Independent Electricity Market Operator

IMO_REP_0080

CONNECTION ASSESSMENT & APPROVAL PROCESS

Preliminary Assessment Report
Bruce 'A' G3 & G4 Restart Project
(Expanded Scope of Work)

CAA ID 2001-047

Final Report

Long Term Forecasts & Assessments Department & Consistent Information Department

June 26, 2002

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Preliminary Assessment Report

Bruce 'A', G3 & G4 Restart

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, on a preliminary basis, 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 a System Impact Assessment of the proposed connection should be conducted 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. This report has been prepared solely for use by the connection applicant(s), HONI 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. In the event that the IMO provides a draft of this report to the connection applicant, you must be aware that the IMO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IMO 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.

Hydro One Networks Inc.

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

The short circuit and thermal loading levels have been computed based on the information provided by the connection proponent 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 OPGI) customers.

In this preliminary feasibility study, short circuit adequacy is assessed only for HONI breakers and does not include other HONI facilities. The short circuit results are only for the purpose of assessing the capabilities of the existing HONI 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 HONI and discussed with the connection proponent(s) upon request.

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

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

Connection Assessment Report

Executive Summary

Project Description

This preliminary assessment has examined the impact of the proposed return to service of Bruce 'A' units G3 and G4 on the reliability of the IMO-controlled grid.

The Bruce NGS consists of eight nuclear generating units, four of which were taken out of service between 1996 and 1998. Presently, only four generating units connected to Bruce B 500 kV switching station are available for operation. Bruce Power L.P. is proposing to reconnect two of the units located on Bruce 'A' 500 kV site to the *IMO-controlled grid*. The transmission facilities emanating from the Bruce NGS are shown in Figure 3.

The scheduled in service date for return to full operation of Bruce 'A' G3 and G4 is the third quarter of 2003.

Incorporation Arrangement

Bruce Power L.P. has indicated that, with the exception of the taps required for the actual connection of the units, it is not planned to replace any of the existing switching station equipment, transformers or add any other new facilities at the station. The two units will be reconnected to the 500 kV Bruce 'A' station at the same positions as they were originally connected via the original single-phase step-up transformers.

Generating Units Capability

The information submitted by the applicant indicated that each unit is rated at 889 MVA and has a Maximum Continuous Rating at the unit's terminal of 825 MW.

Although based on the *Market Rules* definition the rated power of each unit is 800 MW, operation at unit's *Maximum Continuous* rating is allowed – in accordance with the *Market Rules* (Chapter 7 paragraph 9.4.5) – provided that the IMO can direct the generator, when necessary, to reduce its active power output in order to produce *reactive support* within the range required by the *Market Rules*.

Generator Exciter Test

The study concluded that Bruce G3 and G4 excitation systems meet the *Marker Rules* requirements for excitation systems transient response performance.

Interface Power Transfer Capability

The impact of the restart of Bruce G3 and G4 on the transmission system transfer capability and the operating limits was investigated in two parts.

Firstly, a power flow linear analysis was performed to indicate the distribution of the additional Bruce output onto the Ontario transmission interfaces and the interconnections. The purpose of this analysis was to give an indication about the possibility of congestion on the interfaces that are affected by the increase in Bruce Complex power output.

Secondly, a transient stability analysis was performed to determine the system performance with the two additional Bruce ‘A’ units in service superimposed on all the other connection projects for which applications were processed.

Linear Power Flow Analysis

The results from the power flow analysis showed that the power flows on all transmission interfaces that were studied are affected by the proposed restart of two Bruce ‘A’ units. Table 1 of section 3.6.1 summarizes the distribution of power over the impacted transmission interfaces when the power injected at Bruce displaces various generations in the province.

The results show that for peak load conditions:

- the Flow Away of Bruce NGS (FABC) increases by an amount equivalent to the net power injected into the IMO-controlled grid by the two newly connected units,
- the positive Buchanan Longwood Input (BLIP) flow could increase by up to 1176 MW when Bruce generation displaces western Ontario generation; this would also help reduce congestion on the negative BLIP flow,
- the Flow East Towards Toronto (FETT) could increase by about 1400 MW when Bruce generation displaces Ontario generation east of Toronto.

Voltage and Transient Stability

Voltage and transient stability studies were performed using the generator models supplied by Bruce Power L.P. The studies were performed for the most critical recognized contingency, the loss of the double circuit 500 kV line from Bruce to Milton and Claireville (B560 V & B561M).

The voltage stability studies indicate that for system peak load conditions and high negative or positive BLIP flow, the FABC limit without deploying Bruce generation rejection might have to be restricted to less than the full output of six generating units. To eliminate or reduce this restriction it is required that the G3 and G4 participate in the Bruce Special Protection Scheme.

The results of the transient stability assessment indicate that the system transient stability response was within the general guidelines for stability. It appears that the restart of Bruce G3 and G4 does not aggravate the amplitude or damping of the oscillatory system response to the studied contingencies.

Fault Level Assessment

Fault analysis studies were performed to determine the impact of Bruce G3 and G4 reconnection on the existing transmission facilities. The base case for these studies assumed in service all the projects that are ahead of Bruce G3&G4 restart project in the CAA Queue.

The short circuit study results show that, for the monitored 230 kV switching stations, the increase in fault levels due to the restart of Bruce GS units G3 and G4 results in short circuit currents which do not exceed the interrupting capability of the existing circuit breakers.

The results also indicate that it is possible that the next major generation project could bring the fault levels at Claireville TS over the interrupting capability of the existing breakers thus triggering the need to split Claireville TS.

Conclusions and Recommendations

The results of this assessment indicate that:

1. Bruce ‘A’ G3 and G4 restart proposal will not affect the existing power transfer limits of the studied interfaces in Ontario.

2. Bruce G3 and G4 exciter systems meet the *Marker Rules* transient response requirements.

3. The Bruce Special Protection System is adequate for handling up to six Bruce units in service, hence the proposed restart of two Bruce generating units does not trigger the need to revise the Bruce Special Protection System.

4. Bruce units G3 and G4 are required to participate in the Bruce Special Protection System.

5. For system peak load conditions and high “negative” power flows on Buchanan Longwood interface, Bruce generation could alleviate the power congestion on this interface.

6. For system peak load conditions and high positive westbound power flows on the Buchanan Longwood interface the additional Bruce generation could have a higher or lower degree of contribution to congestion, depending on the other generators’ dispatch schedule.

7. During peak load conditions and for particular system scenarios, the additional Bruce generation will contribute to congestion on FETT interface.

8. For high negative BLIP power flows, the FABC flow at 4075 MW is approaching the voltage stability limit, but a higher operating limit will be obtained with the implementation of post contingency generation rejection controls.

9. For high positive BLIP flows the FABC limit could be slightly higher than 4375 MW and, a further increase in operating limits could be obtained with post contingency generation rejection or controls.

10. This project does not affect the transient stability of the IMO-controlled grid.

11. For the monitored 230 kV switching stations, the increase in fault levels due to the restart of Bruce ‘A’, units G3 and G4, results in short circuit currents which do not exceed the interrupting capability of the existing circuit breakers.

IMO Requirements

This section summarizes the requirements identified during this Connection Assessment for re-incorporating Bruce ‘A’ G3 and G4 generating units into the *IMO-controlled grid*.

1. Since the generating units’ connections are not equipped with low voltage breakers, the 500 kV breakers are to be used for synchronizing duty. The two 500 kV synchronizing

breakers must be capable of sustaining 2.0 p.u. voltage across their open terminals to ensure out of phase switching capability.

2. Operation of Bruce G3 and G4 at *Maximum Continuous* rating is allowed – in accordance with the *Market Rules* (Chapter 7 paragraph 9.4.5) – provided that, when necessary, the IMO shall direct the generator to reduce its active power output in order to produce *reactive support* within the range required by the *Market Rules.* If such instruction is issued by the IMO then Bruce Power must reduce its MW output and Bruce Power shall not be entitled to a *congestion management settlement credit*.

3. Bruce ‘A’ G3 and G4 are required to participate in the generation rejection scheme that forms an integral part of the Bruce Special Protection System. It is required that full duplication of the primary communication and logic facilities for the generation rejection scheme be provided.

4. Bruce Power L.P. must complete the IMO facility registration process including meter registration before bringing G3 and G4 in service.

5. Hydro One Networks Inc. has indicated that the Customer Impact Assessment process is not required for this project.

6. A separate System Impact Assessment is not required because the scope of the Preliminary Assessment was expanded to include the transient stability analysis.

Budgetary Cost Estimates

As no major modifications are required to incorporate G3 and G4, and only minor work associated with protection reviews and witness verification during commissioning budgetary cost estimates have not been provided.

Identification of “Sole Beneficiary”

Those facilities that are triggered by, and deemed to be for the sole benefit of this project have been identified in section 8. of this report.

Notification of Approval

This Connection Assessment has investigated the impact of restarting Bruce ‘A’, G3 and G4 generating units, on the reliability of the *IMO-controlled grid* and has identified IMO’s requirements for connection to ensure the project does not adversely affect on the reliability of the *IMO-controlled grid*.

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

1.0 Proposal Description

Bruce Power L.P. has submitted a proposal to return generating units G3 and G4 to service at the Bruce 'A' Nuclear Generating Station.

The two units will be reconnected to the 500 kV Bruce 'A' station at the same positions as they were originally connected.

The scheduled in service date for return to full operation of Bruce 'A' G3 and G4 is the third quarter of 2003.

2.0 Data Verification

The generating unit models used in the study were built based on information submitted by Bruce Power L.P. with the CAA application and data available from the IMO facility registration process.

2.1 Connection

The proposed connection arrangement is shown in Figure 1 and corresponds to the existing station layout. It is proposed to reconnect unit G4 between breakers T4A and T4L560 and G3 between breakers T3T28 and T3E. With the exception of the taps required for the actual connection of the units, at the time of the application there were no plans to replace any of the existing switching station equipment, transformers or add any other new facilities at the station.

For the purpose of this assessment it was assumed that the two step up transformers, T3 and T4 would be retained and used for connecting G3 and G4, respectively. Each step up transformer is configured with three single-phase transformers having the following characteristics:

- Rating –267 MVA,
- Positive sequence impedance – 12.26% on rated power
- Three phase connection: HV side is wye connected and solidly grounded,LV side is delta connected.

The existing configuration shows that the generating units are not equipped with low voltage synchronizing breakers, hence the 500 kV breakers are to be used for synchronizing duty. It is necessary therefore, that the synchronizing breakers are capable of sustaining 2.0 p.u. voltage across their open terminals to ensure out of phase switching capability.

2.2 Capability of Generating Units

The information submitted by the applicant indicated that each unit is rated at 889 MVA and has a Maximum Continuous Rating of 825 MW. For the purpose of this assessment the Maximum Continuous rating is defined at the unit's terminals.

Chapter 4, appendix 4.2 of the *Market Rules*, requires that "a synchronous generation unit shall have that capability to supply at its terminals reactive power within the range between 90% lagging and 95% leading power factor based on rated real power at rated voltage." The rated real power is defined by the *Market Rules* as "the lesser of maximum continuous real power or 90% of the unit name plate MVA."

