IMO_REP_0027

CONNECTION ASSESSMENT & APPROVAL PROCESS

Preliminary Assessment Report
Lake Erie Interconnection Project

CAA ID 2000-017

Final

Long Term Forecasts & Assessments Department

May 31, 2001

Station A Box 4474 Toronto On M5W 4E5 Canada, Tel. 905.855.6406 fax 905.855.6373 www.theIMO.com

Preliminary Assessment Report

Lake Erie Interconnection Project

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.

1.0 Proposal Description

TransÉnergie US Ltd. and Hydro One Inc. have submitted a proposal to construct an interconnection facility comprised of three High-Voltage direct current (HVdc) links connected in parallel across Lake Erie. The maximum capability of the interconnection will be 990 MW. The ultimate stage of the proposed project has three converters in Ontario connected to the 230 kV switchyard at Nanticoke TGS, and the other three converters connected to the Erie-West 345 kV station in Pennsylvania or at a 345 kV connection point close to Ashtabula tap in Ohio, with direct current connection cables under Lake Erie.

The proposal includes three identical HVdc bipoles connected in parallel, each with a capacity of 330 MW. The proponent has indicated that they are prepared to develop a firm project scope based on the findings of the preliminary assessment with respect to the project local impact on the IMO-controlled grid.

The in service date for the proposed project is 2004.

2.0 Connection Arrangement

The proposed connection arrangement that was submitted with the Preliminary Assessment application is shown in Figure 1. 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 switchyard via one single in-line breaker. Figure 2 shows the proposed ultimate arrangement. It should be noted that under this arrangement the entire interconnection would be lost under conditions of one breaker outage.

To eliminate the possibility of losing the entire interconnection due to one breaker open condition, the IMO proposes an alternative connection arrangement as shown in Figure 3.

Arrangement A. In the new arrangement each converter is 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.

Arrangement B. There is one other connection possibility (not shown in Figures) whereby one line termination, N1M for example, could be placed in the middle position of the new diameter (between the two bipoles) and the middle bipole could be terminated between L1L22 and K1L1 breakers. Although this arrangement would eliminate the possible loss of two bipoles, it has one major disadvantage; with this arrangement it is not possible to completely isolate the interconnection (if required) without also taking out one 230 kV circuit.

Alternatively, the same interconnection capability may be achieved by installing two larger bipoles in parallel, with an individual capability of 495 MW. This option could be less expensive than the original proposal since it requires only four converters as opposed to six. It should be noted that the connection at the Nanticoke 230 kV switchyard will likely require the same number of breakers to ensure that a stuck breaker condition does not result in the loss of both bipoles. This will avoid the introduction of a new largest contingency.

3.0 Facility Design Verification

HVdc Dynamic Model

The applicant has submitted a detailed HVdc model that was developed by ABB, for incorporation in the system dynamic model. For reference, the parameters for the Hvdc Light bipole model are show in Exhibit 3.1.

An initial verification of the HVdc model was performed by integrating the HVdc Light models (CHVDCL & PWRHL2) provided in FLEX format with the Preliminary Assessment Application into the system dynamic model. A system snapshot was taken with the HVdc model and the dynamics was initialized with the data provided. The HVdc model initialized without errors during the start of the transient simulation.

Exhibit 3.1: Dynamic Models Applied to the HVDC Light Link at Nanticoke

```
REPORT FOR ALL MODELS                                  BUS  5106 [NANHVDC1 192]
                 *** CALL CHVDCL(        5234,       11395) ***

                            MBASE        ZSOURCE
                           360.00   0.00000+J 0.17000

   BUS NAME    BSKV MID      ICON'S       CON'S         STATE'S       VAR'S
  5106 NANHVDC1 192  1    6268-  6272 149096-149102  52031- 52033 10653-10659

       CTRL_MODE  BLOCK_FLG   REGULATED_BUS   IND_OPERATION  REACTIVE_CTRL
           1          0         0                   0             0
                  Tpo     AC_VC_int_limit   AC_Vctrl_kp    Tac
                 0.0500         1.0000         2.4000     0.0100
                          Tacm       Iacmax       Droop
                         0.0100      1.0000      0.0000

                 *** CALL PWRHL2(        5234,       11401) ***

   BUS NAME    BSKV MID      ICON'S       CON'S         STATE'S       VAR'S
  5106 NANHVDC1 192  1    6298-  6300 149138-149141  52049- 52050 10695-10704

                 VSC STATION 2    MACHID   POWER_CTRL_STATION
              5109 ERWHVDC1 220      1             1

                  Udc_ref       Rdc         Tpo       Tpo_lim
                 300.0000      1.2000      0.0500      0.0500
=============================================================================
REPORT FOR ALL MODELS                                  BUS  5107 [NANHVDC2 192]
                 *** CALL CHVDCL(        5235,       11396) ***
                            MBASE        ZSOURCE
                           360.00   0.00000+J 0.17000

   BUS NAME    BSKV MID      ICON'S       CON'S         STATE'S       VAR'S
  5107 NANHVDC2 192  1    6273-  6277 149103-149109  52034- 52036 10660-10666

       CTRL_MODE  BLOCK_FLG   REGULATED_BUS   IND_OPERATION  REACTIVE_CTRL
           1          0         0                   0             0

                  Tpo     AC_VC_int_limit   AC_Vctrl_kp    Tac
                 0.0500         1.0000         2.4000     0.0100
                          Tacm       Iacmax       Droop
                         0.0100      1.0000      0.0000

                 *** CALL PWRHL2(        5235,       11402) ***

   BUS NAME    BSKV MID      ICON'S       CON'S         STATE'S       VAR'S
  5107 NANHVDC2 192  1    6301-  6303 149142-149145  52051- 52052 10705-10714

                 VSC STATION 2    MACHID   POWER_CTRL_STATION
              5110 ERWHVDC2 220      1             1

                  Udc_ref       Rdc         Tpo       Tpo_lim
                 300.0000      1.2000      0.0500      0.0500
===================================================================================
REPORT FOR ALL MODELS                                  BUS  5108 [NANHVDC3 192]
```

```
*** CALL CHVDCL(        5236,       11397) ***
                            MBASE        ZSOURCE
                           360.00   0.00000+J 0.17000

   BUS NAME    BSKV MID      ICON'S       CON'S         STATE'S       VAR'S
  5108 NANHVDC3 192  1    6278-  6282 149110-149116  52037- 52039 10667-10673

       CTRL_MODE  BLOCK_FLG   REGULATED_BUS   IND_OPERATION  REACTIVE_CTRL
           1         0         0                   0             0
                  Tpo     AC_VC_int_limit   AC_Vctrl_kp    Tac
                 0.0500         1.0000         2.4000     0.0100
Tacm        Iacmax       Droop
                         0.0100      1.0000      0.0000
                 *** CALL PWRHL2(        5236,       11403) ***

   BUS NAME    BSKV MID      ICON'S       CON'S         STATE'S       VAR'S
  5108 NANHVDC3 192  1    6304-  6306 149146-149149  52053- 52054 10715-10724

                 VSC STATION 2    MACHID   POWER_CTRL_STATION
              5111 ERWHVDC3 220      1             1
                  Udc_ref       Rdc         Tpo       Tpo_lim
                 300.0000      1.2000      0.0500      0.0500
```

As an additional test of the system model with the proposed interconnection incorporated, a dynamic simulation for a three-phase fault on circuit N2M at Nanticoke 230 kV, cleared in normal time was run to 10 seconds. The results of this simulation that are shown in Figures 5a and 5b reveal a well-damped and stable transient response of the power system. Figure 5a shows the generator angle response to the fault for selected units at Nanticoke GS, Pickering GS, Beck GS, Lambton GS, Bruce GS and Darlington GS. Figure 5b represents the response of system voltages measured at Nanticoke, Beck, Claireville and Lambton.

