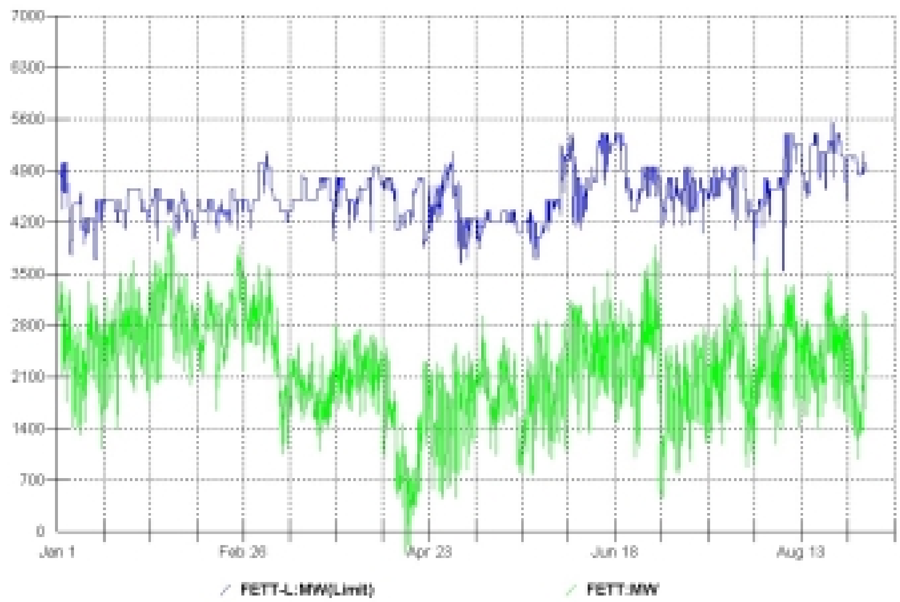
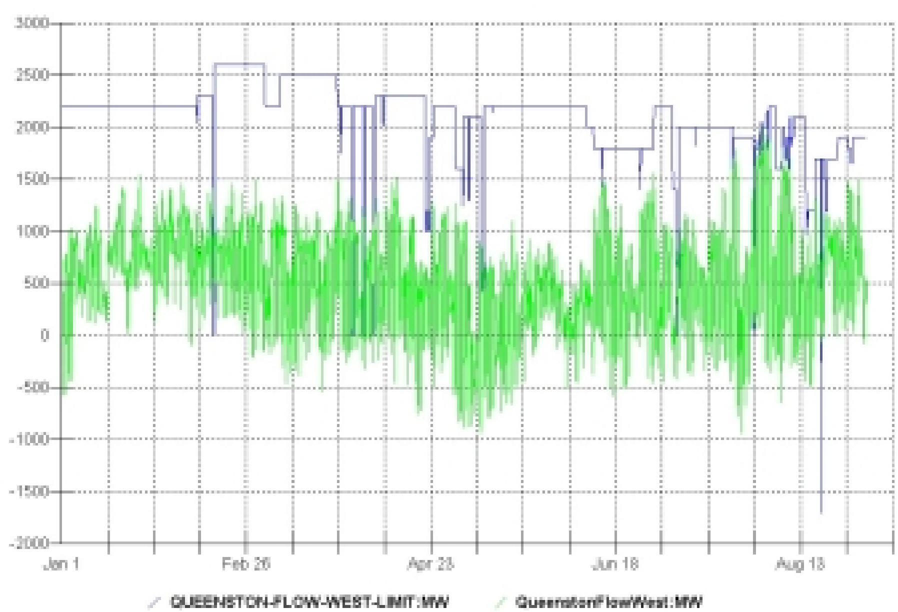


Diagram B. FETT 2001 Records

For conditions of export over the Lake Erie Interconnection significant congestion could appear on the Queenston Flow West when Thorold generation and Lake Erie export are at full output and displace Nanticoke GS and Roseton generation in New York, respectively. It should be noted that in this case the power circulating over the Ontario-Niagara interface could increase by about 480 MW (.2*224+.438*990) and thus affect the QFW flow. This situation could result on an increase of about 610 MW on the QFW interface. Historical records of QFW power flows, for year 2001 are shown in Diagram C.

Diagram C. QFW 2001 Records



An analysis was carried out to evaluate an approximate percent of time when the QFW was within 610 MW of the interface limit. Only the three summer months of 2001 were selected for this analysis. It was estimated that for conditions similar to the summer of 2001 with Thorold generation at maximum output and 990 MW export on the Lake Erie Interconnection, the power flow on *QFW interface could be over the limit for about 15% of the three summer months*.

It should be noted that during the last two to three summers the Lake Erie power Circulation (LEC) seemed to have been lower then in previous years. For the summer of 2001 this can be attributed to the lower Beck GS output due to low water and planned outages to some of the Beck2 units. Thus, congestion on the QFW interface could occur more than 15% of summer time if conditions of maximum generation at Beck GS are present.

It can be concluded that both projects will contribute to power congestion over certain interfaces under situations of peak demand and a particular generation dispatch. However, the power transfer capability of the impacted transmission interfaces is not affected by the proposed developments.

In preparation for these facilities coming into service the IMO will initiate further studies which will establish in detail the system operating limits for the existing and newly defined interfaces, for all elements in service and for critical outages.

6.4 Requirements for Generation Rejection and HVdc Runback

The investigations carried out for the Thorold GS and Lake Erie Interconnection proposals identified that under system peak load conditions the Queenston Flow West Interface and 230 kV interface going into Burlington could become overloaded.

In general, for cases where an interface power transfer limit is dictated by the post-contingency thermal rating of the remaining circuits for the loss of the most critical circuit(s), it is possible to improve the interface transfer limit by adding generation or load rejection schemes.

In order to alleviate the concerns related to possible overloading of the circuits out of Beck (QFW Interface) and the circuits into Burlington (FEIB Interface) during periods of peak load conditions, the IMO requires that generation rejection and HVdc runback facilities be installed at Thorold GS and each of the three HVdc bipoles, respectively. These Special Protection Systems (SPS) are required to assure the reliability of the integrated system and also allow the new proposals to operate at maximum output most of the time during periods of high power flows or transmission facility outages. If these SPS's are not provided the output of the proposed developments may have to be limited, for particular system conditions, to ensure that thermal overloading of the subject interfaces does not occur.

Thorold GS Generation Rejection Scheme

It is required that an automatic generation rejection or run-back scheme be installed at Thorold GS which will trip up to three units for various contingency situations.

The scheme would need to initiate generation rejection (GR) for contingencies and line-end-open conditions involving the 230 kV circuits emanating out of Beck GS2, namely Q30M, Q29HM, Q25BM, Q24HM, Q23BM, Q26A, Q28A and Q32A. In addition, it could be determined through further operating studies that the GR scheme will need to be initiated for contingencies associated with the Ontario-Niagara Interconnection circuits. Furthermore, the generation rejection scheme will have to recognize outage conditions (LEO) of the local transmission facilities

This generation rejection scheme will increase the opportunity for operating the Thorold GS development at maximum output under situations of high power flows and/or transmission outage conditions.

Lake Erie Interconnection Run-back Scheme

It is required that an automatic run-back scheme be installed on each of the three Lake Erie Interconnection HVdc bipoles.

As a minimum the scheme would need to initiate run-back for contingencies and line-end-open conditions involving the 230 kV circuits going into Burlington TS, namely M27B, M28B, Q25BM, Q23BM, B20H and B18H and the 230 kV circuits comprising the Queenston Flow West Interface (Q30M, Q29HM, Q25BM, Q24HM, Q23BM). Other requirements for the initiation of the HVdc run-back scheme could be identified through further operating studies. Furthermore, the HVdc run-back scheme will have to recognize outage conditions of the local transmission facilities

6.5 Mitigating QFW Congestion – Alternative Option

This study identified measures that must be implemented by the connection applicants to maintain the reliability of the *IMO-controlled grid*. However, in general for any transmission congestion situation, the possibility exists for increasing the capability of the limiting transmission interface by adding more transmission circuits and/or raising the thermal limit of the existing circuits.

In this report the IMO is identifying that one option of resolving the QFW congestion problem would be to reinforce this particular transmission interface, but it should be noted that the IMO has not studied any options of reinforcing this transmission interface.

6.6 Comments on Lake Erie Project Staging

TransÉnergie US and Hydro One Inc. have indicated that the Interconnection project could be constructed in stages starting with one bipole and gradually adding the second and third.

It has been determined that the installation of the first 330 MW HVdc bipole will require four 230 kV breakers to be installed at Nanticoke TGS. Two of these breakers should be installed on the new 230 kV station diameter and the other two on the new bus extensions. These facilities are needed to prevent the loss of one Nanticoke unit for a fault associated with the HVdc links under stuck breaker condition.

For the subsequent stages, when the second and third bipole will be installed a new breaker must be added with every bipole.

The facilities required to be installed with every stage are shown in Figure 5.

Recently, TransÉnergie US and Hydro One Inc. have informed the IMO that they are in the process of considering an alternative connection of the three HVdc bipoles into the Nanticoke 500 kV switchyard, or a combination of 230/500 kV connection.

The IMO requires that the applicants produce all the information relevant to the 500 kV option for connection of the Lake Erie Interconnection as soon as it becomes available. As a minimum, the short circuit studies will have to be repeated for the new connection alternative. The results will be reported as an addendum to this SIA report.

6.7 Lake Erie Interconnection Reactive Power Capability

In the system model that was used for these studies, each HVdc converter was represented as a generator which was set to produce power when simulating import scenarios and to absorb power when simulating exports scenarios. For the Preliminary Assessment studies the net reactive capability of each HVdc converter was set, as recommended by the applicant, at +/-72 MVar at the high side of the ac filter bus transformer (i.e. the ac system bus) and the generators were set to control the high side bus voltage. The upper limit of the reactive range of the generators were set to 130 MVar each, in order to allow a delivery of about 80 MVar to the ac bus. This was required to compensate for reactive losses on the converter transformer. The applicant recommended this settings since the +/-72 MVar capability is as measured on the high voltage, ac system bus.

As per PA recommendation number 6, a sensitivity study was performed to identify if the reactive support provided by the three HVdc links is sufficient to maintain the 230 kV Nanticoke voltages at required levels under steady state system conditions. Load flow analysis results are included in the Table 5 below for all transmission elements and one transmission outage case.

Table 5. Nanticoke 230 kV Voltages

Nanticoke Units I/S	No HVdc		Export Case			Import Case		
All Transmission In Service	**230 kV Voltage**	**Mvar per Unit**	**230 kV Voltage**	**Mvar per Unit**		**230 kV Voltage**	**Mvar per Unit**	
		Nanticoke GS		**Nant**	**HVdc Bipole**		**Nant**	**HVdc Bipole**
None	227 kV	0	228 kV	0	130	Less critical	Less critical	
2 Units (500 kV)	238 kV	240	238 kV	215	130	238 kV	170	130
4 Units (500 kV)	240 kV	180	240 kV	165	130	240 kV	140	130
4 Units (230 kV)	246 kV	115	246 kV	115	130	246 kV	104	103
6 Units (3 @ 500 kV, 3 @ 230 kV)	247 kV	210 115	247 kV	160 105	110	247 kV	220 105	Less critical
8 Units	247 kV	210 115	247 kV	150 105	90	247 kV	230 105	Less critical
Transmission Outage Case for 6 Units In Service at Nanticoke GS								
N2M &N6M O/S	247 kV	190 Mvar 106 MVar	247 kV	160 Mvar 105 MVar		247 kV	195 Mvar 105 MVar	
N580M O/S	247.5 kV	225 Mvar 97 MVar	247 kV	170 Mvar 105 MVar		247 kV	200 Mvar 111 MVar	

It is worth noting that the results in Table 5 are for system steady state situations.
The results of these studies show that in most cases where a reduced number of Nanticoke units were in service, the HVdc converters had to produce the maximum reactive power of 130 MVars to control the voltage on the ac side.

The study was repeated for two transmission outage cases, and the results are shown in the bottom half of Table 5. It appears that even with two 230 kV circuits or one 500 kV circuit out of service a 130 Mvar reactive power producing capability for the proposed interconnection is adequate.

One observation from these load flow studies is that in none of these scenarios the HVdc bipoles were required to absorb reactive power. It is possible that for a reduced converter output, say 100 MW, the filters may need to absorb reactive power from the system to maintain the voltage at reasonable levels. However, operating the HVdc converters at reduced output may not be efficient.

Study results indicate that each HVdc converter is required to have a reactive power producing capability of 130 MVars on the LV ac side to meet the steady state system performance requirements. This MVar producing capability is required in order to ensure that the Nanticoke 230 kV voltage is maintained at adequate levels without additional reactive power requirements being imposed the Nanticoke GS units.

A requirement of reactive power absorbing capability has not yet been established, but it is believed that –85 MVars should be adequate.

A parallel could be drawn between the reactive requirements for this HVdc Interconnection and any other interconnection transmission link. Although the HVdc converters were modelled in the study as generators in reality an HVdc link is a transmission element. An interconnection is, in general, required to provide the reactive support necessary for injecting the maximum power at a particular voltage, at the point of connection. The reactive capability that is provided by each HVdc converter appears to meet this requirement.