Based on this definition the rated real power for Bruce ‘A’ G3 or G4 was calculated to be 800 MW. An investigation of the generator capability curves showed that Bruce G3 and G4 meet, at rated power, the reactive power requirements of the *Market Rules*.

Operation at unit’s *Maximum Continuous* rating is allowed – in accordance with the *Market Rules* (Chapter 7 paragraph 9.4.5) – provided that the IMO can direct the generator, when necessary, to reduce its active power output in order to produce *reactive support* within the range required by the *Market Rules.* If such instruction is issued by the IMO then Bruce Power must reduce its MW output and Bruce Power shall not be entitled to a *congestion management settlement credit*.

2.3 Generator Exciter Test

The connection applicant has indicated that the generator controls will remain essentially the same as they were before the disconnection of Bruce ‘A’ G3 and G4. The Exciter and stabilizer models and data are shown in Figure 2.

As part of this assessment the exciter model was tested to identify if its transient response meets 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.

The results of transient stability analysis for the Bruce generating unit G3 and G4 shown in Figures A1 and B1 attached. These results indicate that the exciter and stabilizer installed on units G3 and G4 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. Based on the following formula, the exciter ceiling voltage should be about 1054 V.

[2*Rfd(100^0 C)*IFFL = 2*0.1097*4800 = 1053.12 V]

The response ratio test graph shown in Figure 4 demonstrates that the exciter meets the ceiling voltage requirement.

It can be concluded that the Bruce G3 and G4 exciter systems meet the *Marker Rules* transient response requirements.

It may be necessary to tune the stabilizer parameters to optimum settings during the commissioning of the generation facility. The purpose is to produce an electrical torque in phase with speed changes thus providing optimum damping.

3.0 Interface Power Transfer Capability Assessment

3.1 Description of Existing Transmission Facilities

The Bruce NGS consists of eight nuclear generating units, four of which were taken out of service between 1996 to 1998. Presently, only four generating units connected to Bruce B 500 kV switching station are available for operation. Bruce Power L.P is proposing to reconnect two of the units located on Bruce ‘A’ 500 kV site to the *IMO-controlled grid*. The transmission facilities emanating from the Bruce NGS are shown in Figure 3 and listed below. This system will be referred to in the report as the “Bruce System”.

From Bruce ‘A’ 500 kV:

- one 500 kV double circuit line to Claireville TS (B560V) and to Longwood TS (B562L)
- one 500 kV single circuit to Bruce B 500 kV station (B569B).

From Bruce ‘A’ 230 kV:

- one 230 kV double circuit line to Orangeville TS,
- one 230 kV double circuit line to Detweiler TS,
- one 230 kV double circuit line to Owen Sound TS

From Bruce B 500 kV:

- one 500 kV double circuit line to Milton TS (B561M) and to Longwood TS (B563L),
- one 500 kV single circuit to Bruce ‘A’ 500 kV station (B569B).

The system diagram shown in Figure 3 represents the 230 kV and 500 kV transmission system from Bruce NGS to Nanticoke TGS, Claireville TS and Essa TS.

In addition, the 500 kV transmission system is equipped with a number of high voltage shunt reactors that are used in holding adequate system voltages. The shunt reactors, are:

- three 150 Mvar (R25, R27 and R28) connected to each of the 500/230 kV autotransformers controlling the 500 kV voltage and
- five 150 Mvar (R3, R4, R5, R6 and R7) connected to each of the 500/230 kV autotransformers at Longwood TS.

3.2 Transmission Interface Definitions

The main transmission interfaces addressed in the study area are shown in Figure 3 and described below.

Flow Away of Bruce NGS (FABC)

FABC is defined as the power in MW flowing out of Bruce NGS on B560V, B561M, B562L, B563L, B4V, B5V, B22D, B23D, B27S and B28S measured at Bruce buses.

Buchanan Longwood Input (BLIP)

BLIP is defined as the sum of power flows into Buchanan TS on 230 kV circuits D4W, D5W, M31W, M32W and M33W plus the power flows into Longwood TS on the 500 kV circuits B562L, B563L and N582L.

Flow East to Toronto (FETT)

FETT is the sum of power flows into Greater Toronto Areafrom the east defined as follows:

FETT=(M570V+M571V+V586M+B560V)MW in at Claireville
+(E8V+E9V)MW out at Orangeville
+(R14T+R17T+R19T+R21T)MW out at Trafalgar

3.3 Operating Limits and Bruce SPS

Originally, the Bruce Complex was comprised of eight nuclear units. A set of complex operating security limits was established through extensive studies, to prevent transient and voltage instability in event of contingencies for various pre-contingency system conditions. In order to maximize Bruce Complex power output for various system scenarios and contingencies, special protection systems were implemented. These special protection systems included automated arming of generation and load rejection schemes, and shunt reactor switching schemes. By providing these capabilities, restrictions on the maximum Bruce complex power output could be reduced or eliminated while observing established criteria for transient and voltage stability, equipment overload and voltage decline.

Even after the removal from service of four of the Bruce generating units it was determined the Bruce Special Protection System is to be kept operational in its full capability and original design. Hence, the present proposal of restarting two of the Bruce 'A' generating units does not require a revision of the Bruce Special Protection System. However, the reconnected generating units G3 and G4 are required to be incorporated and participate in the Special Protection System.

The full redundancy of the existing Bruce Special Protection System must be maintained.

It can be concluded that the Bruce Special Protection System is adequate for handling up to six Bruce units in service, hence the proposed restart of two Bruce generating units does not trigger the need to revise the Bruce Special Protection System. Units G3 and G4 are required to participate in the Bruce Special Protection System.

It is required that full duplication of the primary communication and logic facilities for the Generation Rejection scheme be provided.

A review of the Bruce SPS scheme has been initiated due to issues arising from the electricity market deregulation. This review is being jointly conducted by the IMO, Hydro One and Bruce Power. The Data Acquisition Computer System (DACS) which presently oversees the secure operation of the IMO-controlled grid will be replaced with a new Energy Management System (EMS). The new EMS will not have the capability to perform the auto-arming of generation rejection of the Bruce generating units. The IMO will, however, identify the arming requirements to Bruce Power.

The existing operating security limits identify the required amount of post contingency generation rejection which would ensure that the available output of Bruce NGS can be injected into the IMO-controlled grid. A brief description of these limits is given below.

Limits Without Bruce G/R

When generation rejection is not required to improve the FABC limit then the system is operated to "No G/R FABC Limit".

The existing "No G/R" FABC operating security limits show a close dependence between the limit and BLIP flow as shown in Exhibit C of section 3.6.2.1. Specifically, they indicate that with all elements and six 500 kV Bruce units in service and without the deployment of generation rejection in BSPS, the FABC limit varies between 5300 MW for BLIP at 3500 MW and 4500 for BLIP at –1500 MW. These limits could become more restrictive for a variety of system conditions such as outages or low system voltages.

Limits With Bruce G/R

When generation rejection is required to improve the FABC limit then the system is operated to "Post Rejection FABC Limit". This represents the FABC following generation rejection. The pre-contingency FABC limit in this case is not restrictive and it is equal to the Post Rejection FABC Limit plus the net Bruce generation selected for rejection.

The existing operating limits indicate that with one 500 kV Bruce unit armed for rejection the "Post Rejection FABC" varies between 5000 MW for BLIP at 3500 MW to 4200 MW for BLIP at –1500 MW. Assuming a system with all elements in service and system conditions not requiring the application of penalties, then the FABC could be as high as 4990 (4200+ 790-the net output of one Bruce B unit). This limit would be high enough to accommodated the net summer output of all six 500 kV units (4x790 +2x735=4630 MW).

Should be however noted that these limits could become more restrictive for a variety of system conditions such as outages or low system voltages.

3.4 Study Assumptions

Based on the queue principles of the Connection Assessment and Approval process the impact of reconnecting Bruce G3 and G4 was assessed for a system which incorporates all existing facilities and all the connection projects that are ahead of the subject application in the queue.

The power transfer capability study was performed for system peak load conditions.
The system model used in this assessment included all the existing facilities and all the projects that occupy in the IMO CAA queue a position prior to this project. These projects include:

- TransAlta generation project in Sarnia - 490 MW capacity,
- ENRON generation project in Sarnia - 505 MW capacity,
- AES generation project near Leamington - 530 MW capacity,
- ATCO generation project in Windsor - 578 MW capacity,
- Sithe generation project in Mississauga - 763 MW capacity,
- Sithe generation project in Brampton - 932 MW capacity.
- Ontario- Hydro Quebec HVdc interconnection 1250 MW capability
- Pickering A generation,
- Richmond Hill MTS #2,Vaughan MTS #3 and Jim Yarrow MTS,
- Thorold GS, 273 MW capacity,
- Hearn GS, 550 MW capacity

- AGSTAR Power 88 MW, 538 MW
- CALPINE Canada 870 MW capability
- Imperial Oil 106 MW, 106 MW
- Lake Erie Interconnection 990 MW capability

All studies assumed that the Middleport 230 kV bus is split in order to meet the operating requirements described in section 3.4.

3.5 Requirement to Split Middleport 230 kV Bus

Under the present system configuration, in order to avoid exceeding the short circuit interrupting capability of the 230 kV Middleport breakers, it is necessary to split the Middleport 230 kV bus for certain generation dispatch conditions. The requirement to split the Middleport bus is affected by the number of 230/500 kV Middleport autotransformers in service and the number of Nanticoke generating units in service.

The Middleport bus can be operated solid when one of the following conditions is met:

- One 500/230 kV Middleport autotransformer is out of service, or
- Four Nanticoke units (230 kV) are out of service,
- Any five Nanticoke units are out of service.

3.6 Description of Study

The impact of the restart of Bruce G3 and G4 on the transmission system transfer capability and the operating limits was investigated in two parts.

Firstly, a power flow linear analysis was performed to indicate the distribution of the additional Bruce output onto the Ontario transmission interfaces and the interconnections. The purpose of this analysis was to give an indication about the possibility of congestion on the interfaces that are affected by the increase in Bruce Complex power output.

Secondly, a transient stability analysis was performed to determine the system performance with the two additional Bruce units in service superimposed on all the other connection projects for which applications were processed.

3.6.1 Effect on Transmission Interface Loading

The restarting of Bruce G3 and G4 will have a considerable effect on power flow, over the ‘Bruce System’. The analysis of the effect of the additional generation on the loading of various transmission interfaces was performed using PTI linear analysis tool.

Previous operating studies determined that with all elements in service the 500 kV and 230 kV Southern Ontario system is constrained by transient and voltage stability and not transmission thermal overloading. Hence, this part of the study did not investigate system outage distribution factors for various contingencies.

Transmission Distribution Factors

The study concentrated on determining the impact of the additional generation on the 'Bruce System' by calculating the distribution of the additional power on various transmission interfaces. A first set of simulations was performed with all elements in service in which Bruce G3 and G4 generation displaced the power generated at various stations in Ontario and all phase angle regulators were disabled. Table 1 below summarizes the system Transmission Distribution Factors for the generation shifts indicated in the first row for the Ontario transmission interfaces.