A detailed transient stability study will be conducted during the System Impact Assessment for this project.

Auxiliary Equipment

Each Hvdc converter will operate at an ac voltage of 191.5 kV and will be connected to the terminal stations via three single phase transformers. At the Nanticoke terminal the three 191.5/230 kV single phase transformers that will be connecting each HVdc converter are rated at 120 MVA each. Detailed information on the transformer data is shown in Figure 3. It should also be noted that the applicant indicated that the taps are located on the low voltage side of the transformer.

Reactive Power Requirements

The following is a description of the HVdc Light model incorporation in the system PTI load flow.

Two generators were used to model each pair of 330 MW HVdc converters. To represent import scenarios, one generator with positive active output was connected at Nanticoke bus and the other with a negative active output connected at Erie West bus in Pennsylvania. The sign on the generators is reversed when Ontario is exporting to Pennsylvania. Each converter has an ac filter bus that is connected to the local ac system bus via a step-up transformer. The ac filter bus was modeled as a 191.5 kV bus. The step-up transformer reactance is X=17.4% on 360 MVA base. The transformer has +/- 14 taps (+/-21%) on the low side. The ac filter bus voltage was controlled to 200 kV by the transformer taps. The transformer tap range is from 151.3 kV to 231.5 kV with each tap representing a step change of 2.87 kV. *This range was adequate to control 200 kV on the filter bus.*

The net reactive capability of the HVdc system 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 reactive range of the generators were set to 130 MVar in order that the HVdc delivered about 80 MVar to the ac bus. This was required to compensate for reactive losses. The applicant recommended this since the +/-72 MVar capability is as measured on the high voltage, ac system bus.

4.0 Transfer Capability Assessment

The preferred alternative for connecting the proposed HVdc facility is shown in Figure 3. The single line diagram shows that the three HVdc converters are to be connected to the Nanticoke TGS switchyard via new transmission facilities which include breakers, disconnects and short span transmission lines. It is required that all new transmission facilities be rated to carry the maximum power transfers and meet the current interrupting capability specified by the transmitter.

4.1 Description of Existing Facilities

Nanticoke TGS consists of 8 generating units each rated at 500 MW with a net generation to the system of 485 MW (15 MW service the station load). Four of the eight units are connected to the 230 kV switchyard. A detailed diagram of the Nanticoke 230 kV switchyard existing facilities is also shown in Figure 3.

The following transmission facilities represent the egress from the 230 kV switchyard of Nanticoke GS:

- two 230 kV double circuit lines to Middleport TS; N1M and N2M on the east double circuit tower structure and N5M and N6M on the west double circuit tower structure,
- two x 750 MVA auto-transformers, T11 & T12 to Nanticoke 500 kV switchyard,
- two 230 kV circuits, N21J and N22J supplying the Stelco and Jarvis radial load .

The system diagram shown in Figure 4 represents the 230 kV and 500 kV transmission system out of Nanticoke TGS with particular emphasis on the eastbound transmission. As shown in Figure 4, Caledonia TS with a summer peak of about 46 MW and Imperial TS, with a station capability of 83 MW are tapped off the 230 kV circuits N1M, N5M and N2M, respectively. The 230 kV radial circuits N21J and N22J supply the Stelco and Jarvis loads which peak at about 120 MW total (value obtained from year 2000 records).

The 230 kV circuits between Nanticoke and Middleport are equipped with 1843.2 ACSR type conductor with 72/7 aluminum to steel strands and are rated for a maximum annealing operating temperature of 93^{O}C. However, the conductors sag operating temperature limit is 127 ^{O}C. It has been indicated by HONI that operation to the sag temperature must be limited to 50 hours per year in order to achieve a 40-year life span of the conductor.

Table 1 below lists the summer and winter ratings of these circuits.

Table 1. Nanticoke to Middleport 230 kV Circuits Ratings

Circuit	*Summer (35 ^{O} C, 4km/h)**			*Winter(10 ^{O} C, 4km/h)**	
	Continuous Rating		*15 minute LTR*	*Continuous Rating @ 93^{O}C*	*15 minute LTR @ 93^{O}C*
	@ 93^{O}C	*@127^{O}C*	*@ 93^{O}C*		
N1/2M, N5/6M	1350 A	1790 A	1640 A	1660 A	2010 A
	561 MVA	***744 MVA***	682 MVA	690 MVA	835 MVA

* MVA Rating calculated on 240 kV

The transmission system that runs northeast of Middleport TS 230 consists of:
- two 230 kV double circuit lines terminating at Burlington TS (M27/28B andQ23/25BM),
- three 230 kV lines going to Beach TS (M34H, Q24HM and Q29HM), two of which continue to Beck TS (Q24HM and Q29HM) and
- one 230 kV circuit going to Allanburg TS (Q30M).

There are also two 230 kV circuits connecting Beach TS to Burlington TS (B18/20H).

Table 2 below lists the summer and winter ratings of these circuits.

Table 2. Middleport out 230 kV Circuits Ratings

Circuit	*Summer (35 ^{O} C, 4km/h)**		*Winter(10 ^{O} C, 4km/h)**	
	Continuous Rating	*15 minute LTR*	*Continuos Rating*	*15 minute LTR @ 93^{O}C*
B20H/B18H 1192.5/150 ^{O} C	1580 A	1830 A	1730 A	2010A
	657 MVA	761 MVA	719 MVA	835 MVA
Q23BM 1192.5/104 ^{O} C	1180 A	1360 A	1390 A	1730 A
	491 MVA	565 MVA	578 MVA	719 MVA
Q25BM 1192.5/115 ^{O} C	1290 A	1480 A	1480 A	1810 A
	536 MVA	615 MVA	615 MVA	752 MVA
M27B/M28B 1192.5/116^{O} C (Southcote to Horning section)	1300 A	1490 A	1490 A	1820 A
	540 MVA	619 MVA	619 MVA	756 MVA

* MVA Rating calculated on 240 kV

It should be noted that the circuit ratings presented in Tables 1 and 2 have been calculated under conservative system voltage assumptions.

4.2 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 under certain generation dispatch conditions. The requirement to split the Middleport bus is affected by the number of 230/500 kV Middleport autotransformers 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
- At least four Nanticoke units (230 kV) are out of service.

4.3 Study Assumptions

The load flow used in this study originated from the summer 2000 peak system conditions base case. Included in the system model were all the projects that have already received from the IMO approval for connection. These projects include the Sarnia/Windsor generation projects and the Sithe generation projects as follows:

- TransAlta generation project in Sarnia - 580 MVA capacity,
- ENRON generation project in Sarnia - 610 MVA capacity,
- AES generation project near Leamington - 625 MVA capacity,
- ATCO generation project in Windsor - 680 MVA capacity,
- Sithe generation project in Mississauga - 898 MVA capacity,
- Sithe generation project in Brampton - 1096 MVA capacity.
- Ontario- Hydro Quebec HVdc interconnection 1250 MW capability

This study was performed assuming all existing facilities in service.

All studies assumed that the Middleport 230 kV bus is split in order to meet the operating requirements described in section 4.2.

The impact of the proposed interconnection on transfers over other Ontario interconnection interfaces was briefly investigated.