In the SIA application the applicants have indicated that the reactive power capability of each HVdc bipole at full output will be approximately 65MVar to –85 MVar, assumed to be measured on the ac side, the 230 kV side. The upper range may not be sufficient to support a power injection or withdrawal of 330 MW.

7.0 Transient Stability Investigation

The purpose of the stability studies was to determine the performance of the new facilities and the impact of the new proposed connections on the transient stability behaviour of the system under various fault conditions.

The transient stability assessment was performed using a base case that represented system peak load conditions. An all time new system peak of over 25,000 MW was recorded in August 2001 and a new base case was created for this study to represent the latest summer peak conditions. Transient stability analysis was performed for a high Flow East Towards Toronto (FETT) transfer of about 5300 MW and high Queenston Flow West (QFW) of about 1500 MW. The results include plots of machine rotor angles, transient voltages, transient real and reactive power flows.

In assessing if the power system is transiently stable or not, the IMO used a set of general guidelines as follows:

- Evidence of strong damping of system oscillation should be apparent within 10 s,
- A 15% decrease between oscillations is considered adequate.

Three system scenarios were set up using the peak load system representation described above.

The first (**A**) set of studies was performed with a model representing the existing system configuration.

The second (**B**) set of studies was performed with a model which included both Thorold GS and Lake Erie Interconnection projects with maximum *import* of 990 MW over the Lake Erie Interconnection.

The second (**C**) set of studies was performed with a model which included both Thorold GS and Lake Erie Interconnection projects with maximum *export* of 990 MW over the Lake Erie Interconnection.

The study course was planned such that if the results in (**B**) and (**C**) runs would have indicated that transient stability problems could appear with both projects incorporated, then the Lake Erie Interconnection was to be removed and the studies were to be repeated only with the Thorold project incorporated.

Table 6 presents a list of all studied contingencies, the results of the transient stability runs and references to the transient stability plots included in the corresponding Attachments A, B and C that are submitted with this report.

In addition to the detailed contingency analysis presented in Table 6, a comparison was performed between the transient response of the existing system and that of a system including both projects. Two of the most critical faults were selected for this comparison, namely the loss of one of the double circuit 230 kV interconnections to New York at Niagara (BP76 &PA27) and the loss of one double circuit 230 kV line between Nanticoke 230 kV station and Middleport 230 kV TS. The comparative transient responses of selected machine rotor angles and interface power flows are shown in Figure 6.

It can be concluded from Figure 6 that the addition of the two proposed projects does not aggravate the amplitude or damping of the oscillatory system response to the contingencies that were studied.

Table 6. Contingency Study

Contingency	**Existing System**	**Thorold GS, Lake Erie Interconnection Import Case**	**Thorold GS, Lake Erie Interconnection Export Case**
	Stability/Damping (Attachment A)	**Stability/Damping (Attachment B)**	**Stability/Damping (Attachment C)**
Line-Line -Ground Double Circuit Fault Cleared in Normal Time (87 ms at faulted terminal , 112 ms at remote terminal)			
B560V & B561M @ Bruce	Stable/Adequate Plot A1	Stable/Adequate Plot B1	Stable/Adequate Plot C1
BP76 & PA27 @ Beck	Stable/Adequate Plot A2	Stable/Adequate Plot B2	Stable/Adequate Plot C2
M585M & V586M @ Milton	Stable/Adequate Plot A3	Stable/Adequate Plot B3	Stable/Adequate Plot C3
N1M & N2M @ Nanticoke	Stable/Adequate Plot A4	Stable/Adequate Plot B4	Stable/Adequate Plot C4
Q23BM & Q25BM @ Beck	Stable/Adequate Plot A5	Stable/Adequate Plot B5	Stable/Adequate Plot C5
Q29HM & Q25BM @ Beck	Stable/Adequate Plot A6	Stable/Adequate Plot B6	Stable/Adequate Plot C6

	Existing System	Thorold GS, Lake Erie Interconnection Import Case	Thorold GS, Lake Erie Interconnection Export Case
Q26A & Q28A @ Beck	Stable/Adequate Plot A7	Stable/Adequate Plot B7	Stable/Adequate Plot C7
Loss of Two HVdc Bipoles	N/A	Stable/Adequate Plot B8	Stable/Adequate Plot C8
Three Phase Fault Cleared in Normal Time			
3 Phase Fault on B560V @ Milton	Stable/Adequate Plot A8	Stable/Adequate Plot B9	Stable/Adequate Plot C9
3 Phase Fault on PA302 @ Beck2	Stable/Adequate Plot A9	Stable/Adequate Plot B10	Stable/Adequate Plot C10
Line-Line -Ground Double Circuit Fault Cleared in Normal Time with Thorold G/R			
Q29HM & Q25BM @ Beck	N/A	Stable/Adequate Plot B11	Stable/Adequate Plot C11

The following conclusions can de drawn from the results of these studies:

For all studied cases with both developments in service the system transient stability response was within the general guidelines for stability.

The addition of the two proposed projects does not aggravate the amplitude or damping of the oscillatory system response to the studied contingencies.

It can be concluded that the two proposed projects do not affect the transient stability of the power system.

Thorold - Exciter, Stabilizer, Governor Models

In the Preliminary Assessment stage typical models have been assumed for the generator controls at Thorold GS. New models and data for the exciter, stabilizer and governor that have been provided by the generator vendor to be used in the SIA study.

The connection applicant has provided the excitation data in three formats and the stabilizer data in one format. From the formats provided by the applicant the models that were included in the dynamic representation together with the associated parameters are shown in Figure 7.

The connection applicant has requested that GAST governor model be used and provided the associated model parameters.

These models have been tested to identify if their transient responses meet the requirements of the *Market Rules*. The *Market Rules* require that any generating facility that is rated at 10 MVA or larger shall be equipped with an excitation system with voltage response no longer then 50 ms and ceiling voltage at least twice the rated field voltage.

With regard to the exciter response time, the results of transient stability analysis for the Thorold generating unit G1 are shown in Figure 8 attached. These results indicate that the exciter and stabilizer proposed by the connection applicant for installation at Thorold GS have adequate response and provide adequate damping of system oscillations.

With regard to the ceiling voltage, it is required that the exciter ceiling voltage should not be less than 2.0 times rated load field voltage with rated supply voltage and field current. Rated load field voltage should be taken as the field voltage corresponding to rated field current at a field temperature of 100^0 C. The information provided for Thorold GS shows the exciter ceiling voltage to be 428 V. However, a quick calculation indicates that the exciter ceiling voltage should be about 507 V.

[$2*Rfd(100^0 C)*IFFL = 2*0.2670*949.3 = 506.92$]

It is thus required that the exciter ceiling voltage for the exciters proposed to be installed at Thorold GS be raised from 427 V to 507 V.

It is generally recommended that the stabilizer parameters be tuned during the commissioning of the generation facility. The purpose is to produce an electrical torque in phase with speed changes thus providing enough damping. The IMO requires that the connection applicant provide adjustable stabilizers settings within a wide enough range such that near optimum settings can be fixed during commissioning.

The exciter response time curves for G1 and G3 are shown in Figure 9.

The assessment of the Thorold GS proposed control systems indicate that:

- The exciter response time is adequate and sufficient damping is provides,
- It is required to raise the exciter ceiling voltage from 427 V to 507 V,
- The stabilizer model and parameters are adequate, but it is required that an adjustable settings range be provided, thus allowing for optimum settings during commissioning,
- The governor model meets the *Market Rules* requirements.

Thorold GS – Option

The requirement presented in the section above, with respect to the exciter ceiling, was calculated based on the generator data provided by Northland Power Inc. in the PA stage. It was identified in the PA that the generator maximum and minimum reactive power capability do not exactly meet the 0.9 lag (48 MVars) to 0.95 lead (-32 MVars) power factor requirement in the *Market Rules*. From the generator curves it was calculated that at rated power (98.6 MW) the reactive power producing and absorbing capability is 62 MVars and 16 MVars, respectively. However, calculations showed that the range of reactive power capability meets the 15% range specified in the *Market Rules* and therefore the generator was considered adequate. It was based on this generator specific capability that the required exciter ceiling voltage of 507 V was calculated.

There is a second option available to the Northland Power Inc.. If the generator was to be designed to meet exactly the +48 MVars to –32 MVars reactive power capability at rated power of 98.6 MW, then the required exciter ceiling voltage would decrease somewhat. A set of generator capability curves were produced (shown in Figure 10) which result in a rated field voltage (at rated power and 0.9 power factor) of 3.04 pu. Using this value the required exciter ceiling voltage becomes 457 V.

[2*3.04*75.1=457 V]

In conclusion Northland Power Inc. has two choices:

(A) To stay with the generator design submitted with their application and provide an exciter with a ceiling voltage of 507 V, or

(B) Change the generator design to meet exactly the *Market Rules* requirements for reactive capability and provide an exciter with a ceiling voltage of 457 V.

Lake Erie Interconnection

The results of transient study show that the three HVdc transmission Interconnection across Lake Erie do not have a significant impact on the transient stability of the system. The immediate post-fault dynamic behaviour of the HVdc converter will have to be investigated further, after the bipole design and all controls are finalized.

8.0 Fault Level Analysis

The short circuit study looked at 3 phase and L-G faults at Beck, Allanburg, Nanticoke and Middleport and identified any equipment whose fault interrupting capability is inadequate for the following system configurations:

- the existing system,
- each project in isolation ,
- both projects connected to the system.

Short circuit sensitivity studies were performed to determine the effect of the measures that were proposed by the applicants in view of mitigating the increase in the asymmetrical line-to-ground fault currents resulting from their respective developments.

The base case used for the SIA short circuit studies was modified to better represent the transmission facilities and update the modeling of various loads and generators in Ontario, and include an updated short circuit equivalent of the New York system. Due to the model fine-tuning the short circuit study results are slightly different than those reported in the Preliminary Assessment Reports for the respective projects.

8.1 Thorold

The PA report identified that the capability of four of the Beck GS #2 breakers would be exceeded with the addition of the proposed generation at Thorold and required that in the SIA remedial options, that will alleviate the breakers' overloading problem at Beck, be investigated. The following options were investigated:

- Installation of a neutral grounding reactor on each of the Thorold GS step-up transformers; the appropriate size is to be determined by studies.

- Installation of line series reactors,
- Ungrounding the high voltage wye connection of the step-up transformer,
- Installing higher impedance step-up transformer.

Recently, Hydro One Networks Inc. revised some of the short circuit studies for the existing system as a result of updates to equipment models. The new results indicated that the short circuit capability of the Allanburg breakers is presently being exceeded for the existing system without any of the proposed developments incorporated. Currently, an interim operating measure was implemented to resolve the problem until a permanent solution is found. Hydro One Networks Inc. is in the process of installing series reactors at Allanburg TS to decrease the system fault currents.

8.2 Lake Erie Interconnection

The PA study has identified that with the proposed development incorporated the short circuit currents will exceed the ratings of some of the 230 kV breakers at Nanticoke TGS. The following options were investigated:

- Installing a grounding reactor on the converter transformer neutral, and/or
- Installing a grounding reactor on the Nanticoke G2 step-up transformer, or
- Installing ungrounded converter transformers.

8.3 Short Circuit Study Results

All proposed studies were performed with the existing system configuration, together with any facilities that may already have been approved so far by the IMO. The facilities that were included in the system model are listed in section 4 of this report.

The results of the short circuit studies are shown in Tables 7, 8 and 9 below for each of the specified transformer stations. It should be noted that where the contribution of the new developments to fault currents was significant the increase in fault levels is shown in brackets. Also, the fault currents are shown in red for situations where it was found that the short circuit current exceeds the breakers’ interrupting capability.

Table 7. Short Circuit Study Results – Allanburg

Fault Levels at 115 kV Allanburg TS (kA) ***Breaker Symmetrical Rating(kA): 39.3 ; 40.7; 50*** ***Breaker Asymmetrical Rating(kA): 45.4; 45.5; 56.8***					
		Symmetrical Fault(kA)		Asymmetrical Fault(kA)	
		3-phase	L-G	3-phase	L-G
Existing		***32.1***	***36.9***	***39.8***	***42.6***
Thorold *(contribution)*		32.8	38 ***(1.1 kA)***	41.1 ***(1.3 kA)***	44.6 ***(2 kA)***
Lake Erie Tie	No grounding reactors	32.1	36.9	39.8	42.6
	7.5 ohms grounding reactor on T2 at Nanticoke	32.1	36.9	39.8	42.6
	7.5 ohms grounding reactor on HVdc Converter Transformers	32.1	36.9	39.8	42.6
	7.5 ohms grounding reactor on T2 and Converter Transformers	32.1	36.9	39.8	42.6
Thorold & Lake Erie Tie	No grounding reactors	32.8	38.0	41.1	44.6
	7.5 ohms grounding reactor on T2 and Converter Transformers	32.8	38.0	41.1	44.6
	5 ohms grounding reactor on T2 and Converter Transformers	32.8	38.0	41.1	44.6

The effect of the proposed projects on the fault currents seen at Allanburg TS is as follows:

- The Lake Erie Interconnection does not contribute to fault currents seen at Allanburg TS
- The Thorold GS project contributes a maximum of 2 kA to the line-to-ground asymmetrical fault current at Allanburg TS, but the increased fault current will not exceed the fault current interrupting capability of the breakers at Allanburg.