Table 1. Transmission Distribution Factors – Ontario Interfaces

		Monitored Lines		Base Case	1 Lambton GS	2 Nanticoke GS	3 Pickering GS	4 HQ Interconnection
				MW				
1		**INTERFACE FABC**		**4900**	**100%**	**100%**	**100%**	**100%**
	B560V	BRUCE A 500	CLAIRVIL 500	800	0.16731	0.23762	0.30015	0.29537
	B561M	BRUCE B 500	MILTON 500	937.4	0.1847	0.2731	0.31498	0.30776
	B562L	BRUCE A 500	LONGWOOD 500	944.9	0.27103	0.18989	0.13604	0.14203
	B563L	BRUCE B 500	LONGWOOD 500	976.6	0.26051	0.1792	0.12563	0.13165
	B5V	BRUCE A 220	HANOVRB5 220	243	0.02719	0.03027	0.03315	0.03293
	B4V	BRUCE A 220	HANOVRB4 220	239.6	0.02723	0.0303	0.03317	0.03295
	B22D	BRUCE A 220	WINGJB22 220	246.6	0.02638	0.02398	0.02143	0.02176
	B23D	BRUCE A 220	WINGJB23 220	246.5	0.02638	0.02397	0.02143	0.02176
	B27S	BRUCE A 220	OW SND27 220	130.1	0.0079	0.00997	0.01196	0.01178
	B28S	BRUCE A 220	OW SND28 220	64.5	0.00135	0.0017	0.00205	0.00201
2		**INTERFACE BLIP**		**3500**	**80.6%**	**1.93%**	**3.67%**	**6.84%**
	D4W	DETWEILE 220 1	BUCHANAN 220	76.6	0.05038	0.00141	-0.00467	-0.00238
	D5W	DETWEILE 220 2	BUCHANAN 220	76.6	0.05038	0.00141	-0.00467	-0.00238
	M31W	SALFDJ31 220 1	BUCHANAN 220	249.4	0.03762	-0.01913	-0.01827	-0.01623
	M32W	SALFDJ32 220 1	BUCHANAN 220	232.8	0.04049	-0.02059	-0.01975	-0.01754
	M33W	SALFDJ33 220 1	BUCHANAN 220	268.2	0.04667	-0.02376	-0.02367	-0.02101
	B562L	BRUCE A 500 1	LONGWOOD 500	944.9	0.27103	0.18989	0.13604	0.14203
	B563L	BRUCE B 500 1	LONGWOOD 500	976.6	0.26051	0.1792	0.12563	0.13165
	N582L	NANTICOK 500 1	LONGWOOD 500	683.2	0.04901	-0.28915	-0.15393	-0.14578
3		**INTERFACE FETT**		**-807.5**	**6.9%**	**-.79%**	**95.64%**	**86.24%**
	E8V	ORANGVIL 220	ALLISJE8 220 1	-71.5	0.00144	0.01706	0.03252	0.03094
	E9V	ORANGVIL 220	ALLISJE9 220 1	-71.4	0.00144	0.01706	0.03252	0.03094
	M570V	MILTON 500 1	CLAIRVIL 500	-207.5	0.01225	-0.0148	0.15332	0.16145
	M571V	MILTON 500 2	CLAIRVIL 500	-207.5	0.01225	-0.0148	0.15332	0.16145
	R14T	TRAFALGA 220	ERINJR14 220 1	262.6	-0.01357	-0.01048	0.04798	0.0253
	R17T	TRAFALGA 220	ERINJR17 220 1	262.3	-0.01358	-0.01048	0.04798	0.0253
	R19T	TRAFALGA 220	ERINJR19 220 1	270	-0.01447	-0.01112	0.05099	0.0258
	R21T	TRAFALGA 220	ERINJR21 220 1	272.5	-0.01447	-0.01112	0.05099	0.0258
	B560V	CLAIRVIL 500	BRUCE A 500 1	-800	0.16731	0.23762	0.30015	0.29537
	V586M	CLAIRVIL 500	MIDD8086 500 1	-517	-0.06957	-0.20681	0.08663	0.08001

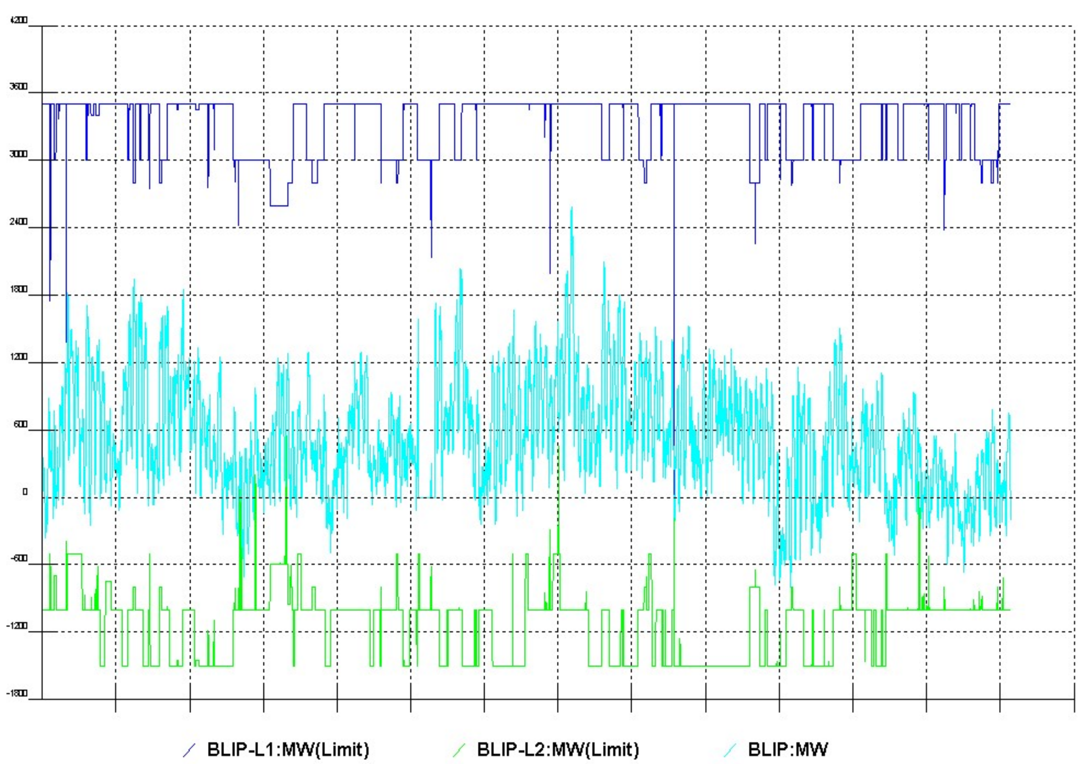
Buchanan Longwood Input

The results indicate that if Bruce generation displaces the generation in Sarnia-Windsor area Ontario about 80% (.8*2*735=1176 MW) of this transfer will show up on Buchanan Longwood Input interface. A brief assessment of summer 2001 historical data, shown in Exhibit A indicated that the BLIP limit was between -1500 MW to 3500 MW and the power transfers over this interface were below 2600 MW. However, with the additional 3000 MW of proposed generation projects in the Sarnia-Windsor area an increase is expected in the negative BLIP flow. It was estimated that for peak load conditions, maximum generation in Sarnia-Windsor area and no transaction over the Ontario-Michigan interface the maximum negative BLIP flow could reach 2250 MW. In this case, the displacement of Sarnia-Windsor area generation by Bruce G3 and G4 results in the unloading of negative BLIP flow and increase of the positive BLIP power flow.

The study results also show that if Bruce generation displaces any other generation in Ontario then its contribution to BLIP flow is insignificant.

It can be concluded that for system peak load conditions the additional Bruce generation could sometimes alleviate the power congestion for high "negative" power flows on the Buchanan Longwood Interface. However, for situation of high westbound power flows on this interface the additional Bruce generation could have a higher or lower degree of contribution to congestion depending on the other generators' dispatch schedule.

Exhibit A. BLIP Transfer/Limit for Year 2001



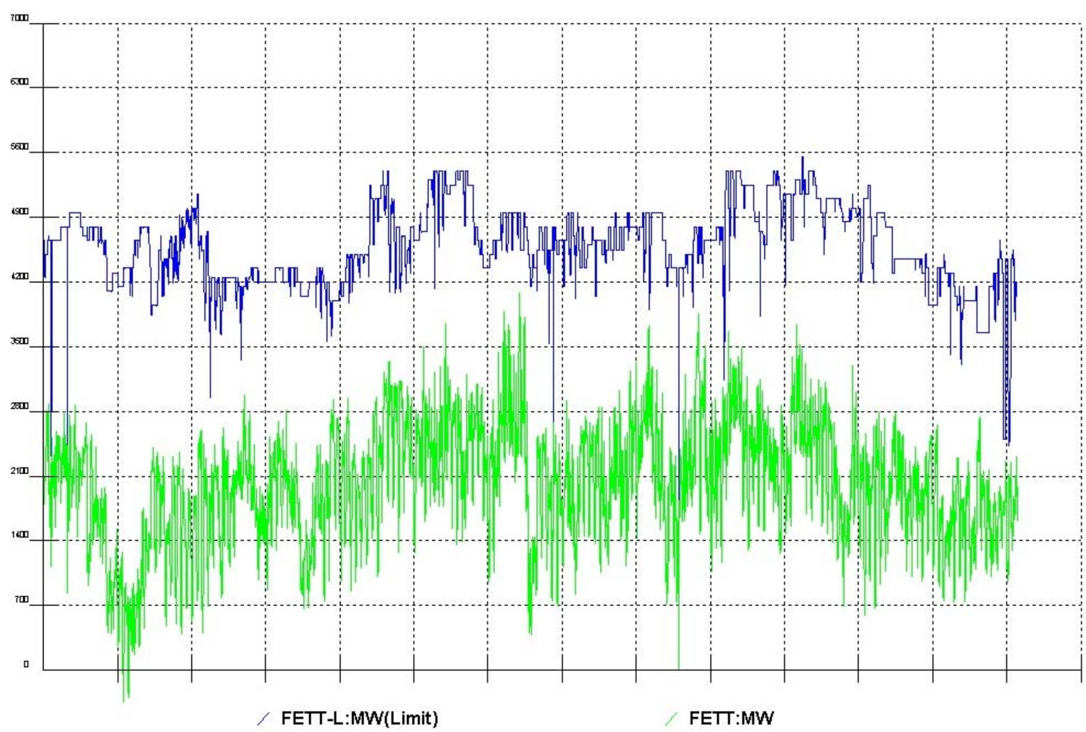
Flow East Towards Toronto

The results indicate that if the Bruce generation displaces Pickering GS generation or imports from Hydro Quebec then most of the Bruce generation will appear on FETT. A brief assessment of year 2001 historical data indicated that the FETT limit was between 3600 MW to 5400 MW and the power transfers over this interface were below 4400 MW. It should be noted that the coincident limit/flow graph in Exhibit B below shows that, with the exception of very short periods of time, the power flows over this interface have been well below its transfer limit.