4.4 Effect on Transmission Thermal Loading

Power transfers across the proposed Lake Erie HVdc link to Nanticoke 230 kV bus will have a considerable effect on the power flow over the 230 kV transmission from Nanticoke TGS to Middleport TS to Burlington TS, and also from Nanticoke 500 kV to Milton to Claireville TS and further to Cherrywood TS. However, the preliminary assessment concentrated on identifying the effect that the proposed project has on the 230 kV system.

In order to monitor the effect of these power transfers on various transmission paths, two new transmission system interfaces were defined as shown in Figure 4. These interfaces are:

- Nanticoke to Middleport 230 kV comprising of the 230 kV circuits N1M, N2M N5M and N6M,
- Middleport to Burlington comprising of three 230 kV double circuit lines; B20H & B18H, Q25BM & Q23BM, and M27B & M28B.

Transfer limits for these two interfaces have not been defined for the existing power system because the operating conditions experienced until now did not result in any limitations over the above named interfaces. With the addition of up to 990 MW of injection or take-off at Nanticoke 230 kV bus it was estimated that possible limitations could arise. Therefore, part of this assessment concentrated on establishing maximum transfer capability for these transmission corridors and ensuring that those limits will not be exceeded.

Hence, the studies addressed two main aspects of the impact of this project on the power transfer capability of the surrounding transmission system in the area of Nanticoke. As a start, studies were performed to determine the maximum power transfer capability and the critical contingencies associated with these transmission corridors. Then, the studies investigated the contribution of the proposed development on the power transfers over these interfaces.

Special attention was given to the *import scenario* because it results in increased power flow conditions over the IMO controlled grid.

The *export scenario* was also studied to identify if any special operating requirements could be necessary to support exports at the full capability of the interconnection.

4.5 Definitions of New Transfer Limits

The interface flows created based on the interface definitions presented in section 4.1 are presented in the paragraphs below.

Linear analysis was used to determine the maximum system transfer capability of these interfaces. The transmission system from Nanticoke to Burlington was stressed by increasing the power transfers from Nanticoke to Central and Eastern Ontario while performing a contingency assessment. A large number of contingencies were screened in this assessment but only the most critical are presented in this report.

Generally, the 15 minute circuit Limited Time Rating is established on the assumption that the pre-contingency loading of the circuit is at 75% of the continuous rating, and thus the LTR is higher than the continuous rating. With the addition of the Lake Erie interconnection it is likely that the 230 kV circuits between Nanticoke and Middleport will be loaded close to their continuous rating for a considerable percentage of time. Hence the post contingency thermal rating would be the same as the continuous.

One way of increasing the post LTR rating would be to use the 127^{O}C continuous rating (the conductor sag temperature) as the basis for the limited time rating instead of the annealing temperature of 93 ^{O}C. This assumes that transmission forced outages occur for less than 50 hours a year and therefore have minimal contribution to annealing. However, HONI will have to be in full agreement with this principle before this LTR is used in operation. For the purpose of this preliminary assessment report it was assumed that the 230 kV circuits out of Nanticoke TGS have an LTR of 744 MVA corresponding to the 127^{O}C continuous rating (see Table 1).

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 continuous rating of this interface is 2360 MVA or 590 MVA per each of the 230 kV circuits. The operating 15 minute LTR for each circuit is 744 MVA.

The transfer capability of this interface was assessed for a case with full output from Nanticoke TGS and maximum import over the Lake Erie interconnection. To determine if maximum power transfers could be sustained over this interface, the contingencies were ranked from worst to least as they impact on the Nanticoke to Middleport circuits. Table 3 below indicated the post contingency circuit loading as a percentage of the circuit LTR for the worst contingencies.

Table 3. Flow Into Middleport for Various Contingencies

<table>
<tr><td colspan="8">With 990 MW HVdc and eight units I/S at Nanticoke</td></tr>
<tr><td colspan="2"></td><td colspan="6">Post-contingency Flows</td></tr>
<tr><td>Circuit</td><td>Base flow(MW)</td><td colspan="2">N1M+N2M Outage/ (%LTR)</td><td colspan="2">N5M+N6M Outage/ (%LTR)</td><td>N2M+T11 Outage(L2E stuck) (%LTR)</td><td>N5M+T12 Outage(L5F stuck) (%LTR)</td></tr>
<tr><td>N1M</td><td>510</td><td colspan="2">0</td><td>690</td><td rowspan="2">93%</td><td>725 (97.5%)</td><td>663 (89%)</td></tr>
<tr><td>N2M</td><td>506</td><td colspan="2">0</td><td>679</td><td>0</td><td>654 (88%)</td></tr>
<tr><td>N5M</td><td>474</td><td>665</td><td rowspan="2">89%</td><td colspan="2">0</td><td>623 (83.7%)</td><td>0</td></tr>
<tr><td>N6M</td><td>469</td><td>655</td><td colspan="2">0</td><td>617 (83%)</td><td>675 (91%)</td></tr>
<tr><td>Total</td><td>1959</td><td>1320</td><td></td><td colspan="2">1369</td><td>1965</td><td>1992</td></tr>
<tr><td>ODF[Note1]</td><td></td><td colspan="2">34%</td><td colspan="2">37.4%</td><td>101.2%</td><td>101.7%</td></tr>
<tr><td>T11</td><td>402</td><td colspan="2">718</td><td colspan="2">693</td><td>-</td><td>783</td></tr>
<tr><td>T12</td><td>412</td><td colspan="2">735</td><td colspan="2">710</td><td>808</td><td>-</td></tr>
<tr><td>LIMIT[Note2]</td><td>2360</td><td colspan="2">2208</td><td colspan="2">2129</td><td>2047</td><td>2195</td></tr>
</table>

Note 1. Outage Distribution Factors on the remaining 230 kV circuits out of Nanticoke for the respective contingencies.
Note2. Limit was calculated based on respecting in post contingency situations, the circuits' limited time ratings.

Firstly, the results presented in Table 3 indicate that the maximum flow from Nanticoke into Middleport with the Lake Erie interconnection incorporated is within the continuous rating of the 230 kV lines.

Secondly, the worst contingency is the loss of N2M and T11 due to L2E stuck breaker condition at Nanticoke; the resulting post contingency flow on N1M is 97% of the 15 minute LTR used for this study.

Using a set of outage distribution factors limits were calculated for each of the studied contingencies and are listed in the last row of Table 3. The flow into Middleport Limit is around ***2047 MW.***

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 continuous and 15 minute Limited Time Ratings are shown in Table 2 in section 4.1.

The results of the PTI linear analysis for this interface are summarized in Table 4 below.

Table 4. Flow East Into Burlington

Monitored Circuit	*Base flow(MW)*	*Post Contingency Flow on Limiting Circuit (MW)*				*Continuous*
		Q23BM & Q24HM Outage	*Q25BM & Q29HM Outage*	*Q24HM & Q29HM Outage*	*M27B & M28B Outage*	
With 990 MW HVdc and eight units I/S at Nanticoke						
Q25BM	484.1	716.2 (117%)	0	639.2 (104%)	559.6 (91%)	491
Q23BM	480.6	0	645.5 (114%)	-	555.4 (98%)	
B18H	216.9	-	-	-	-	
B20H	215.6	-	-	-	-	-
M27B	323.2	-	-	-	-	-
M28B	323.2	-	-	-	-	-
Interface Transfer Capability	2043.8 MW	***1654 MW***	1687 MW	1929 MW	2088 MW	2084 MW

The study was performed with a basecase which maximized the flow into Burlington TS by assuming all units in service at Nanticoke TGS and maximum import over the Lake Erie interconnection which supplied the load in Central Ontario by displacing Pickering generation. A large number of single and double contingencies were investigated but only the most limiting few were listed in Table 4.