Table 8. Short Circuit Study Results – Nanticoke TGS

Fault Levels at 230 kV Nanticoke TGS (kA) ***Breaker Symmetrical Rating(kA): 54.3*** ***Breaker Asymmetrical Rating(kA): 65.6***					
		Symmetrical Fault(kA)		Asymmetrical Fault(kA)	
		3-phase	L-G	3-phase	L-G
Existing (MARGIN)		***46.7*** **(7.6)**	***46.5*** **(7.8)**	***61.0*** **(4.6)**	***62.1*** **(3.5)**
Thorold		46.7	46.5	61.1	62.1
Lake Erie Tie *(increase)*	No grounding reactors	46.7	51.1 ***(4.6 kA)***	61.0	**68.4** ***(6.3 kA)***
	7.5 ohms grounding reactor on T2 at Nanticoke	46.7	49.5 ***(3 kA)***	61.0	**66.3** ***(4.2 kA)***
	7.5 ohms grounding reactor on HVdc Converter Transformers	46.7	49.2 ***(2.7 kA)***	61.0	65.6 ***(3.5 kA)***
	7.5 ohms grounding reactor on T2 and Converter Transformers	46.7	47.2 ***(0.7 kA)***	61.0	62.6 ***(0.5 kA)***
Thorold GS & Lake Erie Tie	No grounding reactors	46.7	51.1 ***(4.6 kA)***	61.1	**68.4** ***(6.3 kA)***
	7.5 ohms grounding reactor on T2 and Converter Transformers	46.7	47.2 ***(0.7 kA)***	61.1	62.6 ***(0.5 kA)***
	5 ohms grounding reactor on T2 and Converter Transformers	46.7	48.0 ***(1.5 kA)***	61.1	64.1 ***(2 kA)***

The effect of the proposed projects on the fault currents at Nanticoke TGS are as follows:

- The Thorold GS project does not contribute to fault currents seen at Nanticoke TGS.
- The Lake Erie Interconnection project contributes a maximum of 6.3 kA to the line-to-ground asymmetrical fault level at Nanticoke TGS when no grounding reactors are provided.
- Installing grounding reactors of 7.5 ohms on each of the HVdc converter transformers would reduce the fault currents to a value equal to the interrupting capability of the Nanticoke TGS breakers; hence no margin would exist.
- Installing grounding reactors of 5 ohms on each of the HVdc converter transformers and the Nanticoke T2 step up transformer would reduce the fault currents to levels within the interrupting capability of the Nanticoke TGS breakers, allowing for a margin of 1.5 kA.

Table 9. Short Circuit Study Results – Beck2 TS

Fault Levels at 230 kV Beck2 TS (kA)
Breaker Symmetrical Rating(kA): 69.5;70.0
Breaker Asymmetrical Rating(kA): 81.5 (four breakers); 83.2

		Symmetrical Fault(kA)		Asymmetrical Fault(kA)	
		3-phase	L-G	3-phase	L-G
Existing (MARGIN)		***54.3*** **(15.2 kA)**	***61.4*** **(8.1 kA)**	***69.2*** **(12.3)**	***78.3*** **(3.2 kA)**
Thorold *(increase)*	No reactor	56.4 ***(2.1 kA)***	63.6 ***(2.2 kA)***	71.18 ***(1.98 kA)***	81.06 ***(2.76 kA)***
	2.5 ohms reactor on the line	56.3 ***(2.0 kA)***	63.5 ***(2.1 kA)***	71.08 ***(1.88 kA)***	80.92 ***(2.62 kA)***
	7.5 ohms grounding rector on each Step-up Transformers	56.4 ***(2.1 kA)***	63.5 ***(2.1 kA)***	71.18 ***(1.98 kA)***	80.95 ***(2.65 kA)***
	Ungrounded HV Wye	56.4 ***(2.1 kA)***	63.0 ***(1.6 kA)***	71.18 ***(1.98 kA)***	80.29 ***(1.99 kA)***
	Z1=11%, Z0=10%	56.1 ***(1.8 kA)***	63.3 ***(1.9 kA)***	70.86 ***(1.98 kA)***	80.68 ***(2.38 kA)***
Lake Erie Tie *(increase)*	No grounding reactors	54.3	61.4	69.2	78.3
	7.5 ohms grounding reactor on T2 at Nanticoke	54.3	61.4	69.2	78.3
	7.5 ohms grounding reactor on HVdc Converter Transformers	54.3	61.4	69.2	78.3
	7.5 ohms grounding reactor on T2 and Converter Transformers	54.3	61.4	69.2	78.3
Thorold GS & Lake Erie Tie	No grounding reactors	56.4	63.6	71.2	81.1
	7.5 ohms grounding reactor on T2 and Converter Transformers	56.4	63.6	71.2	81.1
	5 ohms grounding reactor on T2 and Converter Transformers	56.4	63.6	71.2	81.1

The effect of the proposed projects on the fault currents at Beck2 GS are as follows:

- The Lake Erie Interconnection project does not contribute to fault currents seen at Beck2 GS.

- The Thorold GS project contributes a maximum of 2.76 kA to the line-to-ground asymmetrical fault level at Beck2 GS; however the increased fault current will not exceed the fault current interrupting capability of the lowest rated four breakers at Beck2 GS.
- The lowest contribution to short circuit currents at Beck2 GS was obtained with a model which included ungrounded step-up transformers on each of the three generating units at Thorold GS. The results show that the ungrounding of the step-up transformers would decrease the short circuit current by about 800 A.

Thorold

The results of the short circuit studies indicate that, given the recent operating restriction imposed at Allanburg TS as well as new data for the New York short circuit equivalent and new data for some of the transformers at Beck2 GS, it can be concluded that:

- The Thorold GS project does not contribute to fault currents seen at Nanticoke TGS
- The fault levels for Thorold GS in service with solidly grounded step-up transformers are at:

- 98% for 6 breakers (D1D2, HL6, HL7, L1L6, L7L36, T3D) at Allanburg TS and
- 99% for 4 breakers (DL24, KL23, TL21L23, TL21L24) at Beck2 TS.

Based on the data provided by Northland Power Inc., the fault levels are within the capability of the breakers at Allanburg TS and Beck2 GS. However, as the fault levels at Beck2 GS are very close to the interrupting capability of the breakers it is required that Northland Power consider mitigating measures, such as ungrounding the step-up transformers or installing transformers with higher impedance, to ensure that the final installation of the Thorold plant does not exceed the fault levels as calculated.

A further short circuit analysis will be required when test measurements for the transformers and generators are available.

Lake Erie Interconnection

The results of the short circuit studies indicate that the Lake Erie Interconnection project does not contribute to fault currents seen at Allanburg TS and Beck2 GS.

The studies show that in order to reduce sufficiently the line-to-ground fault current at Nanticoke TGS, it is required that at least 5.0 ohms neutral reactors be installed on the Nanticoke step-up transformer T2 and on all three of the HVdc converter transformers.

One other option that it is recommended for consideration by the applicants, TransÉnergie US Ltd. and Hydro One Inc., is to unground the 230kV side of the converter transformers. In this case the HVdc interconnection will have no contribution to the short circuit current in the area.

9.0 Generation Operation Requirements for Underfrequency System Conditions

The *Market Rules* require that generating facilities be able to operate continuously at full power for a system frequency range between 59.4 to 60.6 Hz. For underfrequency system conditions the generators shall not trip for frequency variations that are above the curve shown in Figure11. However, if this cannot be achieved then automatic load shedding equivalent to the amount of generation to be tripped must be provided in the area. This criterion is required to ensure the maintenance of the stability of an island, if formed, and to avoid major underfrequency load shedding in the area.

10. Conclusions

The System Impact Assessment examined the effect on the reliability of the *IMO-controlled grid* of two proposed projects; Thorold GS in Niagara area and the Lake Erie HVdc Interconnection at Nanticoke. Both projects will be connected to the 230 kV transmission system.

The studies concluded that if both projects are incorporated then:

- Congestion may increase over some Ontario transmission interfaces, under certain scenarios of peak demand, and overloading of these interfaces may occur.
- Thorold GS development contributes to the increase in fault levels at Allanburg TS and Beck2 GS, but the projected fault levels will not exceed the interrupting capability of the existing breakers but will be very close to the interrupting capability of the Beck 2 GS breakers.
- Lake Erie Interconnection development contributes to the increase in fault levels at Nanticoke TGS and the projected fault levels will exceed the interrupting capability of the existing breakers.
- The transient stability performance of the system is not affected by the addition of the two new projects.

The studies concluded that subject to implementation of the requirements identified in this report for each of the projects,

- the proposed facilities have no adverse impact on the adequacy or performance of existing *IMO-controlled grid* equipment;
- the incorporation of the proposed facilities does not reduce the load meeting capability of the *IMO-controlled grid*;
- the incorporation of the proposed facilities results does not degrade the existing system transfer capability;
- there is no adverse impact on the reliability of the *IMO-controlled grid*.

This System Impact Assessment concluded that the incorporation of the proposed projects does not require new transmission facilities in addition to those proposed by each project.

This SIA has identified appropriate measures that if implemented will mitigate the impact of the two projects and meet IMO's requirements.

11.0 Requirements for Thorold GS

This section summarizes the requirements identified during this SIA for incorporating Thorold GS into the *IMO-controlled grid*.

1. Thorold GS project is to be connected to the *IMO-controlled grid* via a 400 m line tap equipped with a HV breaker with associated manually-operated disconnect switches at the generator HV bus end, and one motorized line disconnect at the other end. This arrangement in Figure 2 meets the requirements of the Transmission System Code. It should be noted that the TSC requires that only the disconnect switch 89-LI-Q10P-X be motorized.

2. It is required that the power injected into the 230 kV circuit Q10P does not exceed at any time the continuous rating of this circuit.

3. To address the possible overloading of the 230 kV circuits out of Beck2 GS under conditions of high QFW it is required that an automatic generation rejection or run-back scheme be installed at Thorold GS. The scheme is required to trip up to three units for various contingency situations.

4. The generator controls data provided by Northland Power Inc. showed that the excitation system has a ceiling voltage of 428 V. It is require that the excitation system ceiling voltage be raised to 507 V.

5. It is required that the short circuit studies be repeated after test measurements for the transformers and generators at Thorold GS are available from Northland Power Inc.. Based on the results obtained in the SIA study it is required that Northland Power Inc. consider either installing ungrounded step-up transformers or transformers with higher impedance, to ensure that the final installation of the Thorold plant does not exceed the fault levels as calculated.

12.0 Requirements for Lake Erie Interconnection

This section summarizes the requirements identified during this SIA for incorporating the Lake Erie Interconnection into the *IMO-controlled grid*.

1. The connection of the three HVdc bipoles to the Nanticoke 230 kV switchyard is to be made via six HV breakers and the associated bus and station diameter work as shown in Figure 3. It is required that the installation of the first 330 MW HVdc bipole will provide four 230 kV breakers at the 230 kV Nanticoke TGS. For the subsequent stages, a new breaker has to be added with the installation of each bipole.

2. It is required that the thermal rating of the Nanticoke 230 kV station bus work be obtained and assess whether or not for certain system scenarios it is adequate to support the full output of the proposed HVdc Interconnection. If certain sections of the bus work or other station equipment are found to become overloaded then, the applicants will be required to initiate and undertake work to replace these station equipment and coordinate this work with Hydro One Networks Inc.

3. To address the possible overloading of the 230 kV circuits into Burlington (for import case) and out of Beck2 GS (for export case), it is required that an automatic run-back scheme be installed on each of the three Lake Erie Interconnection HVdc bipoles.

4. It is required that TransÉnergie US Ltd. and Hydro One Inc., consider one of the following two options for reducing the line-to-ground fault currents at Nanticoke TGS:

   - Install at least 5.0 ohms neutral reactors on the Nanticoke G2 step-up transformer T2 and on all three of the HVdc converter transformers, or
   - Unground the 230 kV side of the converter transformers to eliminate the contribution of the interconnection the fault levels in the area.

5. The Preliminary Assessment identified that interactions of a subsysnchronous frequency nature could appear between the generators' turbine and the HVdc converter controls. This is a phenomenon especially observed when the HVdc converters are in the vicinity of a thermal generating station. When this occurs excessive mechanical stresses could appear in the turbine and could cause extended damage. The PA required that studies be performed during the SIA stage to identify if subsysnchronous interactions are present. However, these studies have not been initiated because they are very specialized and need to be carried out after the completion of detailed HVdc converter and controls designs.

6. The IMO requires that, when HVdc converter and control models are finalized, studies must be carried out to identify whether or not subsynchronous resonance oscillations between the turbine and the HVdc controls are of concern. In the case when the presence of subsynchronous interactions is observed, special controls must be designed to alleviate the problem.