Using the distribution power factors listed in Table 1, it can be calculated that about 1400 MW (2x735x0.9564=1406 MW) from Bruce G3 and G4 could appear on the FETT interface if this generation displaces Pickering GS. Consequently, it is likely that, under conditions of peak load and maximum generation output from Bruce and Western Ontario generation, congestion will occur on the FETT interface.

It is estimated that during peak load conditions and for particular system scenarios, the additional Bruce G3 and G4 will increase the power flow on FETT interface if Bruce G3 and G4 are to displace generation east of this interface.

Exhibit B. FETT Transfer/Limit for Year 2001



Interconnections

PTI linear analysis was also performed to determine the distribution of the additional Bruce generation over the Ontario tie lines and the results are listed in Table 2 below. The results indicate that highest impact is observed when Bruce generation displaces the generation in Sarnia-Windsor area. Then, the Michigan to Ontario power flow would increase by 19% (.19*2*735 = 280 MW) of the Bruce additional generation.

Table 2. Transmission Distribution Factors – Ontario Interconnections

	Monitored Lines		Base Case	1 Lambton GS	2 Nanticoke GS	3 Pickering GS	4 HQ Interconnection
			MW				
	Ontario - Michigan		**2056.6**	**-19.4%**	**1.93%**	**3.67%**	**6.84%**
J5D	J5D PS 230	19WTRMN 230	203	0.01113	0.00434	0.00823	0.01525
B3N	7SCOTT 220	19B3N PS 220	289.1	-0.02711	0.00275	0.00561	0.01103
L4D	LAMB L4D 345	19STCPP 345	781	-0.09368	0.00641	0.01205	0.02215
L51D	LAMB L51 220	19STCPP 220	783.4	-0.08425	0.00577	0.01084	0.01992
	Ontario-New York @ Niagara		**-449**	**11.75%**	**-2.17%**	**-.63%**	**5.64%**
PA27	PA27 REG 230	NIAGAR2W 230	-164.1	0.02595	-0.00461	-0.0017	0.01044
BP76	BP76 REG 230	PACKARD2 230	-92.5	0.02415	-0.00419	-0.00177	0.00857
PA302	BECK B 345	NIAG 345	-96.1	0.03366	-0.00644	-0.00139	0.01868
PA301	BECK A 345	NIAG 345	-96.3	0.03374	-0.00645	-0.00139	0.01873
	Ontario-Niagara @ St. Lawrence		**69.7**	**6.15%**	**0.25%**	**-2.8%**	**-12.45%**
L33P	STLAWL34 230	MOSES E 230	34.9	0.03355	0.00134	-0.01523	-0.06798
L34P	STLAWL33 230	MOSES E 230	34.8	0.02791	0.00112	-0.01267	-0.05656

It should be noted the possible power flow congestion on the above named interfaces has been assessed using historical system performances that were observed in the regulated market and an estimate of near future generation addition. Hence, these patterns would likely change with the opening of the competitive electricity market in Ontario.

3.6.2 Voltage and Transient Stability Studies

3.6.2.1 System Model

Voltage and transient stability studies were performed to establish whether or not the restart of the two Bruce units in addition to all the other Ontario generation developments that have been so far investigated by the IMO, has an adverse impact on the IMO controlled grid.

Two load flows were set up to model stressed system conditions in order to study post contingency system voltages and dynamic performance with six units in service at Bruce GS. All transmission elements were considered to be in service. The Ontario primary demand load was set at about 25,350 MW and the post contingency load was represented as real power proportional to $V^{1.5}$ and reactive power proportional to V^2.

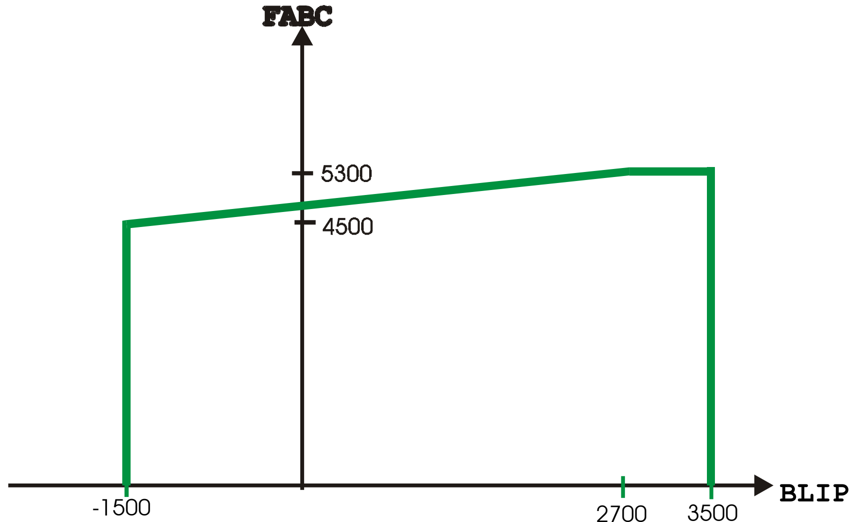


Exhibit C. FABC/BLIP Limit

It should be noted that, the power flow test levels for FABC were selected based on previously established transient and voltage stability operating limits for a system with six units in service at Bruce GS and no generation armed for rejection. In general, with all elements in service and no penalties, the relationship between FABC and BLIP limits is shown in Exhibit C.

However, the FABC operating limit could be lower than shown due to additional penalties owing to generation dispatch, reactor switching, elements out of service and/or low voltages in other operating systems and, summer and winter loading conditions.

In the CAA studies the FABC test power flows were adjusted to match, as close as possible, present system operating limits taking into account all the system penalties that might have to be imposed due to pre-contingency system conditions. To allow for variations in system conditions and modelling inaccuracies the transient stability simulations must be stable for power transfer equivalent to a 10 % margin over the system operating limits.

The characteristics of each load flow case and the results of studies are described in the sections below.

3.6.2.2 Description of Case Studies

The details associated with each test case are presented in this section.

Case A simulates the following system conditions:

- FABC Flow = 4535 MW, representing about 10% over the present operating system limit[1] (including penalties); the operating limit is 4075 MW
- BLIP=-1500 MW, representing current negative BLIP limit,
- FETT= 5080 MW, which is close to the present system limit
- Central –East = 3000 MW, representing high loading of the US restrictive interface.
- Two reactors (2x150 MX) in service at Bruce, which are switched out in post fault

[1] The criteria for voltage and transient stability requires that stable post contingency system behaviour be demonstrated for power flows 10% above the established operating limit.

- No reactors in service at Longwood.

Case B simulates the following system conditions:

- FABC Flow = 4861 MW, representing 10% above the present system limit (including penalties); the operating limit is 4375 MW
- BLIP= 3500 MW, representing current positive BLIP limit,
- FETT= 2655 MW,
- Central –East = 3000 MW, representing high loading of the US restrictive interface,
- Two reactors (2x150 MX) in service at Bruce, which are not switched out in post fault,
- No reactors in service at Longwood.

3.6.2.3 Voltage Decline Study

The post contingency voltage declines were studied only for the most critical contingency, namely the loss of double circuit 500 kV line B560V&B561M.

Case A

The post contingency voltage decline study results for Case A are summarized in tables 3 and 4.

Table 3. Post-contingency Voltage Decline - Study Results for 500 kV Stations

Case A	Voltages at 500 kV Stations (kV)					
	Bruce A	Bruce B	Longwood	Nanticoke	Milton	Claireville
Pre-contingency	549	549	544	536	518	520
Immediate Post-contingency	539	541	515	515	499	504
% Change	**1.82**	**1.46**	**5.33**	**3.92**	**3.67**	**3.08**
Post ULTC Action	532	534	500	500	485	492
% Change	**3.10**	**2.73**	**8.09**	**6.72**	**6.37**	**5.38**

Table 4. Post-contingency Voltage Decline - Study Results for 230 kV Stations

Case A	Voltages at 230 kV Stations (kV)						
	Bruce A	Longwood	Buchanan	Detweiler	Orangeville	Middleport	Burlington
Pre-contingency	250	247	238	237	239	245	239
Immediate Post-contingency	243	236	226	221	221	236	230
% Change	**2.80**	**4.45**	**5.04**	**6.75**	**7.53**	**3.67**	**3.77**
Post ULTC Action	237.00	229.00	215.00	209.00	210.00	228.00	222.00
% Change	**5.20**	**7.29**	**9.66**	**11.81**	**12.13**	**6.94**	**7.11**

An analysis of the post contingency voltage decline shows that the immediate post contingency voltage are within the 10% voltage decline criteria but *after underload tap changers action the 500 kV and 230 kV voltages decline even further. The large voltage declines indicate that the system may be approaching the voltage instability point and that the operating security limit may not be much higher than 4075 MW. Rejecting Bruce generation for this contingency would reduce the post contingency voltage decline and permit higher operating security limits. The effect of deploying the Bruce G/R scheme was not studies here.*

It is likely that under these conditions the full net output (790x4+735x2= 4630 MW) of six Bruce generating units could not be accommodated unless provisions are made for Bruce generation rejection schemes.

The effect of implementing generation rejection has not been studied here because the IMO is currently undergoing a full review of system operating limits in view of DACS decommissioning. New operating limits and requirements for Bruce Special Protection System will be developed.

It can be concluded that for system peak load conditions and high negative BLIP flow, the FABC limit without deploying Bruce generation rejection will, under certain circumstances have to be restricted to less than the full output of six generating units. To eliminate or reduce this restriction it is required that the G3 and G4 participate in the Bruce Special Protection Scheme.

The IMO will be providing a complete set of system operating limits including functional requirements for a simplified "Bruce Special Protection Scheme" as part of the DACS decommissioning project.

Case B

The post contingency voltage decline study results for Case B are summarized in tables 5 and 6.

An analysis of post contingency voltage declines shows that the immediate post contingency voltage are within the 10% voltage decline criteria and the 500 kV and 230 kV voltages remained almost unchanged after underload tap changers action.