The results of the study show that the critical contingency is the loss of the double circuit 230 kV line Q23BM/Q24HM due to limitation imposed by the 15 minute LTR of circuit Q25BM. In order to respect the post contingency limit of Q25BM the flow over the FEIB must be limited to ***1654 MW*** with all elements in service. The power transfer limits that were calculated for the other contingencies listed in the table are above 1654 MW.

Hence, the pre-contingency flow on this interface must be reduced by about 400 MW from the maximum possible transfers, to respect the new transfer limit.

4.6 Impact on Power Transfers - Distribution Factors

Linear analysis was performed to determine the distribution of the power over the main Ontario transmission interfaces and the interconnections when the HVdc power injection is displaced with generation from various parts of the interconnected system. Table 5 below summarizes the system Transmission Distribution Factors for the generation shifts indicated in the first row.

Table 5. Transmission Distribution Factors

	Monitored Lines		Base Case	1 Lambton	2 Bruce	3 Beck	4 Pick	5 ChatFal	6 Saund	7 Mich	8 NewYork
			MW								
1	INTERFAC	NAN2-MID	1910	0.512	0.479	0.583	0.491	0.493	0.511	0.517	0.541
	NANTICOK	CALEDJN1,N1N	510	0.126	0.119	0.147	0.124	0.124	0.129	0.128	0.136
	NANTICOK	MIDDLDK1,N2M	506	0.126	0.12	0.148	0.124	0.125	0.129	0.128	0.136
	NANTICOK	CALEDJN5,N5M	474	0.13	0.12	0.144	0.121	0.122	0.127	0.131	0.135
	NANTICOK	MIDDLDK2,N6M	469	0.13	0.12	0.144	0.121	0.122	0.127	0.131	0.135
2	NANTICOK	NANTICOK,T11	-402	-0.241	-0.257	-0.206	-0.252	-0.25	-0.242	-0.238	-0.227
3	NANTICOK	NANTICOK,T12	-412	-0.247	-0.264	-0.211	-0.258	-0.256	-0.247	-0.244	-0.232
4	INTERFAC	OH-STLAW	-37	0.054	-0.009	0.082	-0.038	-0.128	-0.341	0.073	0.217
	STLAWR33	STLAWL33	-17	0.025	-0.004	0.037	-0.018	-0.059	-0.156	0.033	0.099
	STLAWR34	STLAWL34	-20	0.029	-0.005	0.044	-0.021	-0.07	-0.185	0.04	0.118
5	NANTICOK	MIDD 500	1381	0.093	0.124	0.154	0.206	0.202	0.185	0.101	0.143
6	NANTICOK	MIDD 500	1458	0.117	0.167	0.167	0.226	0.22	0.202	0.124	0.16
7	NANTICOK	LONGWOOD	-76	0.278	0.231	0.096	0.077	0.085	0.103	0.257	0.155
8	INTERFAC	FEIB	2239	0.044	0.163	-0.111	0.282	0.228	0.151	0.036	0.008
9	INTERFAC	FETT	5169	0.072	0.001	0.088	0.956	0.868	0.662	0.095	0.237
10	INTERFAC	OH>MI	-1272	-0.228	-0.027	0.119	0.011	0.041	0.116	0.701	0.326
	INTERFAC	B3N	-84	-0.021	-0.003	0.017	0.002	0.006	0.017	0.093	0.046
	INTERFAC	L51D	-452	-0.104	-0.009	0.036	0.003	0.013	0.035	0.246	0.1
	INTERFAC	L4D	-511	-0.119	-0.01	0.042	0.004	0.014	0.04	0.28	0.113
	INTERFAC	J5D	-226	0.015	-0.006	0.024	0.002	0.008	0.023	0.082	0.066
11	INTERFAC	BLIP	-418	0.772	-0.027	0.119	0.011	0.041	0.116	0.701	0.326
12	INTERFAC	MIDD-AUT	485	0.003	-0.086	0.118	-0.099	-0.09	-0.045	0.01	0.038
13	INTERFAC	NANT-AUT	-814	-0.488	-0.521	-0.417	-0.509	-0.507	-0.489	-0.483	-0.459
14	INTERFAC	NOUT (230, 500)	4722	1	1	1	1	1	1	1	1
15	INTERFAC	QFW	1334	-0.16	-0.036	-0.793	-0.03	-0.088	-0.221	-0.207	-0.438
16	INTERFAC	OH-NIAG	-843	0.16	0.036	-0.207	0.03	0.088	0.221	0.207	0.438
	INTERFAC	BP76	-181	0.032	0.007	-0.039	0.005	0.015	0.036	0.042	0.078
	INTERFAC	PA27	-251	0.035	0.008	-0.043	0.006	0.017	0.043	0.045	0.089
	INTERFAC	PA301	-206	0.046	0.011	-0.063	0.01	0.028	0.071	0.06	0.136
	INTERFAC	PA302	-205	0.046	0.011	-0.062	0.01	0.028	0.071	0.06	0.136

It should be observed that the distribution factors listed in row 15 indicate that an import over the Lake Erie interconnection would in effect back off the Queenston Flow West power transfers thus alleviating the congestion on this interface.

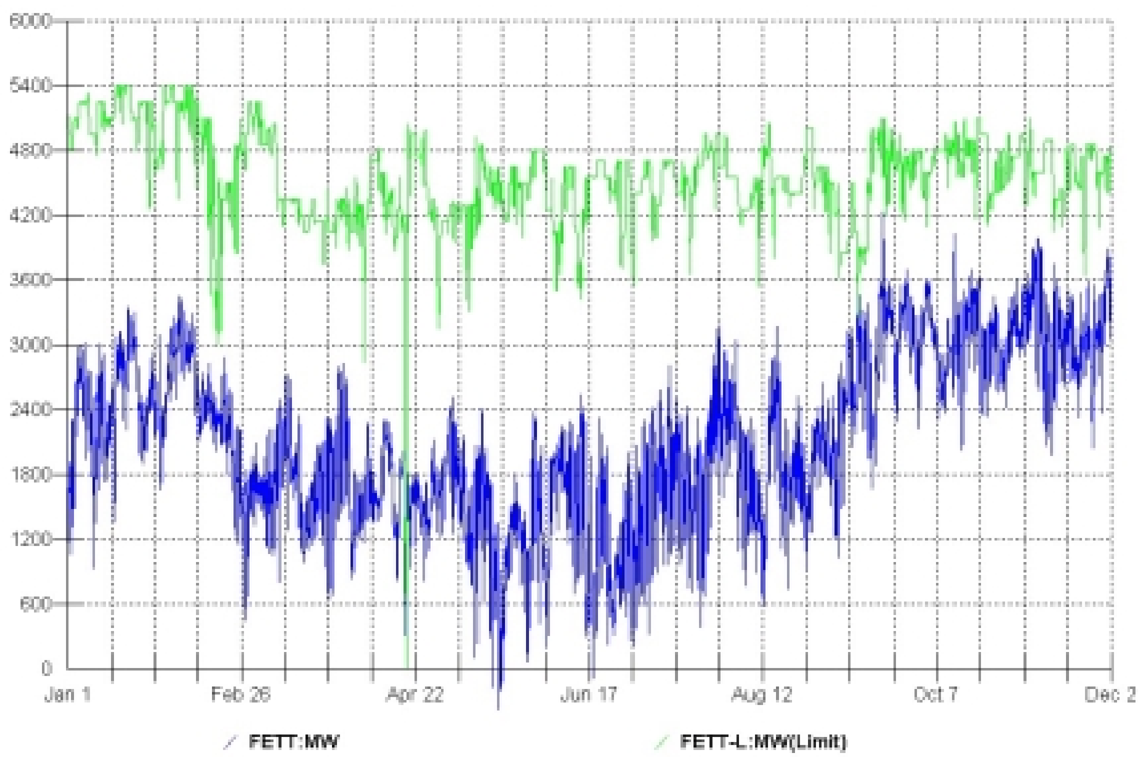
4.6.1 Import Scenarios

The main effect of the proposed 990 MW interconnection for import situations is the potential for congestion on the Ontario transmission interfaces.