13.0 Other Assessments

The connection applicants were required to contact Hydro One Networks Inc. and initiate a Customer Impact Assessment process for each of the two projects in the cluster.

Thorold GS Project

Hydro One Networks Inc. has produced a draft CIA report for Thorold GS project. The report concludes that:

1. The results of the short circuit analysis showed a 25% increase of the short circuit level at the customer connection points at Donohue CTS. The customer should review the short circuit capability of their equipment in light of the increase. Hydro One Networks Inc. believes that the resulting short circuit levels are below the Donohue CTS breaker capabilities but recommends that the equipment capability should be verified.

2. When in operation, the Thorold plant will provide small assistance in supporting the voltages seen by the connected customers; and the plant does not adversely impact the local voltage performance in the Beck Allanburg area under system disturbances.

3. The connection of the Thorold plant with the proposed changes is not expected to materially reduce the reliability of supply to the stations and the connected customers supplied from the circuits Q10P, Q26A, and Q32A.

In conclusion, the connection of the Thorold plant is not expected to have a significant impact on the customers in the area assuming that the customer at Donohue CTS can tolerate a 25% increase in short circuit level.

Lake Erie Interconnection Project

Currently Hydro One Networks Inc. provided verbal preliminary findings of the impact of the new proposed Interconnection on the existing connected customers in the Nanticoke area. The CIA study did not identify a major impact on customer voltages or significant increase in short circuit levels at the HV point of connection. Hydro One Networks Inc. indicated that the resulting short circuit levels could be below the customers' breaker capabilities and recommends that the equipment capability be verified.

If the draft CIA report identifies additional impact then this report will be amended to reflect these findings.

14.0 Identification of "Sole Beneficiary"

Section 9.1.3 of the Transmission System Code states that "the cost of modifications and upgrades on specific network facilities that are triggered by and are for the sole benefit of the generator shall be borne by the generator."
The IMO considers that the following modifications are for the sole benefit of the Northland Power Inc. development at Thorold GS:

(a) The installation of generation rejection scheme or run-back scheme.

The generation rejection scheme would allow Northland Power to maximize the output of their Thorold power generation station, particularly during conditions of peak load and high Queenston Flow West situations and also during transmission facilities outage conditions. Therefore the scheme will only benefit Thorold GS.

(b) The installation of higher impedance step-up transformers or step-up transformers with ungrounded HV wye windings.

The installation of a higher impedance step-up transformer or ungrounded wye connection will limit the contribution of the new generation development to the fault levels at Beck2 GS. Either impact mitigating measure is considered to be for the direct benefit of Thorold development.

(c) The facilities at the point of connection of Thorold GS.

The line tap required to be installed at the point of connection to the *IMO-controlled grid*, the protective relaying, the data monitoring facilities and the metering facilities are required to allow the participation of Thorold GS in the electricity market, and hence for the sole benefit of the applicant.

The IMO considers that the following modifications are for the sole benefit of the Lake Erie Interconnection development:

(d) The installation of HVdc run-back scheme for each bipole.

It is considered that the run-back scheme will only benefit the Lake Erie Interconnection development. This scheme will allow the Interconnection to operate at the maximum output, and may be armed during most conditions of high power flows into Burlington or high Queenston Flow West situations, and also during certain transmission facilities outage conditions.

(e) The installation of at least 5.0 ohms neutral reactors on the Nanticoke step-up transformer T2 and on all three of the HVdc converter transformers, or install ungrounded converter transformers.

This particular requirement will ensure that the contribution of the new Interconnection to the line-to ground fault currents at Nanticoke 230 kV station will not result in fault levels above the breakers' interrupting capability. It is to the sole benefit of the Interconnection development that these facilities are required to be installed and would avoid higher cost breaker replacement work.

(f) The facilities at the Ontario point of connection of the Lake Erie HVdc Interconnection.

The breakers and bus work to be installed at the point of connection of the Lake Erie Interconnection to the *IMO-controlled grid*, the protective relaying, the data monitoring facilities and the metering facilities are required to allow the participation of new development in the electricity market, and hence for the sole benefit of the applicants.

15.0 Budgetary Cost Estimates

Hydro One has provided the following budgetary cost estimates for the facilities and the work that would be needed to connect each project to the *IMO-controlled grid*:

For the Northland Power Thorold development the cost of connection was estimated at $1.5M to $2.5M. This includes the connection work at the tap point, protection modifications as required on Q10P, Q26A, and Q32A, and the Generation Rejection facilities. The estimate assumes that the Generation Rejection or run-back schemes will be NPCC impactive and thus required to be fully duplicated (Type I) and that the primary communication and logic facilities for the Generation Rejection scheme will be located at the Beck2 TS.

For the Lake Erie Interconnection development the cost of connection was estimated at $4.5M to $6.5M. This estimate includes extending the 230kV bus, one new 230kV diameter suitable for three terminations, 6 new 230kV breakers, 3 line terminations, and associated protection, SCADA, and communication facilities and required modifications. This estimate does not include the additional costs associated with runback schemes for the HVdc facilities.

It should be noted that these are approximate budgetary cost estimate without the benefit of preliminary engineering or preliminary technical specifications. Neither do these estimates make any allowance for site conditions, take account of transmission facility outages or construction constraints, and associated work that may be triggered by other unforeseen difficulties.

16.0 Notification of Approval

This System Impact Assessment has assessed the impact of the Thorold GS project and the Lake Erie Interconnection project on the *IMO-controlled grid* and has identified IMO's requirements for connection to ensure that neither of these projects has a negative effect on the reliability of the *IMO-controlled grid*.

It is recommended that a *Notification of Approval* be granted to each of these projects, subject to the implementation of the requirements stipulated in this report.

Appendix A

Preliminary Assessment Recommendations

1.1 Thorold GS

Impact on Transfer Capability

The PA studies indicated that the addition of the proposed 348 MVA project at Thorold has the following impact on the transfer capability of the local transmission facilities:

- overloading of the 230 kV circuit Q10P above its continuous rating (continuous of 228 MVA; 15 minute LTR of 232 MVA with a sag temperature of 60^0C);
- increased flow through the Allanburg transformer T4 (but the resulting power did not exceed the continuous of post-contingency transformer rating); and,
- increased flow over the Queenston Flow West interface by a maximum of 238 MW (year 2000 historical records show that the QFW operating limit may not exceeded).

The PA report identified measures that need to be taken to mitigate the impact of the proposed project on the local transfer capability but a feasibility assessment of these measures was not covered.

Impact on Fault Levels

The PA fault analysis studies indicated that due to the increased fault levels resulting from the addition of the Northland Power development at Thorold:

- the capability of four of the 230 kV breakers at Beck GS#2 will be exceeded;
- the capability of eight 115 kV breakers at Allanburg will be exceeded; and,
- the capability of the 230 kV breakers at Middleport will not be exceeded.

1.2 Lake Erie Interconnection Project

The following conclusions were from the results of the PA for the Lake Erie Interconnection proposal:

1. The addition of the proposed interconnection will not affect the existing power transfer limits of the studied interfaces in Ontario or the interconnections between Ontario and New York.
2. Preliminary studies show that the dynamic model for the HVdc converters provided by the applicant with their PA application was initialized correctly and did not introduce any suspect behaviour of the system transient response.
3. It has been estimated that for high levels of imports over the new proposed Lake Erie Interconnection, congestion could occur on various transmission interfaces in Ontario.
4. It has been estimated that for high levels of imports over the new proposed Lake Erie Interconnection, congestion on Queenston Flow West interface may be reduced.

5. It can be concluded that high levels of exports over the new proposed Lake Erie Interconnection do not impact the reliability of the *IMO-controlled grid* but could contribute to congestion on the QFW interface.
6. The asymmetrical short circuit current rating of seven breakers at Nanticoke 230 kV will be exceeded with two bipoles in service. In the ultimate stage the asymmetrical short circuit current rating of ten breakers will be exceeded.

The following recommendations and requirements were identified in the PA:

1. TransÉnergie US Ltd. and Hydro One Inc. will have to proceed with an System Impact Assessment application as soon as possible.
2. The HVdc bipoles connection arrangement at the ac terminal stations must ensure that any recognized contingency will not result in the loss of more than two out of three bipoles.
3. Further study work will be performed as part of the SIA that will investigate the transient stability behaviour of the HVdc interconnection and the effect it might have on the *IMO-controlled grid*.
4. Studies must be performed to determine if coordination of the design of the HVdc controls with the *IMO-controlled grid* operating requirements is needed (i.e. run back schemes).
5. The impact of a double contingency involving two bipoles on the Ontario- Michigan Interconnection will be studied under the SIA.
6. Further studies will be performed as part of the SIA to identify particular system requirements for conditions of maximum exports on the Lake Erie Interconnection. One specific concern is the need to have in service a minimum number of Nanticoke units to supply the Vars required maintaining the system voltage with acceptable levels.
7. Studies must be carried out to identify if subsynchronous resonance interactions between the turbine and the HVdc controls present a concern.

Appendix B

Circuit Thermal Capability - Assumptions

This Appendix describes the assumptions used in calculating the thermal limits of the 230 kV circuits in the Niagara- Nanticoke area.

Table A contains the thermal limits for the narious sections of the particular circuit as indicated under the circuit identifier. As emphasized by Hydro One in previous assessments the most limiting conditions are expected to appear during peak load summer conditions. Therefore an ambient temperature of 35^0 C and voltage of 240 kV were selected to calculate the summer ampacity limits and MVA limits shown in the table. This results in more restrictive thermal limits than the normal planning criterion (which uses 30^0 C) that has been used so far.

It should be pointed out that some of the entries in the circuits'15 minute current rating column contain two values. These values represent the post contingency current limits for a pre-contingency circuit loading of 75% and 90% (the value in brackets) of the continuous rating, respectively. So far the practice has been to calculate the post-contingency rating based on a pre-contingency circuit loading of 75% of its continuous limit. However, with the addition of new generating facilities it is estimated that the pre-contingency flows on the transmission circuit may be at times higher than 75% of the continuous rating. Thus the lower post-contingency rating, although was not used in the study, was also quoted for some circuits, in brackets.

The ampacity rating of these facilities were established based on assumptions used for new or modified connection assessment studies. The actual ampacity ratings during operations is usually determined in real-time and is 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.

Table A. Niagara-Nanticoke 230 kV Circuits Ratings

	Summer (35 ^{O}C, 4km/h)*		***Winter(10 ^{O}C, 4km/h)****	
Circuit	***Continuous Rating***	***15 minute LTR***	***Continuos Rating***	***15 minute LTR***
Q32A 1192.5/116 ^{O}C	1300 A	1510 A	1550 A	1850
	540 MVA	628 MVA	644 MVA	769 MVA
Q30M (Beck-Allanburg) 1192.5/150 ^{O}C	1580 A	1830 A (1690 A)	1730 A	2090A (1940 A)
	657 MVA	761 MVA	719 MVA	835 MVA
Q30M (Allanburg-Middleport) 795.0/109 ^{O}C	960 A	1070 A	1120 A	1320 A
	399 MVA	445 MVA	466 MVA	549 MVA
Q28A 1192.5/86 ^{O}C	970 A	1130 A (1040 A)	1230 A	1560 A (1490 A)
	403 MVA	436 MVA	549 MVA	640 MVA
Q26A 1192.5/86 ^{O}C	970 A	1050 A	1230 A	1540 A
	403 MVA	436 MVA	511 MVA	640 MVA
Q25BM (Middleport-Neale) 1277.5/93 ^{O}C	1080 A	1250 A (1160 A)	1330 A	1660 A (1580 A)
	449 MVA	520 MVA	553 MVA	690 MVA
Q25BM (Neale-Beck) 1192.5/109 ^{O}C	1000 A	1160 A (1070 A)	1250 A	1580 A (1500 A)
	416 MVA	482 MVA	520 MVA	657 MVA
Q25BM (Neale-Burlington) 1192.5/115 ^{O}C	1290 A	1480 A (1380 A)	1480	1810 A (1720 A)
	536 MVA	615 MVA	615 MVA	752 MVA
Q23BM (Middleport-Neale) 1277.5/93 ^{O}C	1080 A	1250 A (1160 A)	1330 A	1660 A (1580 A)
	449 MVA	520 MVA	553 MVA	690 MVA
Q23BM (Neale-Beck) 1192.5/108 ^{O}C	1220 A	1420 A (1310 A)	1430 A	1770 A (1670 A)
	507 MVA	590 MVA	594 MVA	735 MVA
Q23BM (Neale-Burlington) 1192.5/104 ^{O}C	1180 A	1360 A	1390 A	1730 A
	491 MVA	565 MVA	578 MVA	719 MVA
Q24HM 1277.5/93 ^{O}C	1080 A	1250 A (1160 A)	1330 A	1660 A (1580 A)
	449 MVA	520 MVA	553 MVA	690 MVA
Q29HM 1192.5/93 ^{O}C	1080 A	1250 A (1160 A)	1330 A	1660 A (1580 A)
	449 MVA	520 MVA	553 MVA	690 MVA
B20H/B18H 1192.5/150 ^{O}C	1580 A	1830 A	1730 A	2010A
	657 MVA	761 MVA	719 MVA	835 MVA
M27B/M28B 1192.5/116 ^{O}C (Southcote-Horning)	1300 A	1490 A	1490 A	1820 A
	540 MVA	619 MVA	619 MVA	756 MVA