Table 5. Post-contingency Voltage Decline - Study Results for 500 kV Stations

Case B	Voltages at 500 kV Stations (kV)					
	Bruce A	Bruce B	Longwood	Nanticoke	Milton	Claireville
Pre-contingency	548	549	520	535	523	526
Immediate Post-contingency	540	542	499	529	513	518
% Change	**1.46**	**1.28**	**4.04**	**1.12**	**1.91**	**1.52**
Post ULTC Action	540	542	498	529	513	518
% Change	**1.46**	**1.28**	**4.23**	**1.12**	**1.91**	**1.52**

Table 6. Post-contingency Voltage Decline - Study Results for 230 kV Stations

Case B	Voltages at 230 kV Stations (kV)						
	Bruce A	Longwood	Buchanan	Detweiler	Orangeville	Middleport	Burlington
Pre-contingency	250	248	242	238	240	245	240
Immediate Post-contingency	248	238	234	232	233	242	237
% Change	**0.80**	**4.03**	**3.31**	**2.52**	**2.92**	**1.22**	**1.25**
Post ULTC Action	248	238	233	231	232	242	237
% Change	**0.80**	**4.03**	**3.72**	**2.94**	**3.33**	**1.22**	**1.25**

It can be concluded that for the system conditions simulated in case B, the FABC limit could be slightly higher than 4375 MW. *Rejecting Bruce generation for this contingency would reduce the post contingency voltage decline and permit higher operating security limits. The effect of deploying the Bruce G/R scheme was not studies here.*

It can be concluded that for system peak load conditions and high positive BLIP flow, the FABC limit without deploying Bruce generation rejection will under certain circumstances have to be restricted to less than the full output of six generating units. To eliminate or reduce this restriction it is required that the G3 and G4 participate in the Bruce Special Protection Scheme.

The IMO will be providing a complete set of system operating limits including functional requirements for a simplified "Bruce Special Protection Scheme" as part of the DACS decommissioning project.

3.6.2.4 Transient Stability Investigation

The purpose of the stability studies was to determine the impact of reconnecting Bruce G3 and G4 units on the transient stability behaviour of the system for various critical faults.

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 in amplitude between oscillations is considered adequate.

The dynamic simulations were performed for a line-to-line-to-ground fault on B560V and B561M at Willow Creek Jct. and a three-phase fault on B560V at Bruce, and records of machine rotor angle variations and buses voltage variations were plotted.

The results of the transient stability runs for Case A are shown in Figures A1 and A2 and for Case B in Figures B1 and B2, both attached at the end of this report.

For all studied cases the system transient stability response was within the general guidelines for stability. It appears that the restart of Bruce G3 and G4 does not aggravate the amplitude or damping of the oscillatory system response to the studied contingencies.

It can be concluded that this project does not affect the transient stability of the power system.

4.0 Fault Levels Analysis

Based on the queue principles of the Connection Assessment and Approval process the impact of reconnecting Bruce G3 and G4 was assessed for a system which incorporates all existing facilities and all the connection projects that are ahead in the queue of the subject application.

Some of the projects that precede the Bruce G3 and G4 restart in the CAA queue, have a considerable contribution to short circuit currents bringing the fault levels, at some switching stations, close to the interrupting capability of existing station breakers. The reconnection of Bruce G3 and G4 will also add to the system short circuit currents. In order to assess this impact the first study case scenario assumed in service all the projects listed in section 3.5 of this report. However, some of the projects included in this maximum scenario will be coming into service after mid 2003. Hence, additional scenarios were created to look at the sensitivity of the fault levels with some of the considered projects out of service.

Thus, the following scenarios were set up:

(A) All in service as per section 3.5 (maximum system representation),
(B) Hearn GS excluded,
(C) Hearn GS and Sithe Goreway excluded,
(D) Hearn GS, Sithe Goreway and Sithe Southdown excluded.

Hydro One Networks Inc. has performed fault level studies to determine the effect of reconnecting Bruce G3 and G4 on the short circuit levels experienced at various transformer stations in the Bruce System and at locations where previous CAA studies indicated that there is a narrow margin between the breaker capability and the fault levels. The monitored stations were selected based on their electrical proximity to the Bruce Complex as listed in the leftmost column in Table 7.

The table below summarizes the results of the short circuit analysis for maximum system representation

Table 7. Fault Levels – Scenario A

Station		**Symmetrical(kA)**		**Asymmetrical(kA)**		**Breaker Ratings**	
		3-phase	**L-G**	**3-phase**	**L-G**	**Symmetrical**	**Asymmetrical**
Claireville 230 kV	**Baseline**	73.58	77.32	94.62	92.01	**80 kA**	**96kA**
	With G3&G4	74.09	77.32	95.28	92.46		
		0.51	**0.38**	**0.66**	**0.45**		
Richview 230 kV	**Baseline**	63.17	57.87	77.19	62.38	**69.5 kA**	**83.4 kA**
	With G3&G4	63.5	58.08	77.6	62.61		
		0.34	**0.21**	**0.41**	**0.23**		
Detweiler 230 kV	**Baseline**	20.49	18.04	22.48	20.42	**39.4 kA**	**46.2 kA**
	With G3&G4	20.7	18.15	22.71	20.54		
		0.21	**0.11**	**0.23**	**0.12**		
Orangeville 230 kV	**Baseline**	15.73	13.43	16.65	14.72	**46.2 kA**	**54.2 kA**
	With G3&G4	15.90	13.52	16.84	14.82		
		0.18	**0.09**	**0.19**	**0.10**		
Buchanan 230 kV	**Baseline**	29.78	25.27	32.67	28.2	**37.1 kA**	**46.2 kA**
	With G3&G4	30.05	25.40	32.96	28.34		
		0.27	**0.13**	**0.29**	**0.14**		
Nanticoke 230 kV	**Baseline**	46.9	46.62	61.3	62.29	**54.3 kA**	**65.6**
	With G3&G4	47.09	46.74	61.59	62.95		
		0.18	**0.12**	**0.29**	**0.16**		

The results presented in Table 7 show that the restart of Bruce G3 and G4 result in a moderate increase in short circuit currents at various IMO-controlled grid switching stations. The calculations show that the fault levels at most of the monitored stations are well below the interrupting capability of the station breakers even after the reconnection of G3 and G4 at Bruce GS. From all the stations that were monitored in the study, the largest increase in short circuit levels due to the two units' restart was observed at Claireville TS where the asymmetrical short circuit levels increase by 660 A to a value of 95.28 kA. Although this value does not exceed the rating of the existing breakers it is getting close to their current interrupting capability.

It is likely that the next major generation project could bring the fault levels at Claireville TS over the interrupting capability of the existing breakers thus triggering the need to split Claireville TS.

The results for scenarios B, C and D have not been summarized because the outcome from scenario A indicates that existing breakers' ratings are not exceeded.

The short circuit study results show that, for the monitored 230 kV switching stations, the increase in fault levels due to the restart of Bruce GS units G3 and G4 results in short circuit currents which do not exceed the interrupting capability of the existing circuit breakers.

5.0 Conclusions and Recommendations

The following conclusions can be drawn from the results of the preliminary assessment for the Bruce 'A' G3 and G4 restart proposal:

1. The restart of Bruce 'A' G3 and G4 will not affect the existing power transfer limits of the studied interfaces in Ontario.

2. Bruce G3 and G4 exciter systems meet the *Marker Rules* transient response requirements.

3. The Bruce Special Protection System is adequate for handling up to six Bruce units in service, hence the proposed restart of two Bruce generating units does not trigger the need to revise of the Bruce Special Protection System.

4. Bruce units G3 and G4 are required to participate in the Bruce Special Protection System.

5. For system peak load conditions and high "negative" power flows on the Buchanan Longwood interface, Bruce generation could alleviate the power congestion on this interface.

6. For system peak load conditions and high positive westbound power flows on thr Buchanan Longwood interface the additional Bruce generation could have a higher or lower degree of contribution to congestion, depending on the other generators' dispatch schedule.

7. During peak load conditions and for particular system scenarios, the additional Bruce generation will contribute to congestion on FETT interface.

8. For the high negative BLIP power flows, the FABC flow at 4075 MW is approaching the voltage stability limit, but higher operating limit will be obtained with the implementation of post contingency generation rejection controls.

9. For high positive BLIP flows the FABC limit could be slightly higher than 4375 MW and, a further increase in operating limits could be obtained with post contingency generation rejection or controls.

10. This project does not affect the transient stability of the IMO-controlled grid.

11. The short circuit study results show that, for the monitored 230 kV switching stations, the increase in fault levels due to the restart of Bruce ‘A’, units G3 and G4, results in short circuit currents which do not exceed the interrupting capability of the existing circuit breakers.

6.0 IMO Requirements

This section summarizes the requirements identified during this Connection Assessment for re-incorporating of Bruce ‘A’ G3 and G4 generating units into the *IMO-controlled grid*.

1. The generating units’ connections are not equipped with low voltage breakers, hence the 500 kV breakers are to be used for synchronizing duty. The two 500 kV synchronizing breakers must be capable of sustaining 2.0 p.u. voltage across their open terminals to ensure out of phase switching capability.

2. Operation at unit’s *Maximum Continuous* rating is allowed – in accordance with the *Market Rules* (Chapter 7 paragraph 9.4.5) – provided that, when necessary, the IMO shall direct the generator to reduce its active power output in order to produce *reactive support* within the range required by the *Market Rules.* If such instruction is issued by the IMO then Bruce Power must reduce its MW output and Bruce Power shall not be entitled to a *congestion management settlement credit*.

3. Bruce ‘A’ G3 and G4 are required to participate in the generation rejection scheme that forms integral part of the Bruce Special Protection System. Full duplication of the primary communication and logic facilities for the generation rejection scheme is required.

4. Bruce Power L.P. must complete the IMO facility registration process including meter registration before bringing G3 and G4 in service.

5. Hydro One Networks Inc. has indicated that the Customer Impact Assessment process is not required for this project.

6. A separate System Impact Assessment is not required because the scope of the Preliminary Assessment was expanded to include the transient stability analysis.

7.0 Budgetary Cost Estimates

As no major modifications are required to incorporate G3 and G4 but only minor work associated with protection reviews and witness verification during commissioning, Hydro One Networks Inc. has notified that budgetary cost estimates are not applicable.