Flow East Towards Toronto

The results indicate that if the transfer over the new *Lake Erie interconnection displaces the generation in the central or eastern Ontario* most of this transfer, (about 950 MW) will show up on Flow East Towards Toronto interface (item 9 in Table 5). A brief assessment of year 2000 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 Figure 6 below shows that, with the exception of very short periods of time, the power flows over this interface have been well below the its transfer limit. It is estimated that with the addition of the Lake Erie interconnection there will be times when congestion could occur on this interface.

Figure 6. FETT Transfer/Limit for Year 2000

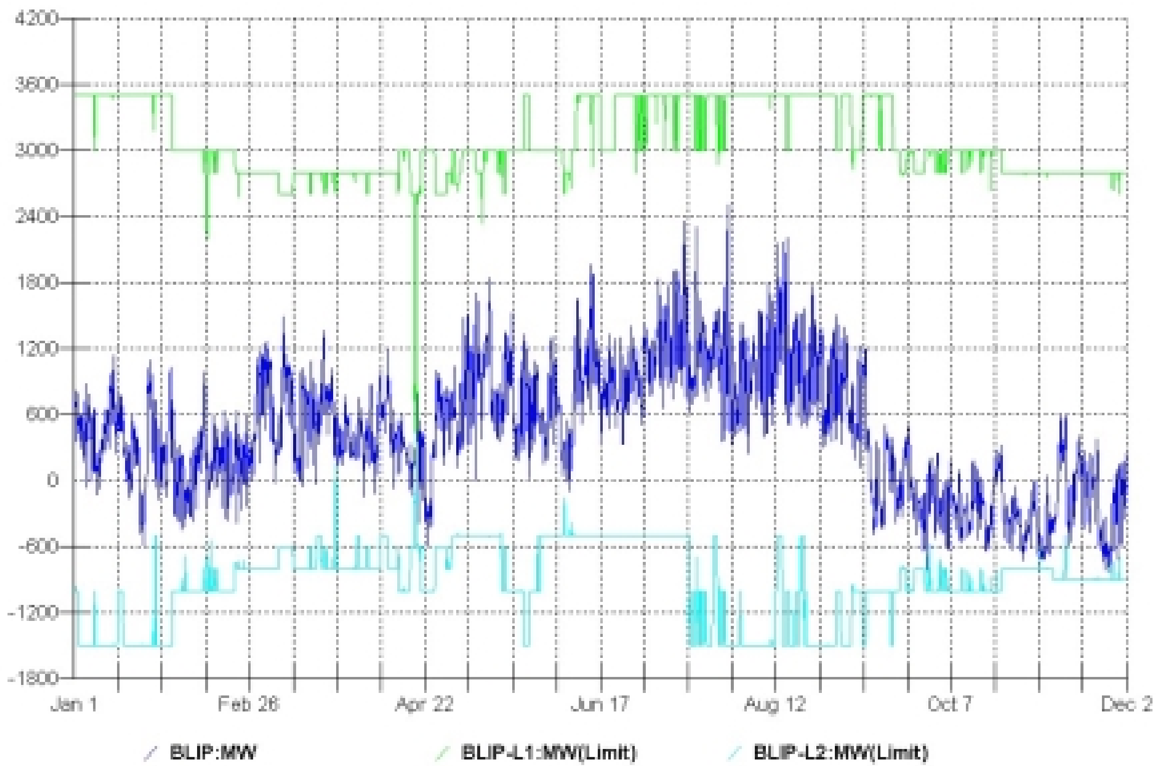


A quick calculation was performed using the year 2000 actual distribution of the FETT power flow and transmission limit to determine an approximate percentage of time that congestion could occur on this interface with a maximum import of 990 MW over the Lake Erie interconnection. The results show that the FETT interface could experience congestion for up to 12% of the time.

Bruce Longwood Input

The results indicate that if the transfer over the new *Lake Erie interconnection displaces the generation in the western Ontario* most of the transfer (about 765 MW) will show up on Bruce Longwood Input interface (item 11 in Table 5). A brief assessment of year 2000 historical data indicated that the BLIP limit was between 2800 MW to 3500 MW and the power transfers over this interface were below 2400 MW. It should be noted that the coincident limit/flow graph in Figure 7 below shows that, with the exception of very short periods of time, the power flows over this interface have been well below the its transfer limit. It is estimated that with the addition of the Lake Erie interconnection there will be times when congestion could occur on this interface.

Figure 7. BLIP Transfer/Limit for Year 2000



A quick calculation was performed using the year 2000 actual distribution of the BLIP power flow and transmission limit to determine an approximate percentage of time that congestion could occur on this interface with a maximum import of 990 MW over the Lake Erie interconnection. The results show that the BLIP interface could experience congestion for up to 2% of the time.

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 that these patterns would certainly change with the opening of the competitive electricity market in Ontario.

4.6.2 Export Scenario

For the situations when transfers are made from Ontario over the proposed Lake Erie interconnection the main area of concern is the impact of maximum power transfers on the area voltages. A sensitivity analysis was carried out to identify the effect of the new project on the area steady state voltages for different number on Nanticoke generating units in service.

The results of the studies indicated that even with Nanticoke generation out of service the steady state voltages at Nanticoke 230 kV, Middleport 230 kV and Burlington 230 kV buses are not depressed under the presence of high export over the HVdc interconnection.

It is however worth noting that, depending on the Ontario generation dispatch high export scenarios may aggravate the power congestion situation on the QFW transmission interface (see Table5 for distribution factors).

4.7 Impact on Ontario Interconnections

The PTI linear analysis was also used to determine the effect of the loss of two of the HVdc bipoles (representing a recognized contingency) on the other Ontario interconnections and establish if the loss of 660 MW of export from Ontario introduces a new critical contingency for the interconnected system.

Table 6 below summarized the Outage Distribution Factors on the interconnection circuits for the loss of the HVdc link.

Table 6. Outage Distribution Factors for Loss of Lake Erie Interconnection

ODF	Ontario-Niagara				Ontario-Michigan				Ont-NY	
	BP76	PA27	PA301	PA302	B3N	L51D	L4D	J5D	L33P	L34P
Circuit	.093	.097	.118	.117	.059	.127	.145	.085	.062	.073
Interface	**.425**				**.416**				**.135**	

Effect on the St Lawrence Ties

Firstly, the impact of the loss of two HVdc bipoles on the St. Lawrence ties was studied. Presently, the power transfer capability of the St. Lawrence interconnection (L33P&L34P) is calculated on-line and it is based on the loss of the companion circuit. Using the ODF's established in Table 6 an assessment was carried out to identify if the loss of two Hvdc bipoles at Nanticoke would imposed more restrictive limits on the St Lawrence interconnection. The results are summarized in Table 7.