* MVA Rating calculated on 240 kV

FIGURES

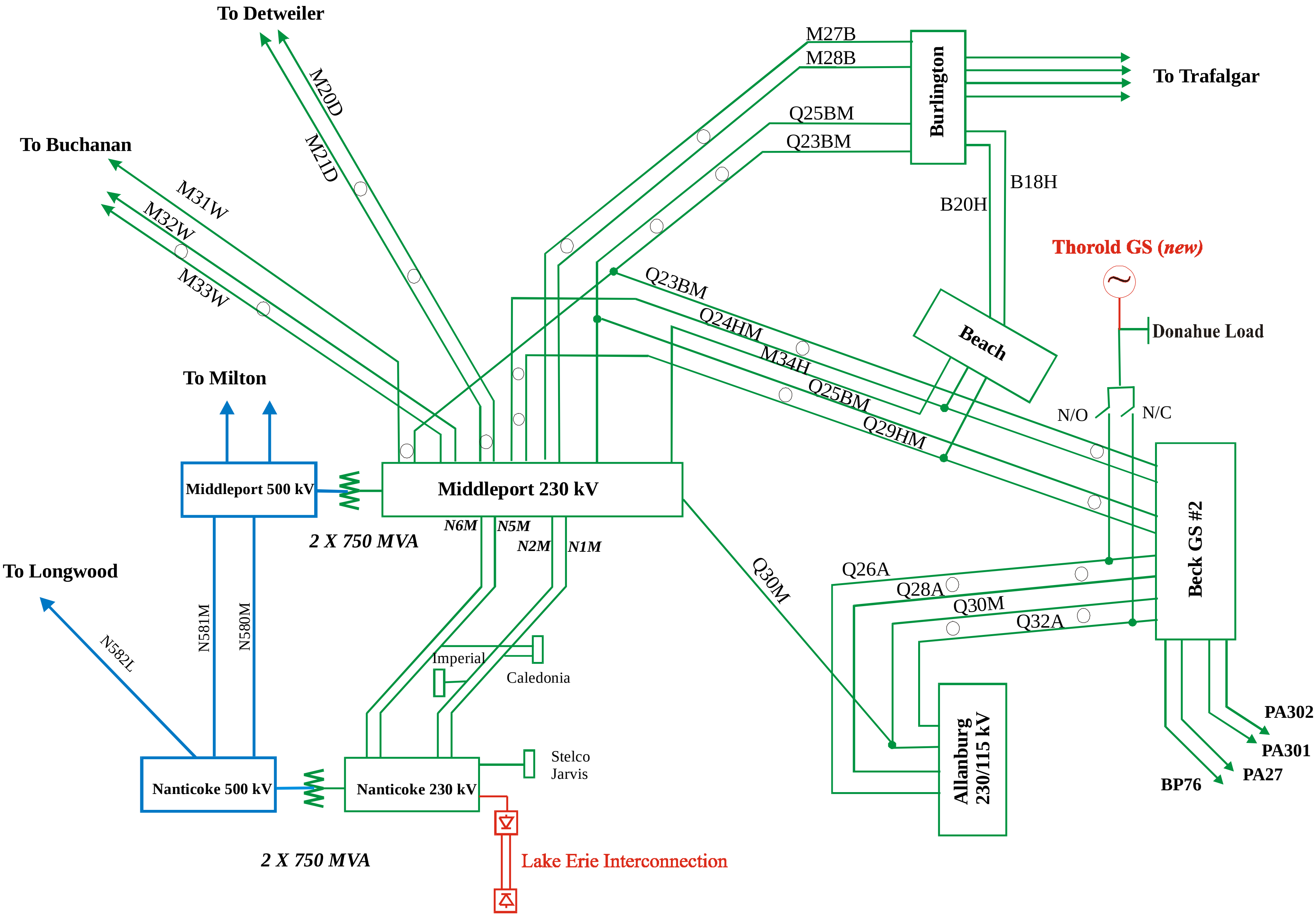


Figure 1. Niagara-Nanticoke Area Proposed Connectivity for the New Projects

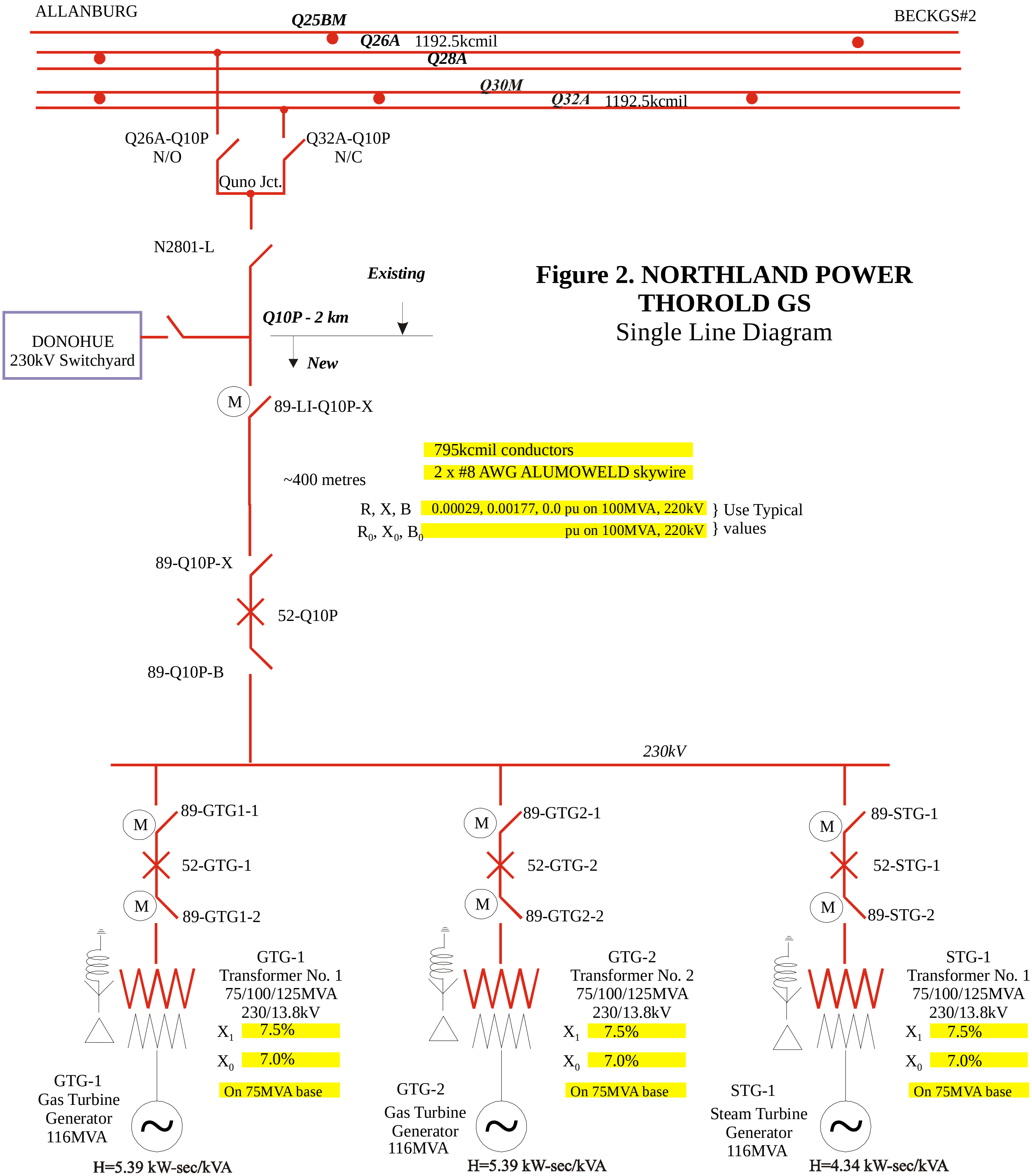
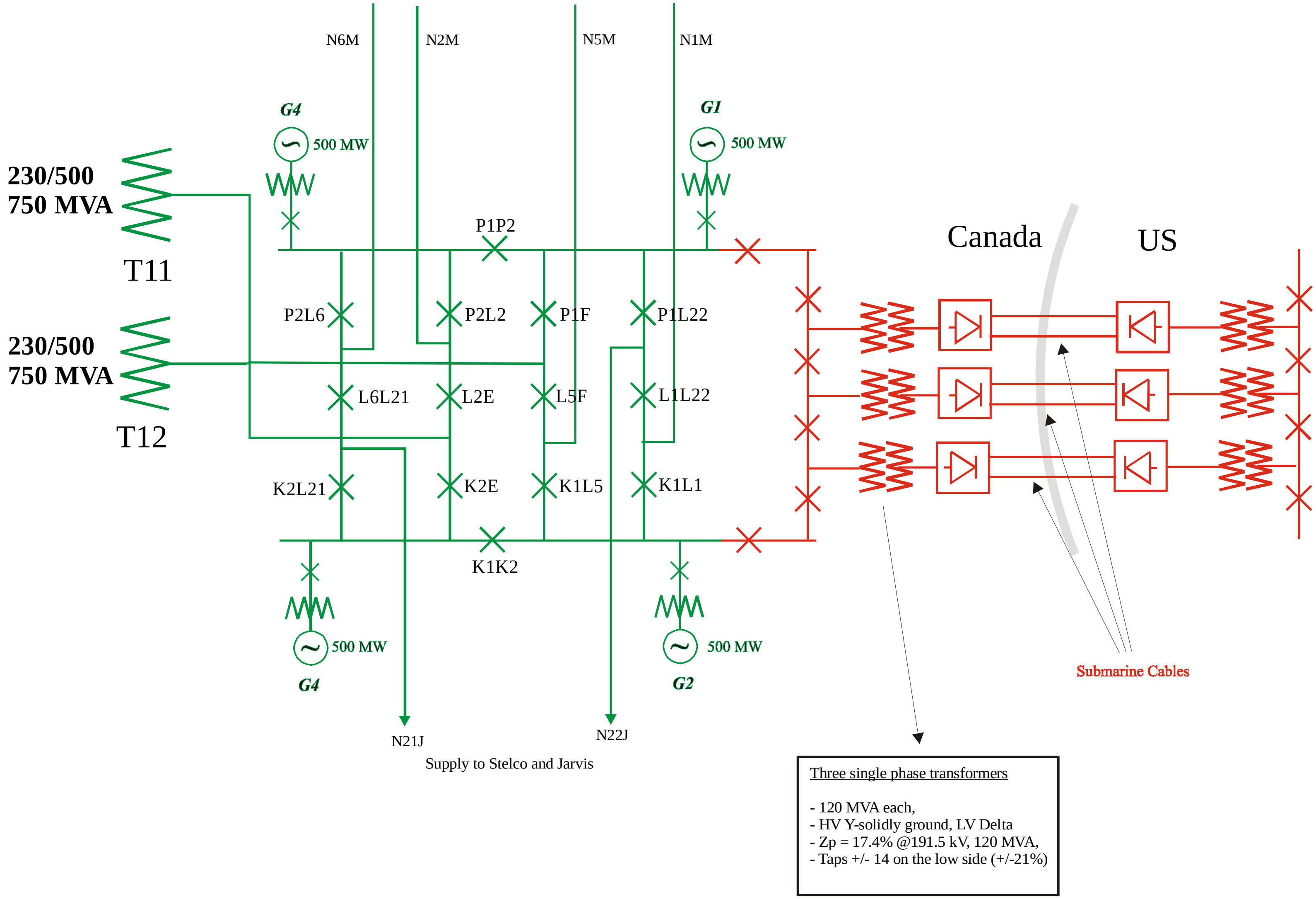


Figure 2. NORTHLAND POWER THOROLD GS
Single Line Diagram

Generator Data: Gas & Steam Turbines On 116MVA base

X_d	2.321pu	X_q	2.213pu	X_2	0.221pu	T'_{do}	5.375sec	T'_{qo}	0.478pu
X'_d	0.332pu	X'_q	0.484pu	X_0	0.133pu	T''_{do}	0.022sec	T''_{qo}	0.043pu
X''_d	0.230pu	X''_q	0.228pu	X_l	0.196pu				