8.0 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 Bruce Power L.P. for the restart of units G3 and G4:

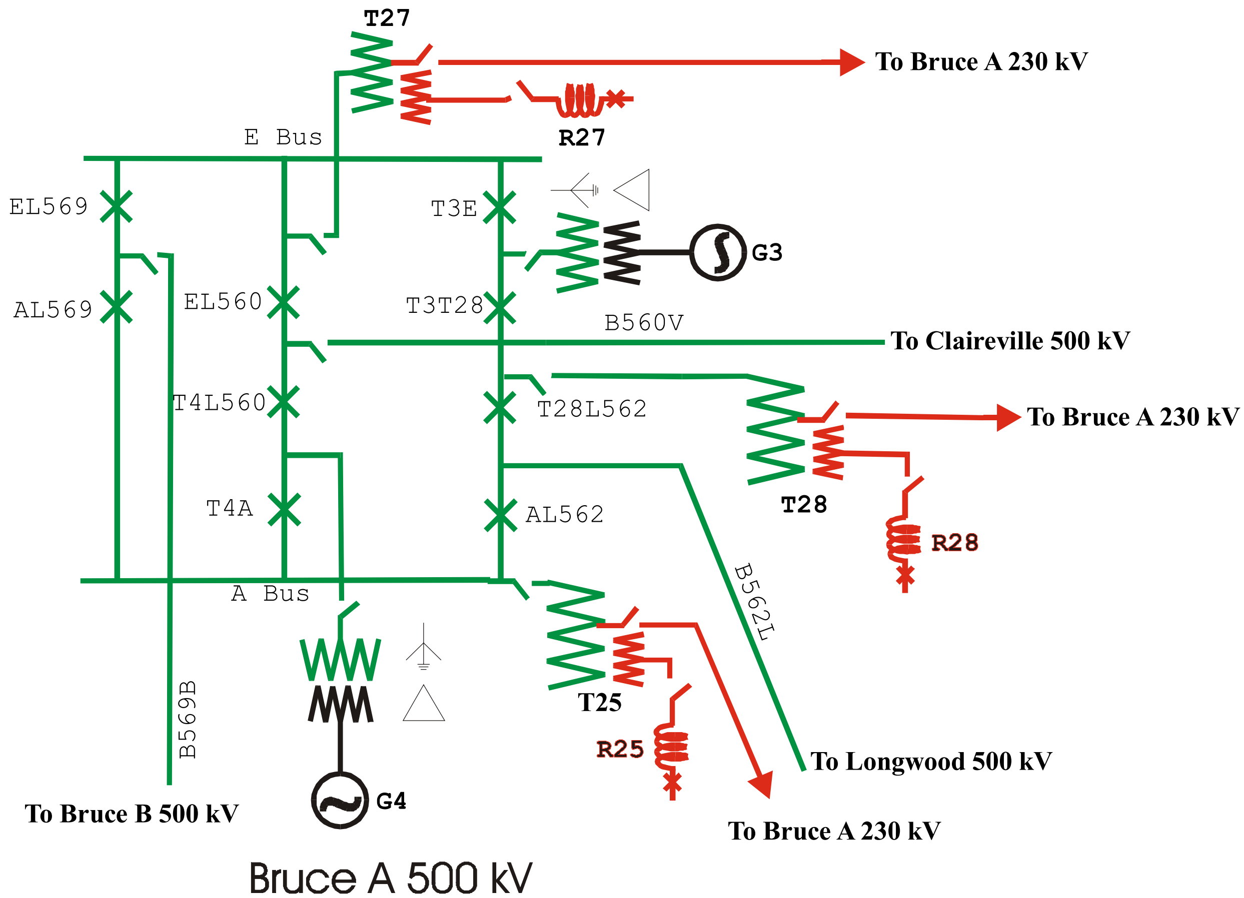
(a) All work related to the review of existing facilities and/or installation of new facilities required for participation of G3 and G4 in the Bruce Special Protection System scheme.

(b) All the facilities required for connecting Bruce 'A' G3 and G4 to the Bruce 500 kV switchyard.

9.0 Notification of Approval

This Connection Assessment has investigated the impact of restarting Bruce 'A', G3 and G4 generating units, on the reliability of the *IMO-controlled grid* and has identified IMO's requirements for connection to ensure the project does not adversely affect on the reliability of the *IMO-controlled grid*.

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



T3 Data
Three Single Phase
267 MVA
525/17.6 kV
X_1 12.13%; 12.13%;12.26%
On 267 MVA base

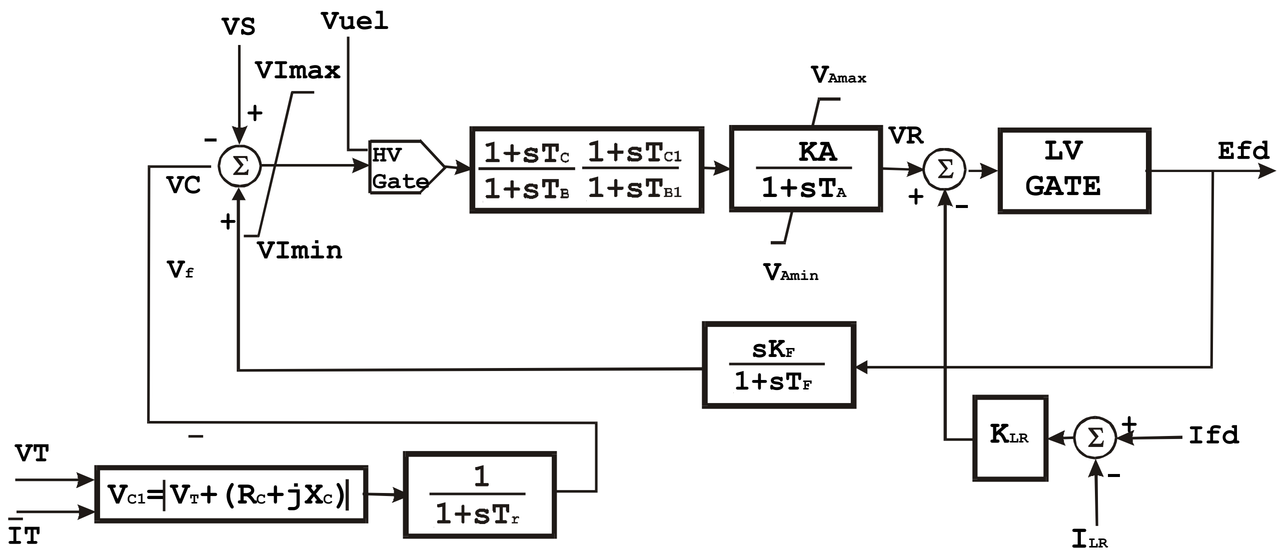
T4 Data
Three Single Phase
267 MVA
525/17.6 kV
X_1 12.02%; 12.01%;12.06%
On 267 MVA base

Generator Data: On 889 MVA base H 6.47 kW-sec/kVA

X_d	1.75pu	X_q	1.72pu	X_2	0.26pu	T'_{do}	8.5sec	T'_{qo}	1.24pu
X'_d	0.427pu	X'_q	0.65pu	X_0	0.123pu	T''_{do}	0.037sec	T''_{qo}	0.074pu
X''_d	0.265pu	X''_q	0.228pu	X_l	0.265pu				

Figure 1. Bruce A500 kV Station Layout and Generator Data

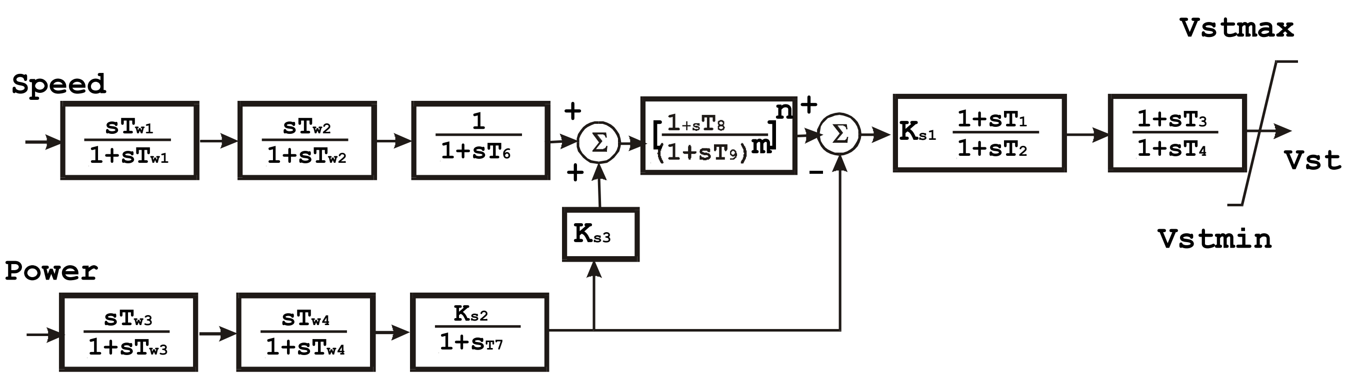
IEEE Type ST1A Exciter Model



T_R=0.02 T_B=1.0 T_C=1.0 T_{C1}=1.0 T_{B1}=1.0 KA=172 T_A=0.0 VImax=9999 VImin=-9999

V_{Rmax}=8.89 V_{Rmin}=-1.85 V_{Amax}=9999 V_{Amin}=-9999 Kc=0.143 K_F=0.0 T_F=1.0 X_C=0.0 R_C=0.0

IEEE Type PSS2A Dual-Input Stabilizer Model



T_{w1}=10.0 T_{w2}=15.0 T_6=0.0 T_{w3}=10.0 T_{w4}=0.0 T_7=15.0 K_{S2}=1.159 K_{S3}=1.0 T_8=0.3 T_9=0.15

K_{S1}=20.0 T_1=0.065 T_2=0.021 T_3=0.065 T_4=0.021 V_{STmax}=9999 V_{STmin}=-9999 n=2 m=4