Table 7. St. Lawrence Interconnection

Contingency	*Flow limits on L33P, St Laurence to Moses in New York*	
	Maximum pre-contingency to respect STE rating of 334 MVA	*Continuous Rating*
Loss of HVdc	334-0.062*660=293.	240 MVA
Loss of L34P	334/1.634= 204	240 MVA
L34P+6u G/R	(334+0.39*360)/1.634=290	240 MVA

These results confirmed that the effect on L33P of losing L34P is more severe than the loss of HVdc. The flow on L33P is limited to 290 MW with G/R compared to 293 MW for the loss of HVdc.

Therefore, the proposed HVdc interconnection does not have an adverse impact on the existing power transfer capability of the St. Lawrence ties.

Effect on the Niagara Interconnections

Secondly, the linear analysis evaluated the impact of the HVdc bipoles at Nanticoke on the Niagara interconnection.

Under normal conditions, the Niagara ties BP76, PA27, PA301 & PA302 are operated such that their loading does not exceed the more restrictive of,

- The continuous rating in pre-contingency,
- STE rating following double circuit contingencies and stuck breaker contingencies in Ontario, or
- LTE rating following single contingencies.

Again, preliminary calculations were performed to identify the impact of 660 MW HVdc loss at Nanticoke on the Niagara ties. The assessment targeted the two most limiting circuits of the Niagara interconnection, BP76 and PA27. The maximum allowable pre-contingency flows on BP76 & PA27 were calculated, such that the post-contingency rating of each circuit is respected for both single and double contingencies. The results are summarized in Table 8 below.

Table 8. Niagara Interconnection

Contingency	*BP76 Max Flow to Respect STE (MVA)*		*PA27 Max Flow to Respect STE (MVA)*	
	Max Pre Flow	*Cont./ LTE/STE (MVA)*	*Max Pre Flow*	*Cont./LTE/STE (MVA)*
Loss of 2 x 330 HVdc	558-.093*660 = ***496 MVA***	400 / 460 / 558	569-.097*660 = ***505 MVA***	478 / 492 / 569
Loss 1 x 330 HVdc	460-.093*330 = ***429 MVA***		492-.097*330 = ***460 MVA***	
Loss of PA27	460-.26*(.75*478)= ***366 MVA***		-	
Loss of BP76	-		478-.313(.75*460)= ***370 MVA***	

The results show that for the double contingency on the HVdc bipoles, the calculated maximum pre-contingency flows are less restrictive than the continuous ratings of the interconnection circuits PA27 and BP76. Based on these results, it can be concluded that the loss of two HVdc bipoles at Nanticoke will not impact on the transfer capability over the Niagara ties.

These preliminary results indicate that it is possible that the loss of only one of the bipoles may limit the pre-contingency flow to a value less that the continuous rating. But, this does not represent the most limiting first contingency since the loss of PA27 or BP76 on the companion circuit is more limiting (shown in red in Table 8).

In conclusion, a single or double contingency associated with HVdc bipoles at Nanticoke will not impact on the transfer capability over the Niagara ties.

Effect on Ontario-Michigan Interconnection

Thirdly, linear analysis was used to investigate the impact of the HVdc bipoles on the Ontario-Michigan interconnection. By using the ODF’s listed in Table 6 it was determined that if two of the Lake Erie HVdc bipoles are lost then, about 275 MW would appear on the Ontario-Michigan interface.

Transfers across the Ontario-Michigan interface are currently limited to capability of about 2410 MW for export conditions and 1500 MW for import conditions.

Currently, the Ontario-Michigan interface is being upgraded to increase the transfer capability of this interface. It is expected that the project will be completed before the coming in service of the Lake Erie HVdc interconnection. The Ontario- Michigan interface reinforcement includes:

- On B3N on the Michigan side, a new 675 MVA phase shifter,
- On L51D, a new 845 MVA phase shifter in Ontario and a 1000 MVA autotransformer in Michigan,
- On L5D, the paralleling of the two existing transformers T7 and T8 and the installation of a new 845 MVA phase shifter.

Presently, the operating limits of the upgraded interconnection have not been developed and the continuous and Limited Time Ratings of the circuits are not yet available. Considering the scope of the preliminary study and the lack of facility ratings data, it was decided to address the detailed calculation of the impact of the loss of one or two of the Lake Erie HVdc bipoles in the second phase of the Connection Assessment Process, namely the System Impact Assessment.

At the start of the SIA process, HONI will be required to provide information on the continuous, Limited Time and Shorts Time ratings for the upgraded Ontario-Michigan interface.

5.0 Fault Levels Analysis

HONI has performed preliminary fault level studies to determine the effect of the three parallel HVdc bipoles on the existing station equipment at Nanticoke TGS and Middleport TS.

The following assumptions were used for every bipole in setting up the study case:

- the converter transformers are connected to the 230 kV bus through zero impedance line,
- the converter transformers are configured as 3 single phase 120 MVA, 230/191.5 kV transformers,
- the transformer positive sequence impedance is 17.4% on 191.5 kV and 120 MVA

This study also assumed that the transmission lines from the converter station will not have significant mutual impedance effects on the existing 500 and 230 kV lines which egress from Nanticoke TGS.

The results of the short circuit analysis showed that the proposed interconnection would result in a very small increase in the fault currents at Middleport TS or the Nanticoke 500 kV switchyard. The resulting short fault levels would be within the short circuit interrupting capability of the breakers at these locations.

The impact of the proposed link on the short circuit levels at the Nanticoke TGS 230 kV switchyard is reported in Table 8 below. The results indicated that the proposed new interconnection does not affect the three phase fault short circuit currents seen be at Nanticoke 230 kV switchyard. However, each HVdc bipole would increase the symmetrical line-to-ground fault level by up to 1.7 kA and the asymmetrical line-to-ground fault level by up to 2.4 kA.

Table 8: Short Circuit Assessment of Nanticoke TGS 230 kV Breakers

Condition	*3-Phase Sym (kA)*	*L-G Sym (kA)*	*3-Phase Asym (kA)*	*L-G Asym (kA)*
230 kV Breaker Rating ==>	**54.3**	**54.3**	**65.6**	**65.6**
Existing System				
+ Sarnia-Windsor and Sithe	47.1	47.1	61.6	63.0
+ 1 Bipole	47.1	48.8	61.6	65.1
+ 2 Bipole	47.1	50.3	61.6	67.5
+ 3 Bipole	47.1	51.6	61.6	69.2

While the L-G symmetrical short circuit current resulting from the contribution of all three HVdc bipoles is well under the breakers interrupting capability, it is the asymmetrical line-to-ground levels which will exceed the asymmetrical breaker ratings with the addition of two or more bipoles. Further analysis showed that with two bipoles the asymmetrical rating of seven breakers would be exceeded, with three other breakers virtually at the maximum breaker capability. With three bipoles, the asymmetrical rating of ten breakers will be exceeded.

Table 9 lists the breakers whose ratings will be exceeded.

Table 9. Breakers with Asymmetrical Ratings Exceeded

Breaker	*2 Bipoles (% of Rating)*	*3 Bipoles (% of Rating)*
K1L5	100.5	103.2
K2L21	102.9	105.4
L1L22	102.9	105.4
L5F	100.5	103.2
L6L21	102.9	105.4
P1L22	102.9	105.4
P2L6	101.5	104.1
K1L1	99.9	102.7
L2E	99.5	101.4
P2L2	99.5	102.2

To ensure short circuit adequacy of the 230 kV Nanticoke breakers, a number of options will be investigated as part of the System Impact Assessment. Solutions may be found which will reduce the number of Nanticoke 230 kV breakers that need to be upgrated in order to accommodate the incorporation of the second and third HVdc bipoles.