Legend
Existing Facilities
New Facilities

Figure 3. Connection to Nanticoke 230 kV

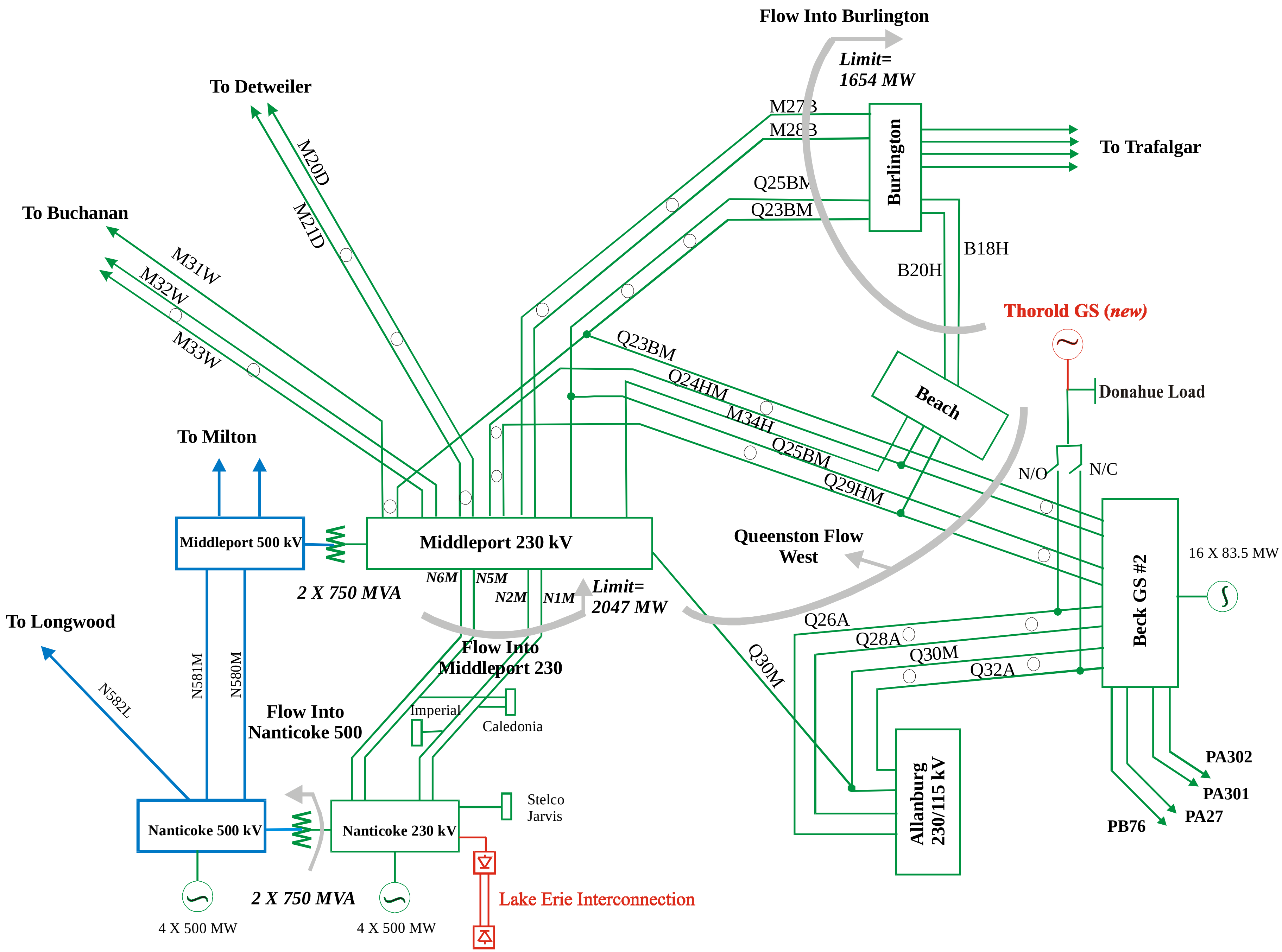


Figure 4. Niagara-Nanticoke Area Tranmission Interface Definition

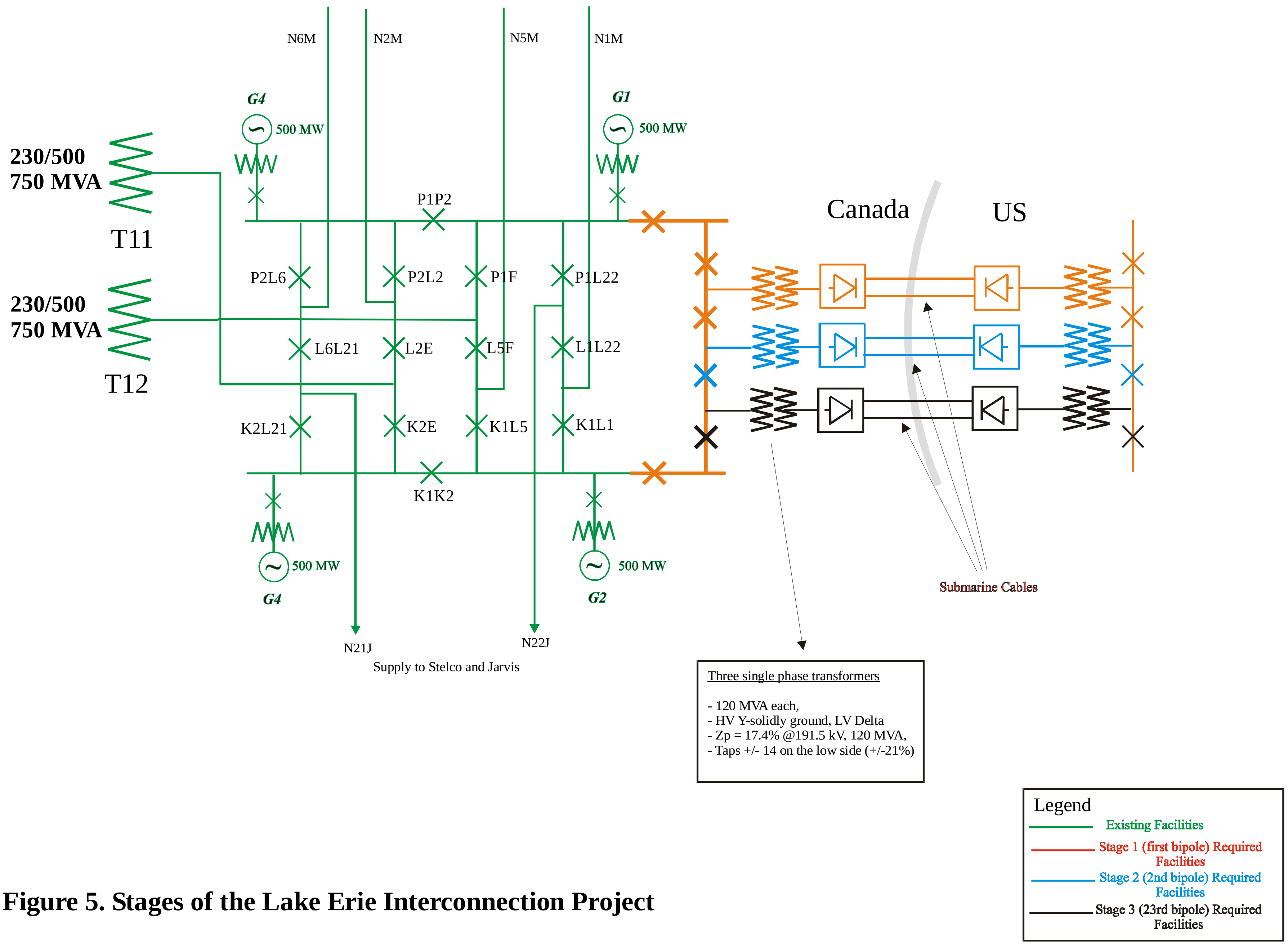


Figure 5. Stages of the Lake Erie Interconnection Project

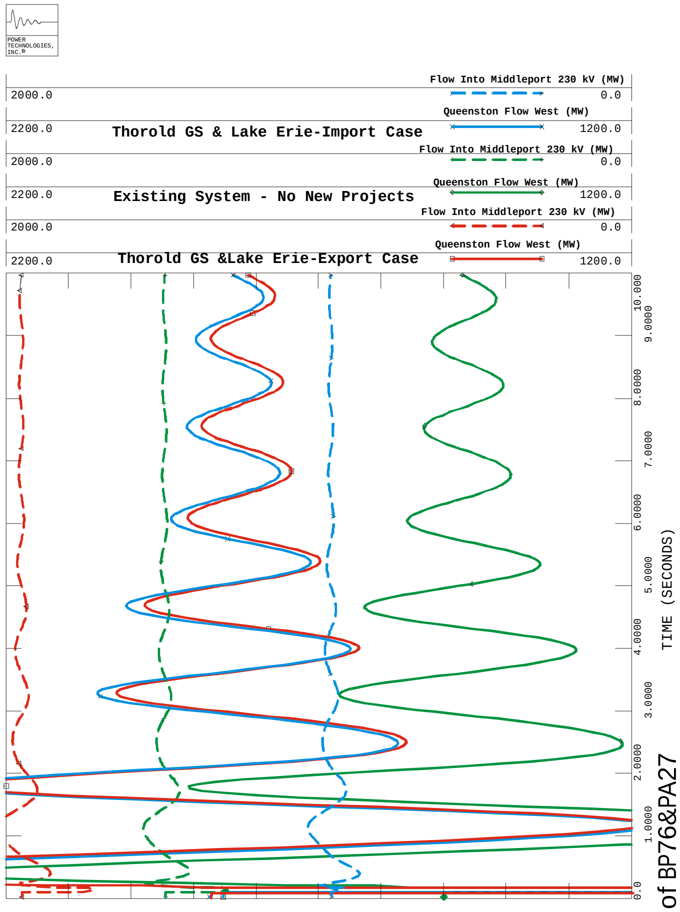


Figure 6A. Loss of BP76&PA27

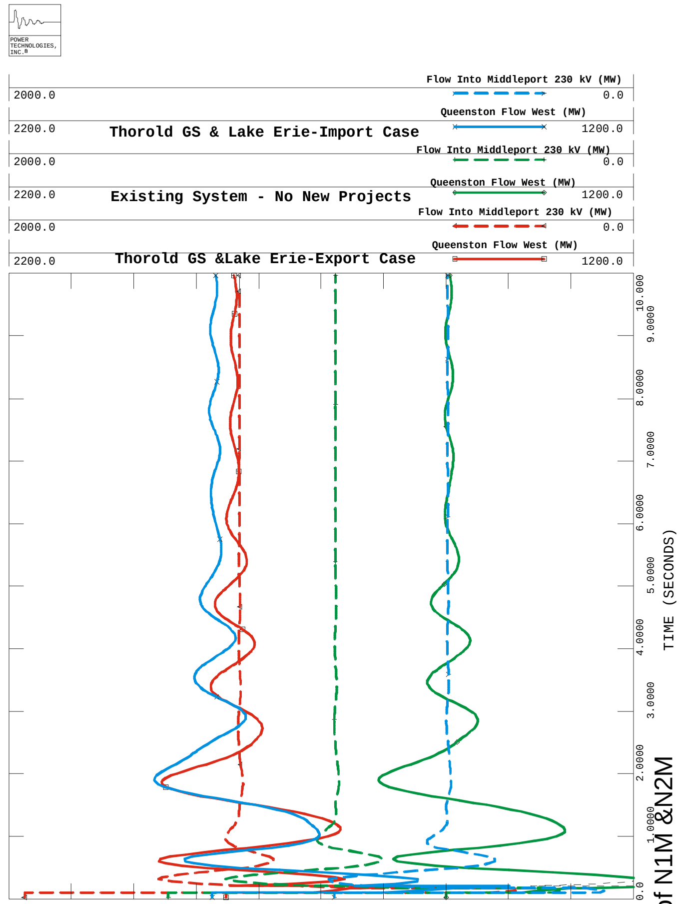
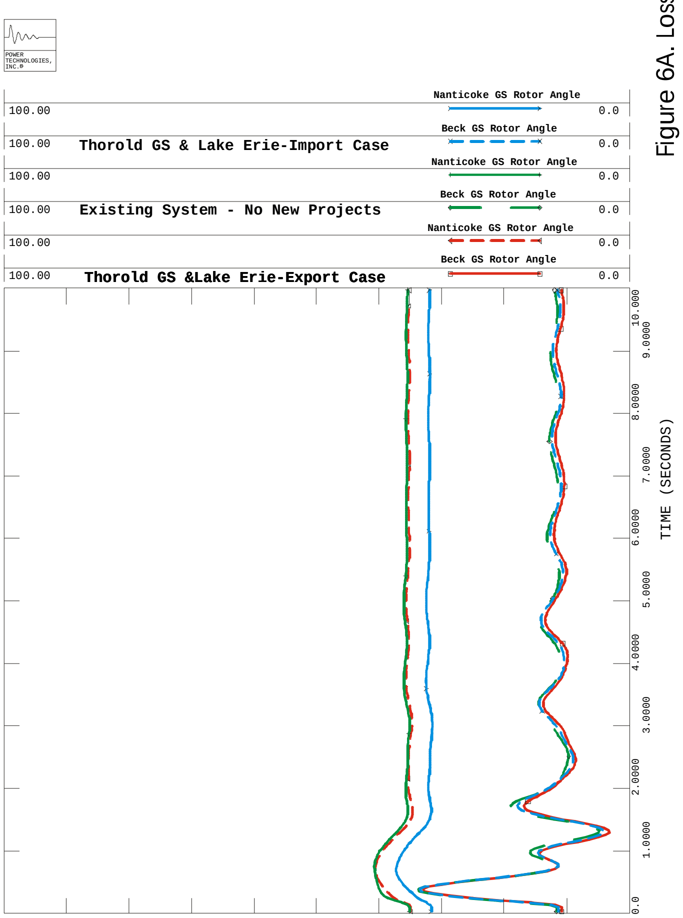