FIGURE 2. Exciter and Stabilizer Models for Bruce A, G3 and G4

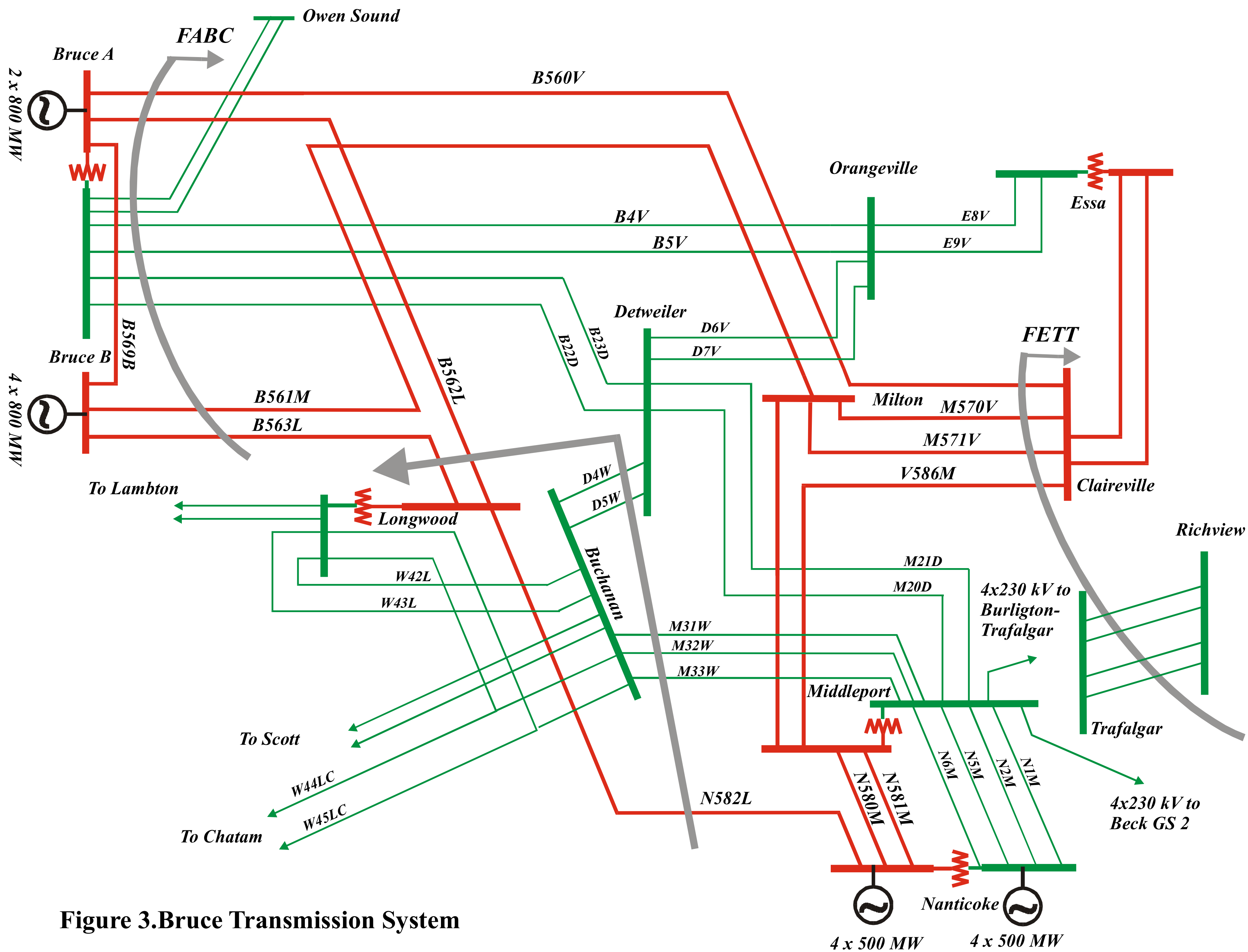


Figure 3.Bruce Transmission System

BRUCE021, BLIP=3500, FABC=4900
2LB8N1LK4D6B7P2LX, MIDDLEPORT 220 SPLIT

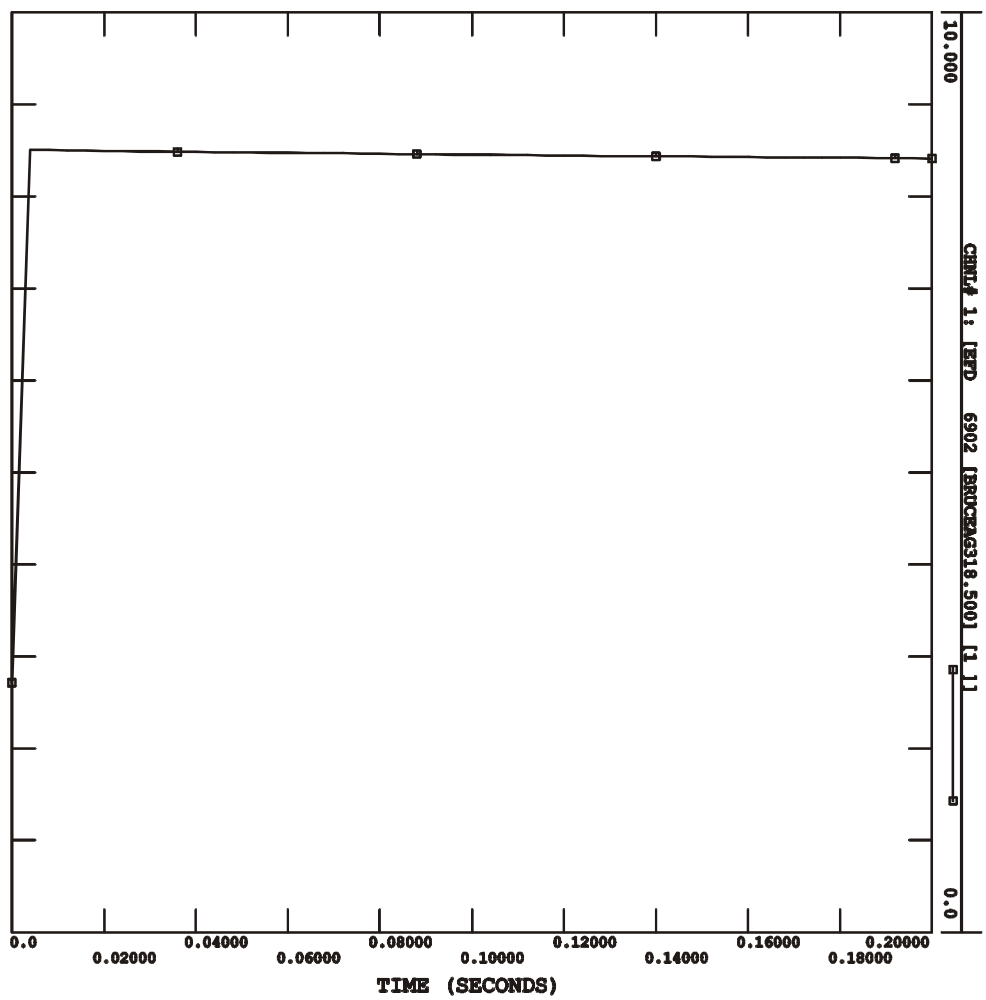
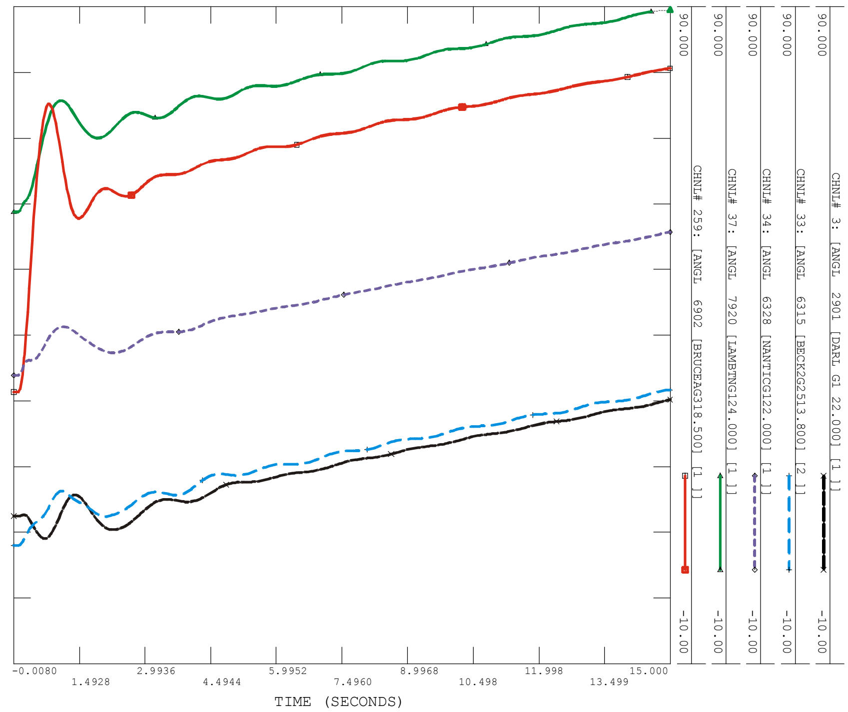


Figure 4. RESPONSE RATIO TEST

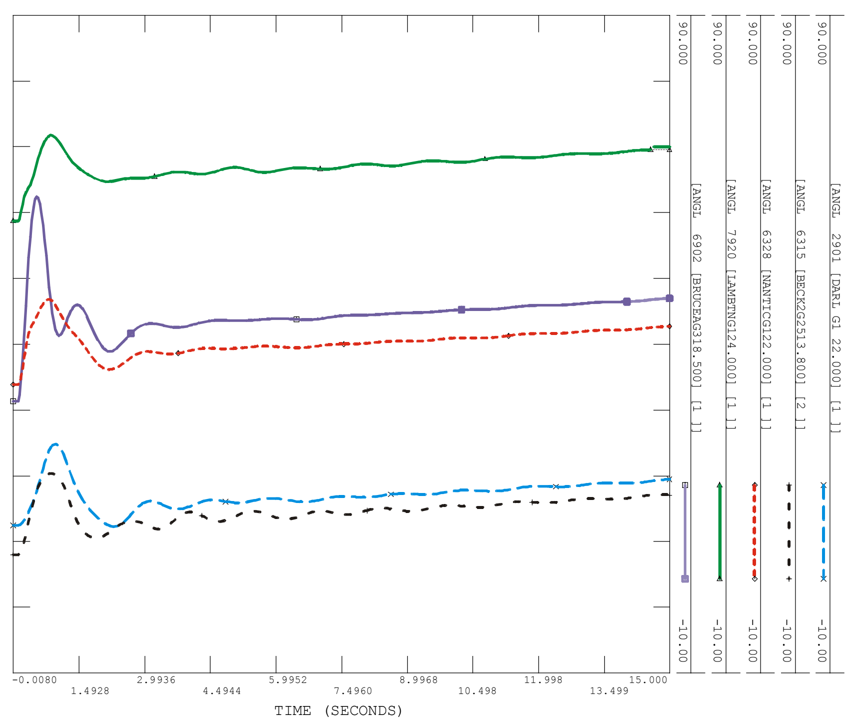
POWER TECHNOLOGIES, INC.

BRUCE008 BLIP=-1500, FETT=5050, FABC=4535, 2R@BRUCE
MIDDLEPORT 230KV BUS SPLIT, GENERATION AT ERIE W REVERSED.