HONI has suggested that a number of options be further explored when more detailed configuration and equipment data for the proposed HVdc interconnection become available. One option would be to add a grounding reactor on the neutral of the 230 kV winding of the T2 step-up transformer. Presently, neutral grounding reactors exist on the other three step-up transformers and adding the grounding reactor on T2 will reduce the line-to-ground fault levels. Further studies will be required to determine the extent of the reduction. It should be noted that the T2 transformer is owned by OPGI and permission from OPGI is required to make changes to T2.

6.0 Subsynchronous Resonance Issue

Over the years it has been observed in the industry that interactions of a subsysnchronous frequency could appear between the generators' turbine and the HVdc converter controls especially when the 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.

Hence, studies must be carried out to identify if 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.

TransÉnergie US Ltd. and Hydro One Inc. are required to initiate this work as part of the SIA

7.0 Conclusions and Recommendations

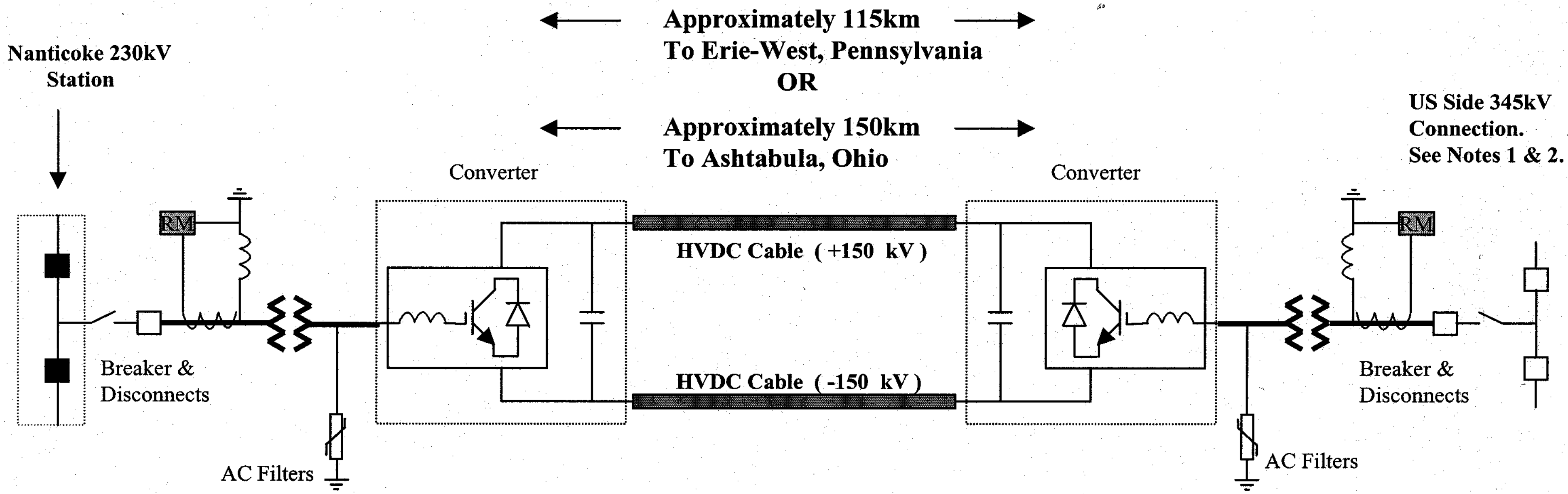
The following conclusions can be drawn from the results of the preliminary assessment for the Lake Erie interconnection proposal:

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 have been identified this preliminary assessment:

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 to perform a transient stability analysis of the effects of the Hvdc interconnection 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.

Transfer Capability - 330 MW
(Phase 1 of 3)



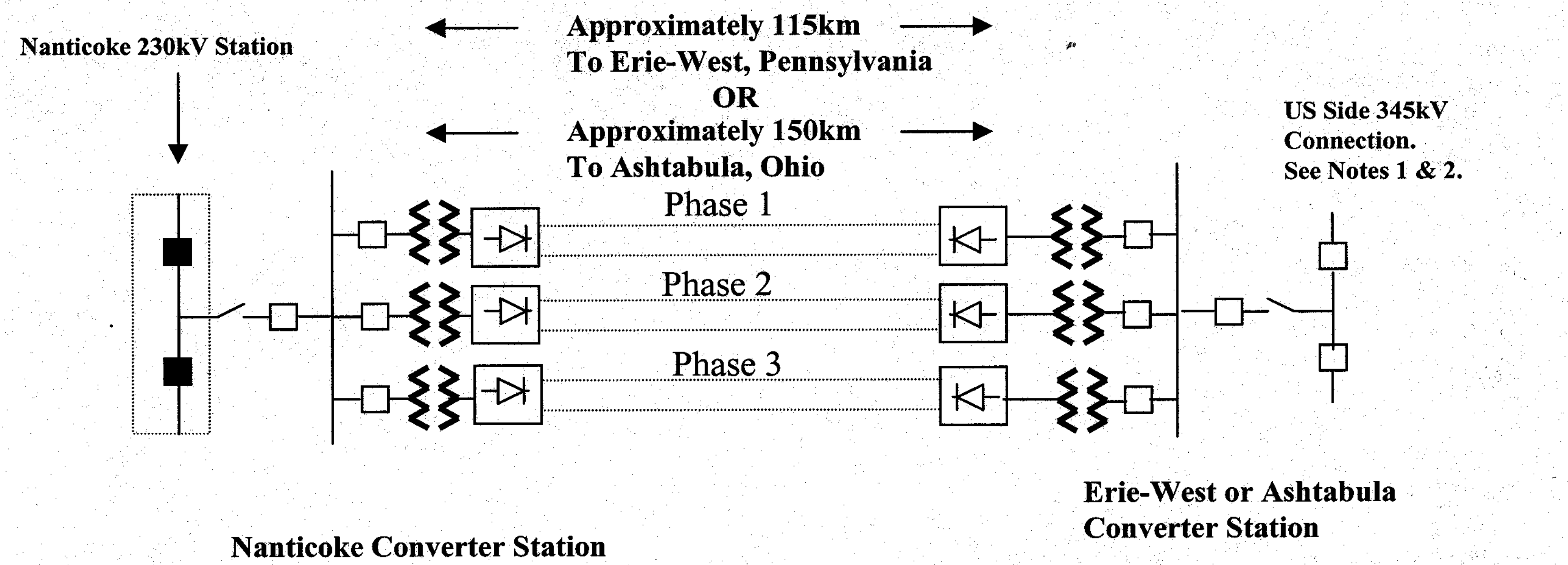
Nanticoke Converter Station

Erie-West or Ashtabula Converter Station

Notes: 1) Erie-West Connection into Erie-West 345kV Station
2) Ashtabula Connection taps 345 kV line between Erie-West and Perry near Ashtabula Tap

Figure 1 - Preliminary Simplified One-line of HVDC Transmission System

Transfer Capability - 330 MW net
For Each Phase



Notes: 1) Erie-West Connection into Erie-West 345kV Station
2) Ashtabula Connection taps 345 kV line between Erie-West and Perry near Ashtabula Tap

Note: Up to three Phases possible

Figure 2 - Preliminary Simplified One-line of HVDC Transmission System With Possible Phases