Figure 6B. Loss of N1M &N2M



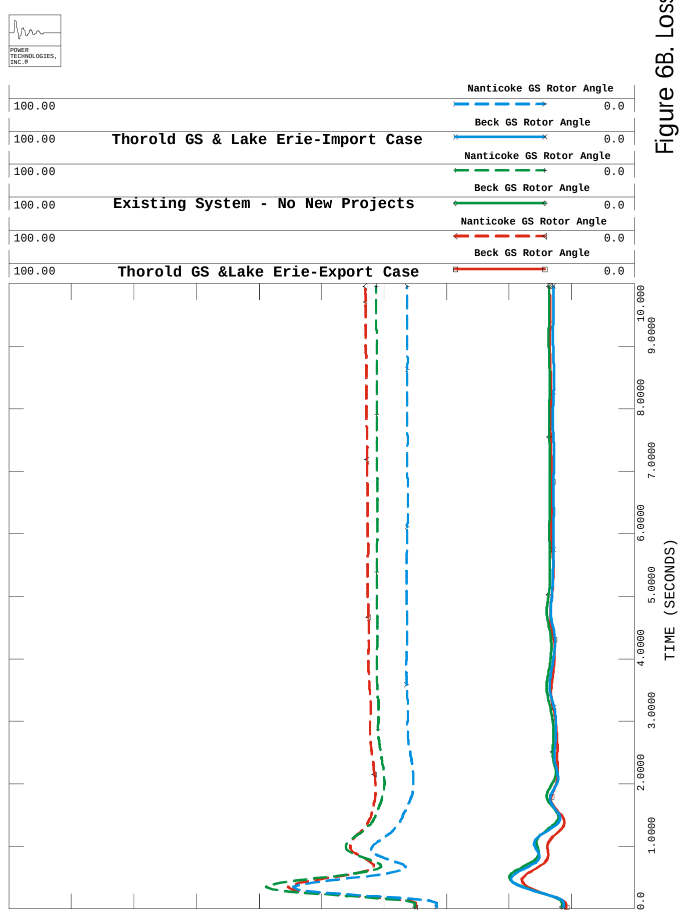
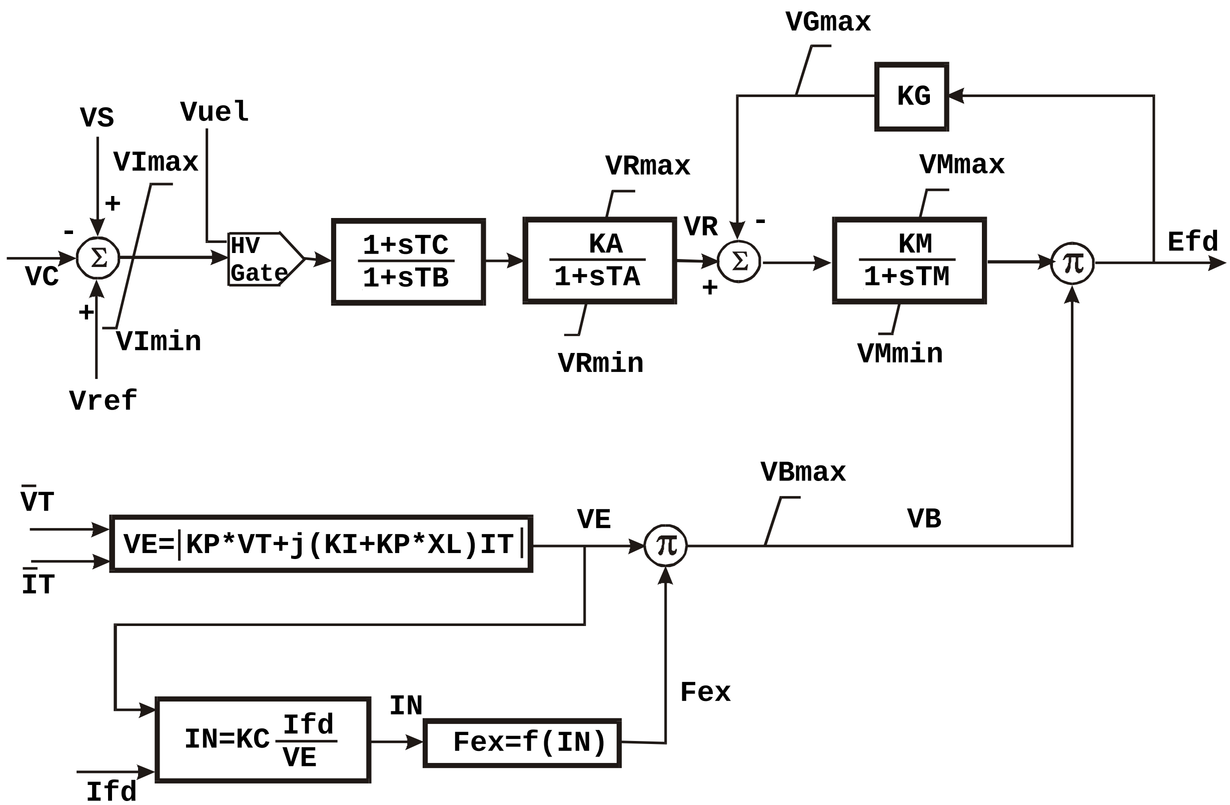


Figure 6. Both Projects Versus Existing System-Transient Comparison



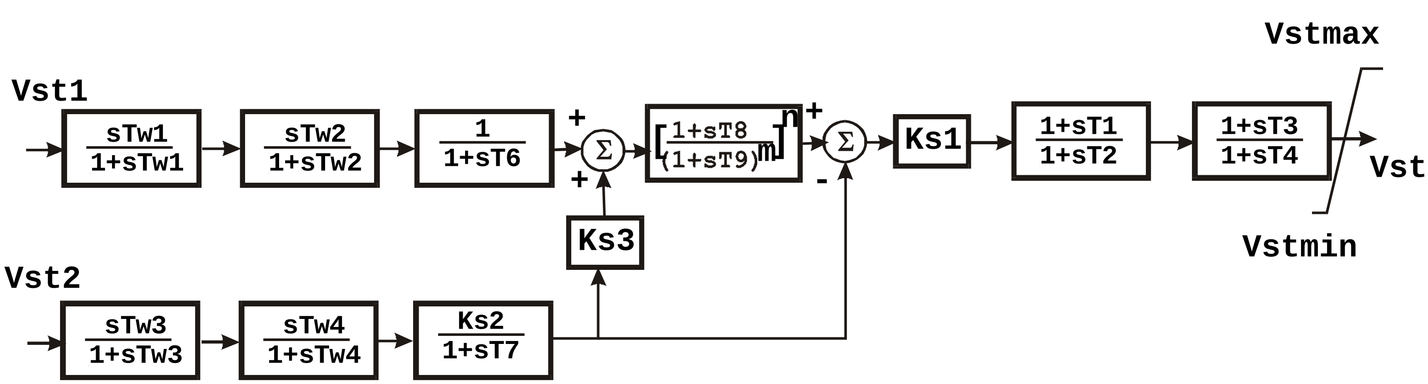
TC=1.0 TB=233.8 TA=0.0 TM=0.0 TR=0.0 KA=2000 KM=1.0

VImax=1.0 VImin=-1.0 VRmax=1.0 VRmin=-0.87 VMmax=99.0 VMmin=-99.0

KG=0 KP=5.84 KI=0.0 Kc=0.12 X1=0.0 VBmax=7.31 VGmax=1.0

Theta=0.0

IEEE Type ST3A Exciter Model



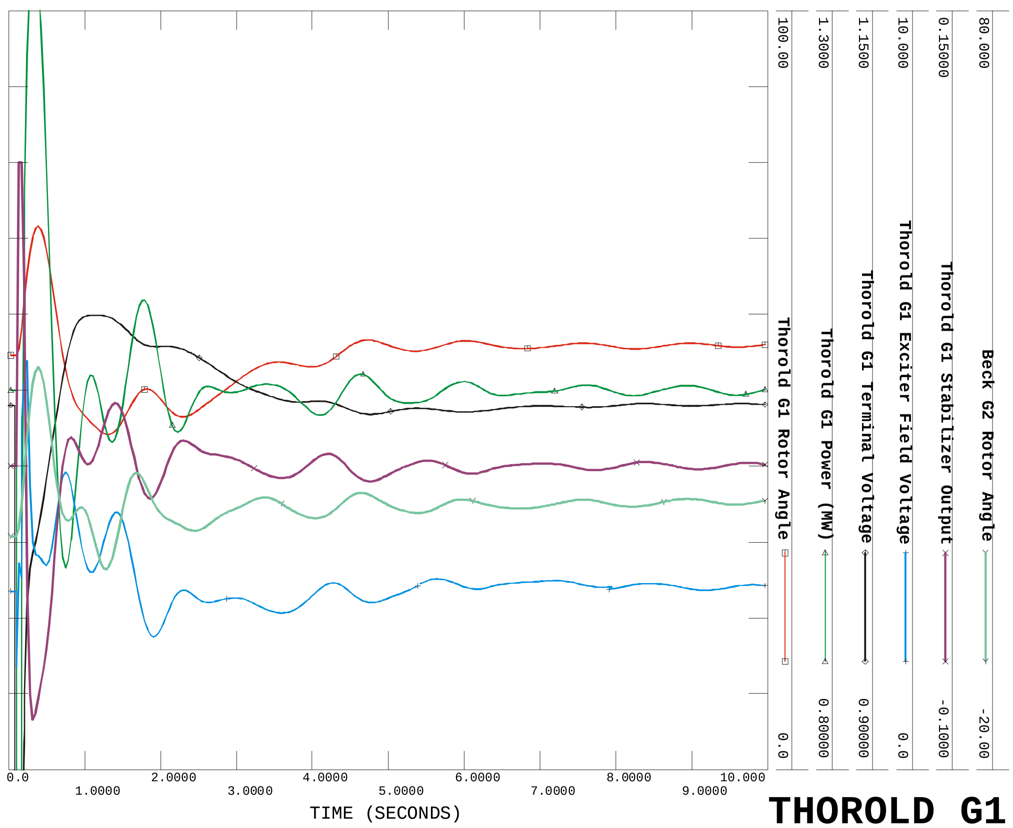
Tw1=2.0 Tw2=2.0 Tw3=2.0 Tw4=0 T6=0 T7=2.0 T8=0.5 T9=0.1