CASE A



Double Line to Ground Fault on B560V&B561M



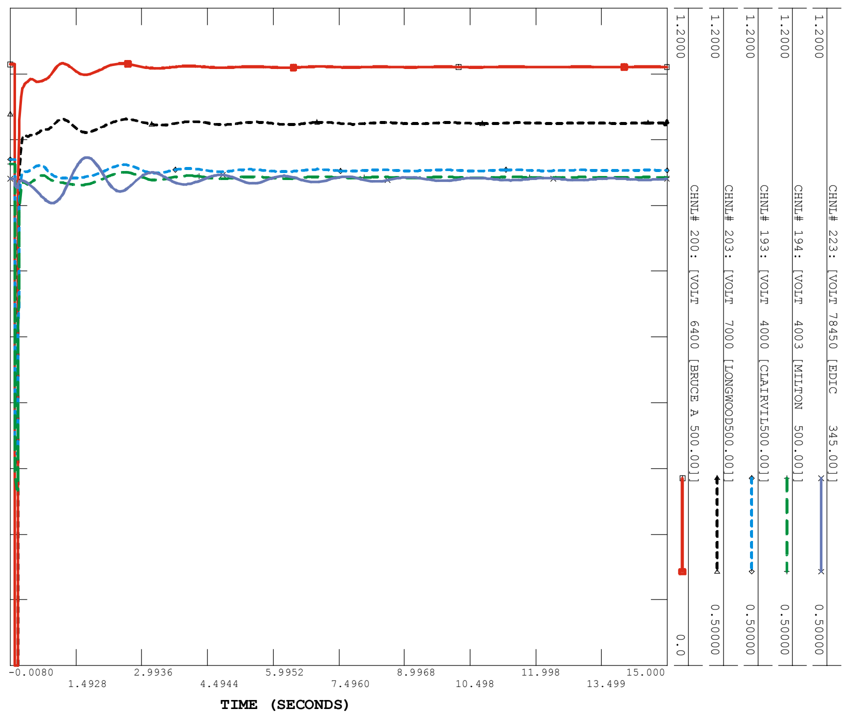
Three Phase Fault on B560V at Bruce

Figure A1.Rotor ANGLES

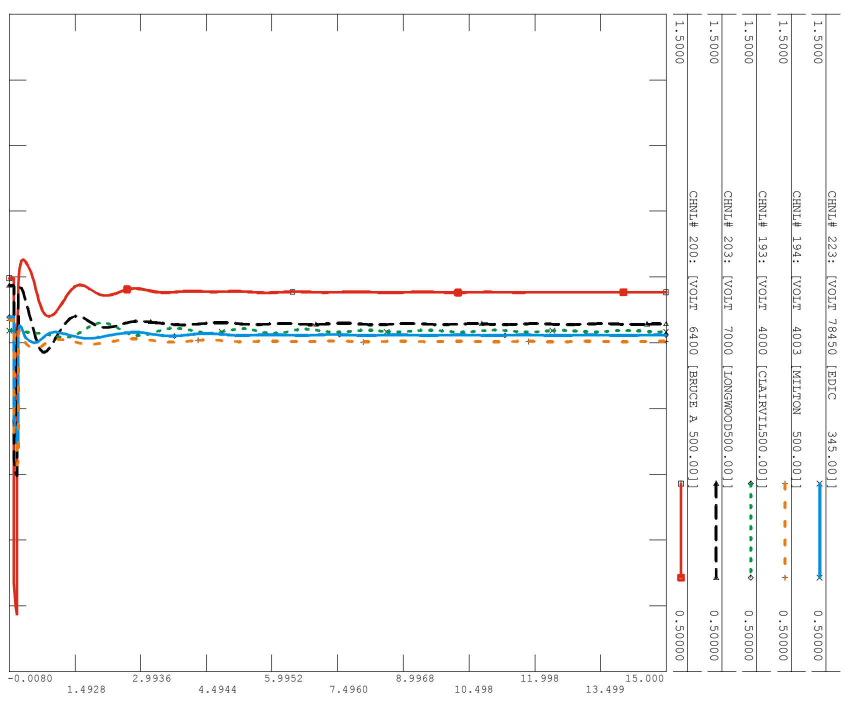
BRUCE008 BLIP=-1500, FETT=5050, FABC=4535, 2R@BRUCE
MIDDLEPORT 230KV BUS SPLIT, GENERATION AT ERIE W REVERSED.

POWER TECHNOLOGIES, INC.®

Case A



Double Line to Ground Fault on B560V&B561M

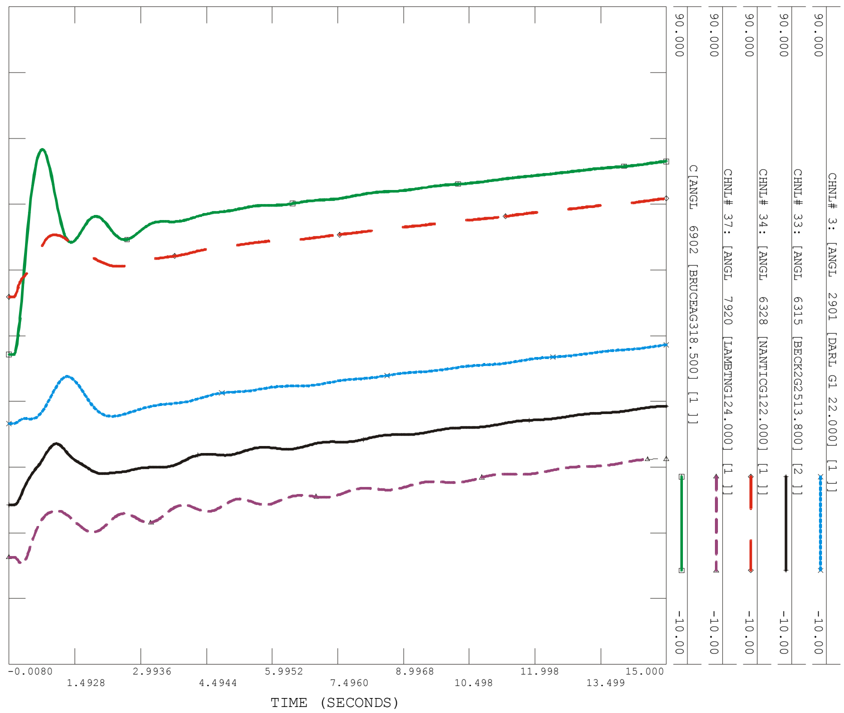


Three Phase Fault on B560V at Bruce

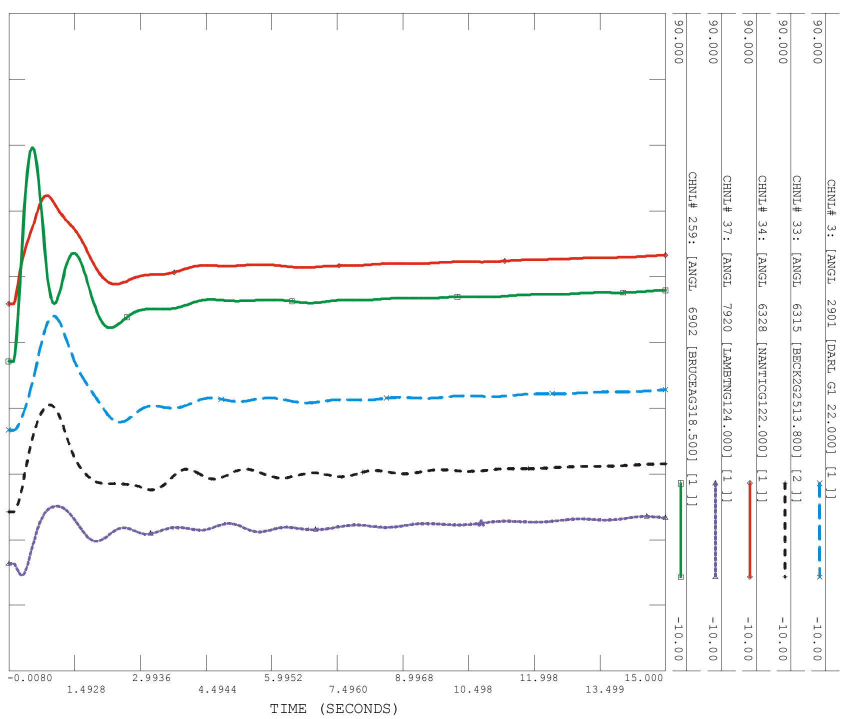
Figure A2. Voltages

POWER TECHNOLOGIES, INC.®

BRUCE021, BLIP=3500, FABC=4900
2LB8N1LK4D6B7P2LX, MIDDLEPORT 220 SPLIT
CASE B



Double Line to Ground Fault on B560V&B561M



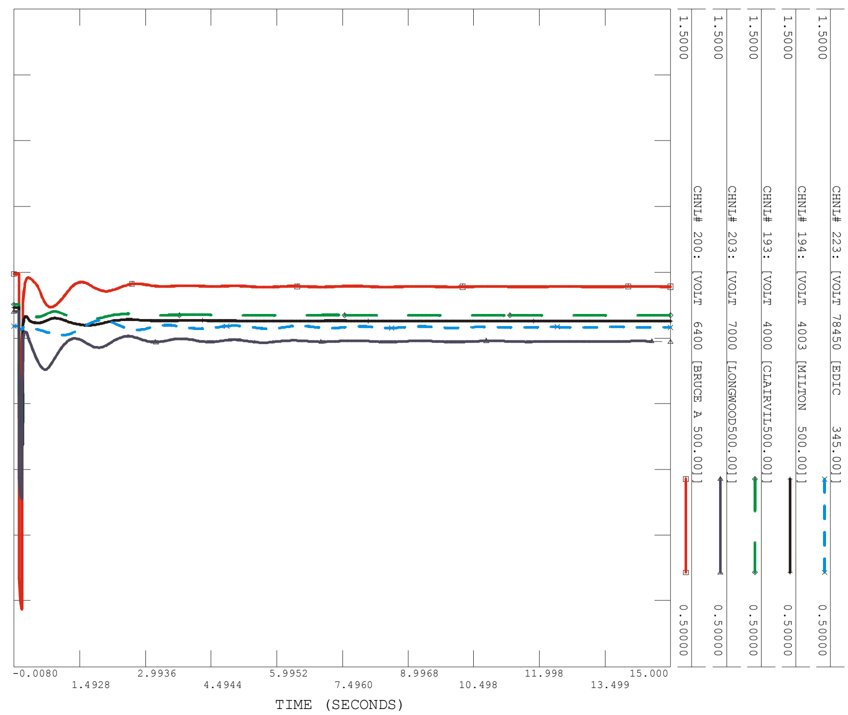
Three Phase Fault on B560V at Bruce

Figure B1.Rotor ANGLES

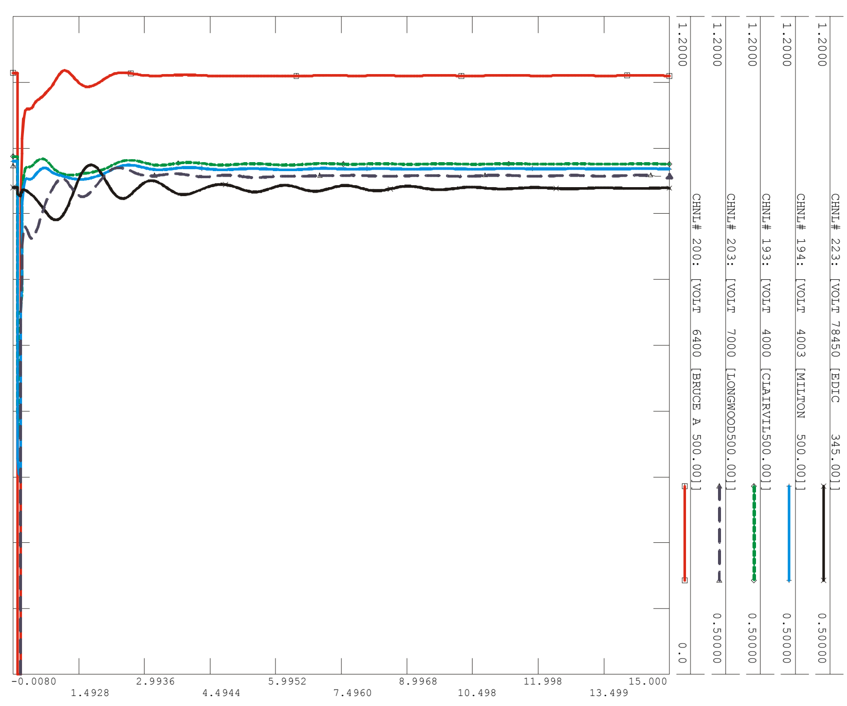
POWER TECHNOLOGIES, INC.®

BRUCE021, BLIP=3500, FABC=4900
2LB8N1LK4D6B7P2LX, MIDDLEPORT 220 SPLIT

Case B



Double Line to Ground Fault on B560V&B561M



Three Phase Fault on B560V at Bruce

Figure B2. Voltages