T1=0.2 T2=0.05 T3=0.2 T4=0.05 Ks1=10 Ks2=0.186 Ks3=1.0

Vstmax=0.1 Vstmin=-0.1

IEEE Type PSS2A Dual Input Stabilizer Model

FIGURE 7. Exciter and Stabilizer Models for Thorold G1 & G2



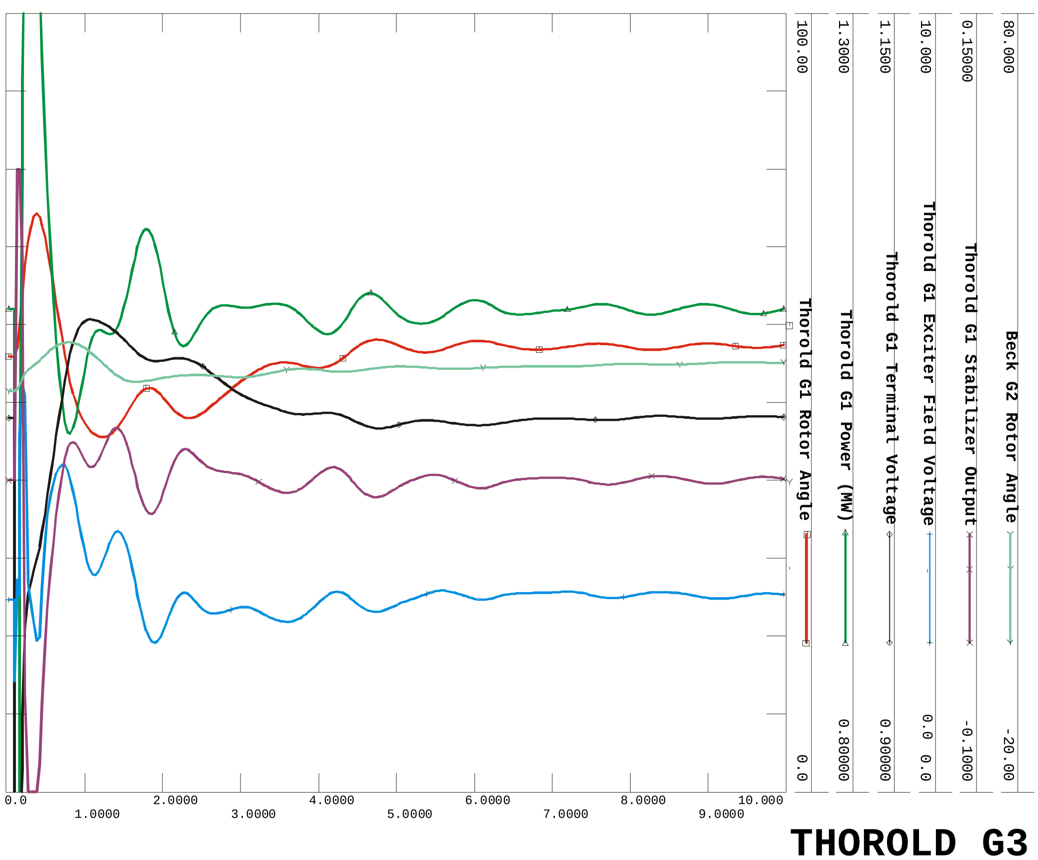


Figure 8. Thorold G1&G3 Machine Response to Lossof Double 230 kV Q26A and Q28A

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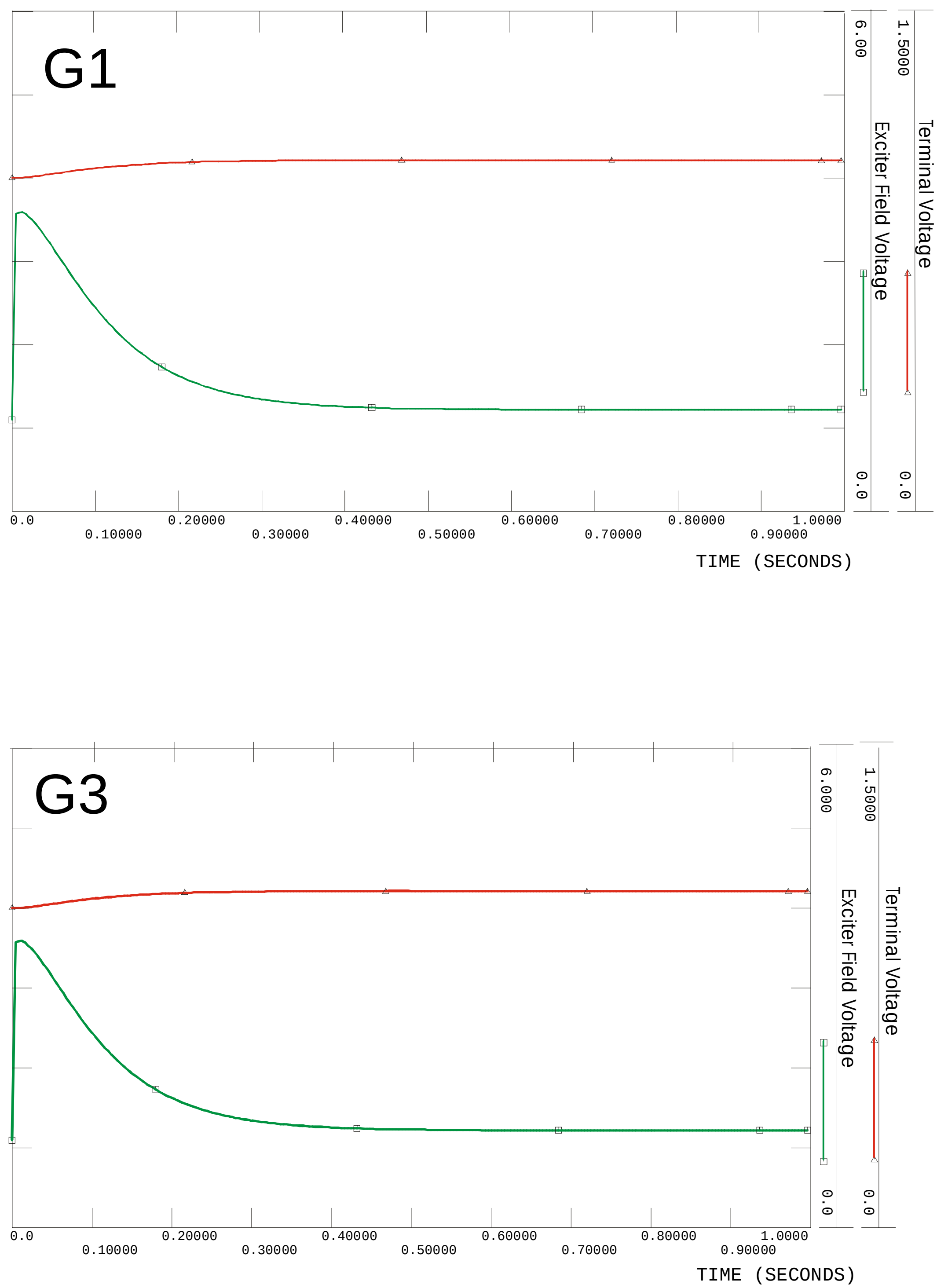


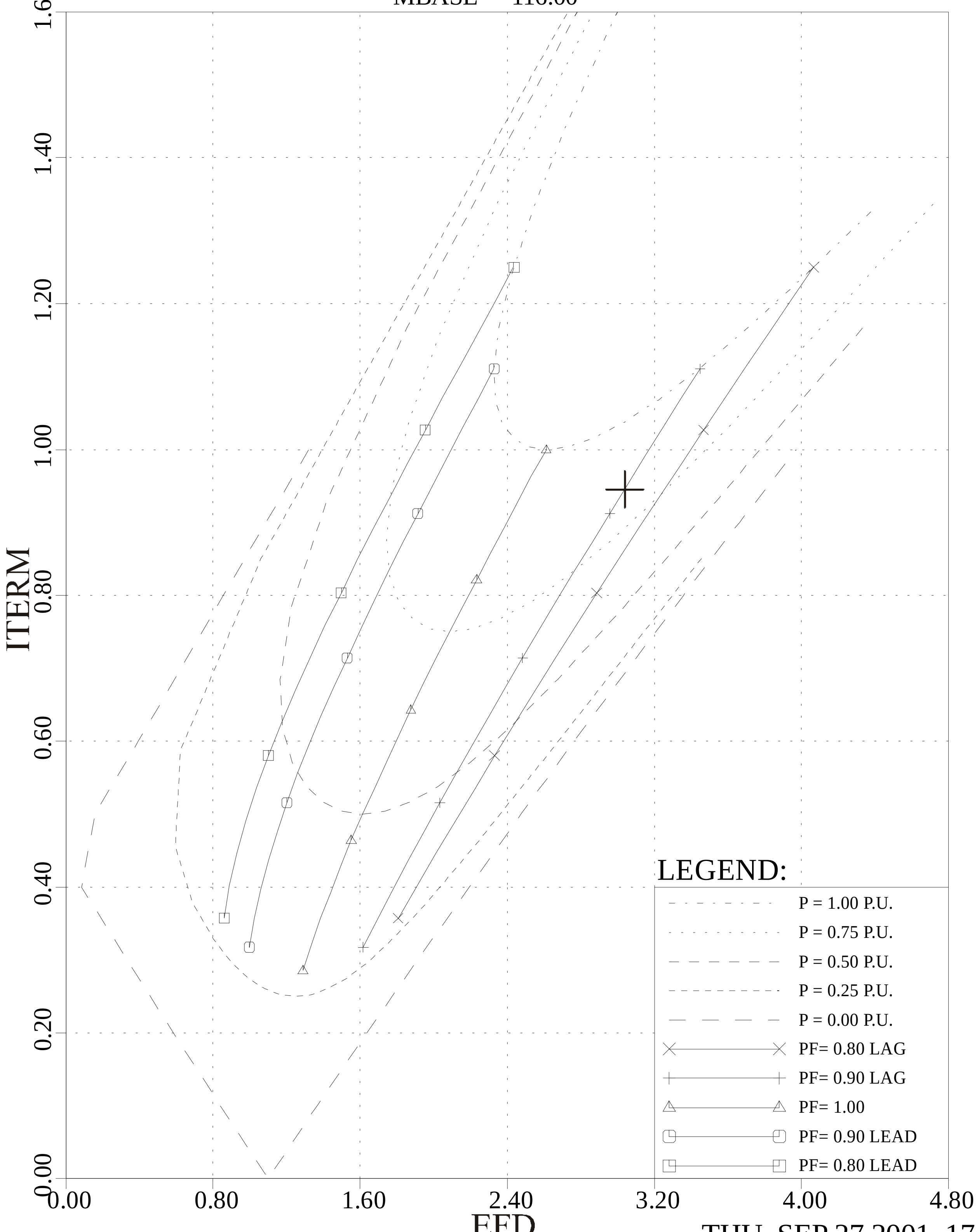
FIGURE 9. THOROLD G1&G3 EXCITER RESPONSE

FIGURE 10. GENERATOR V CURVES

XD =	2.3210	XL =	0.1960
XQ =	2.2130	R =	0.0000
X'D =	0.3320	VTERM =	1.0000
X'Q =	0.4840	S(1.0)=	0.1000
X" =	0.2300	S(1.2)=	0.4600

EFD = 3.04PU @ PLOAD = 98.6MW QLOAD = 48.0MVAR

MBASE = 116.00



THU, SEP 27 2001 17:33
THOROLD

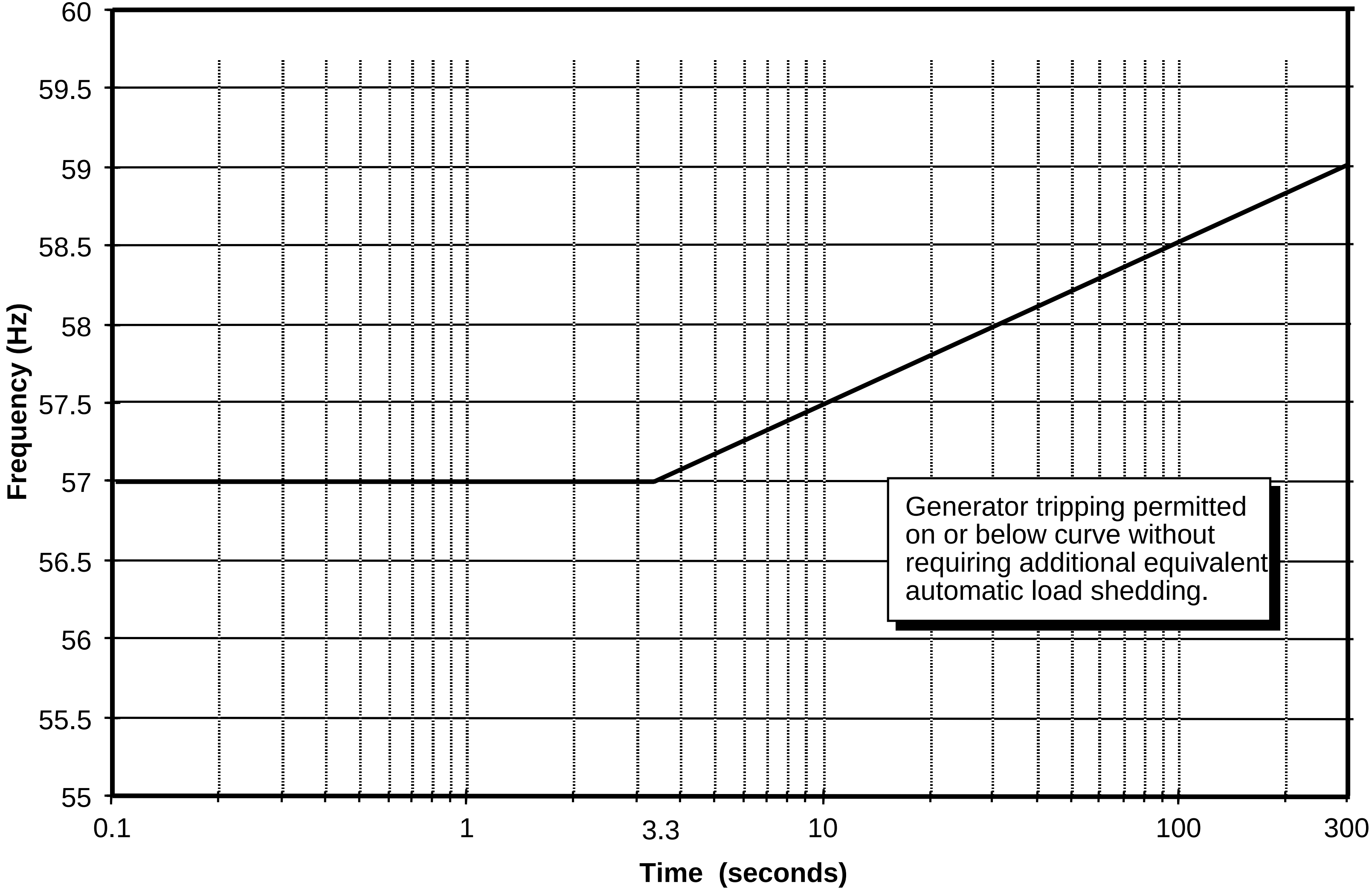


Figure 11. Underfrequency Generator Tripping