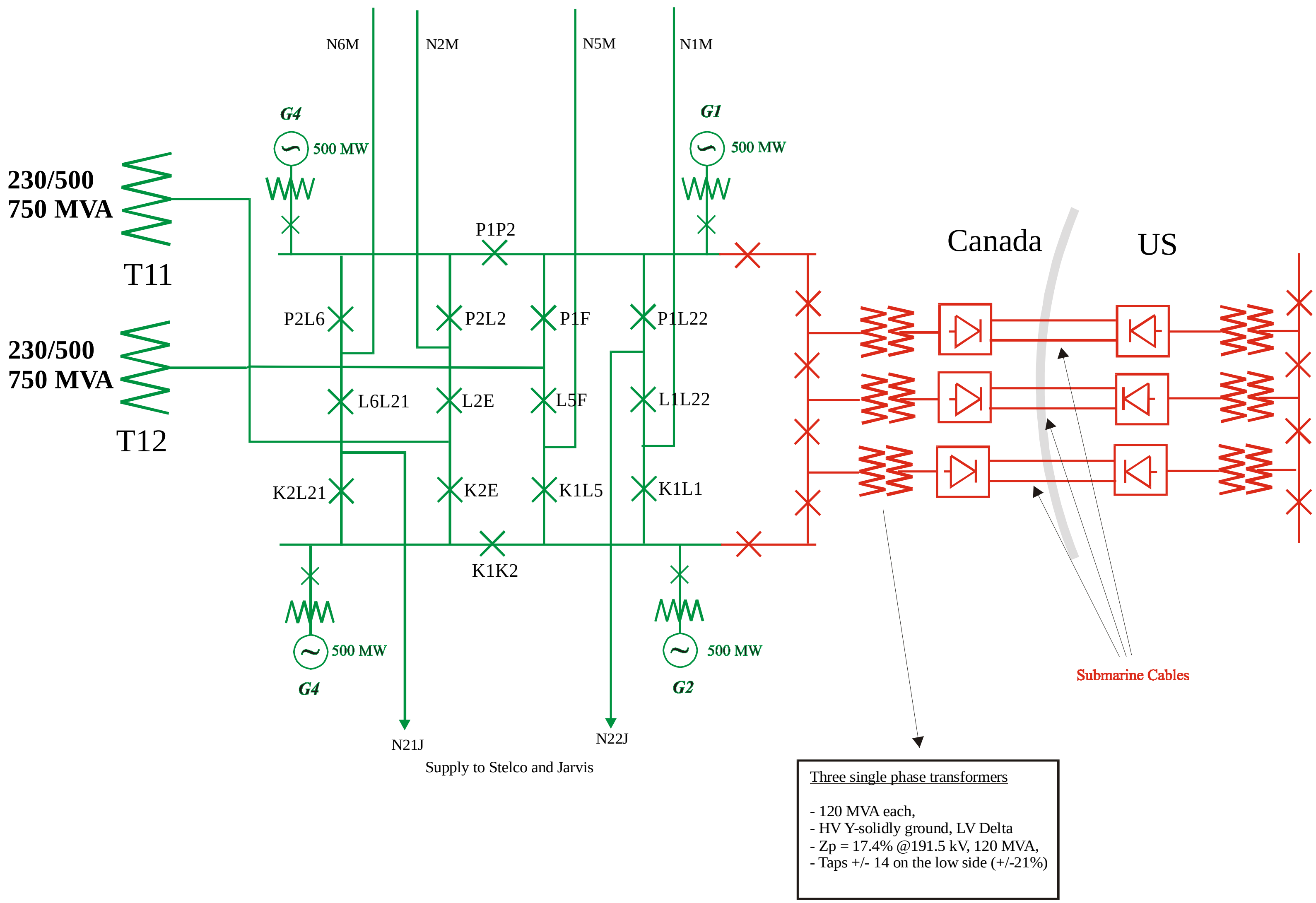


Figure 3. Connection to Nanticoke 230 kV

Legend

Existing Facilities

New Facilities

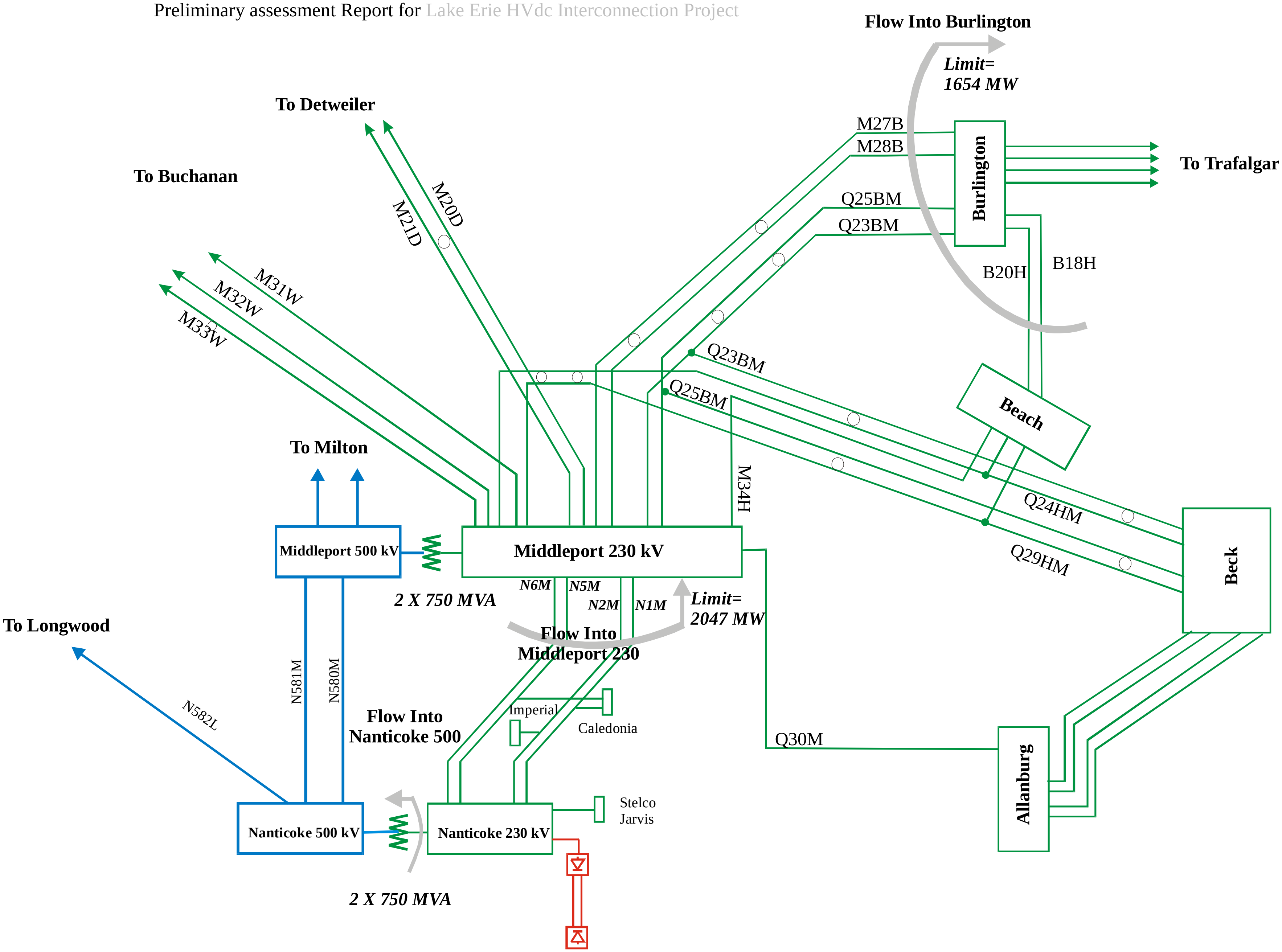


Figure 4. Nanticoke to Burlington System Configuration and Interfaces

Transient Stability response to a Three-Phase fault at Nanticoke 230 kV on Circuit N2M

Figure 5a. Generator Angle

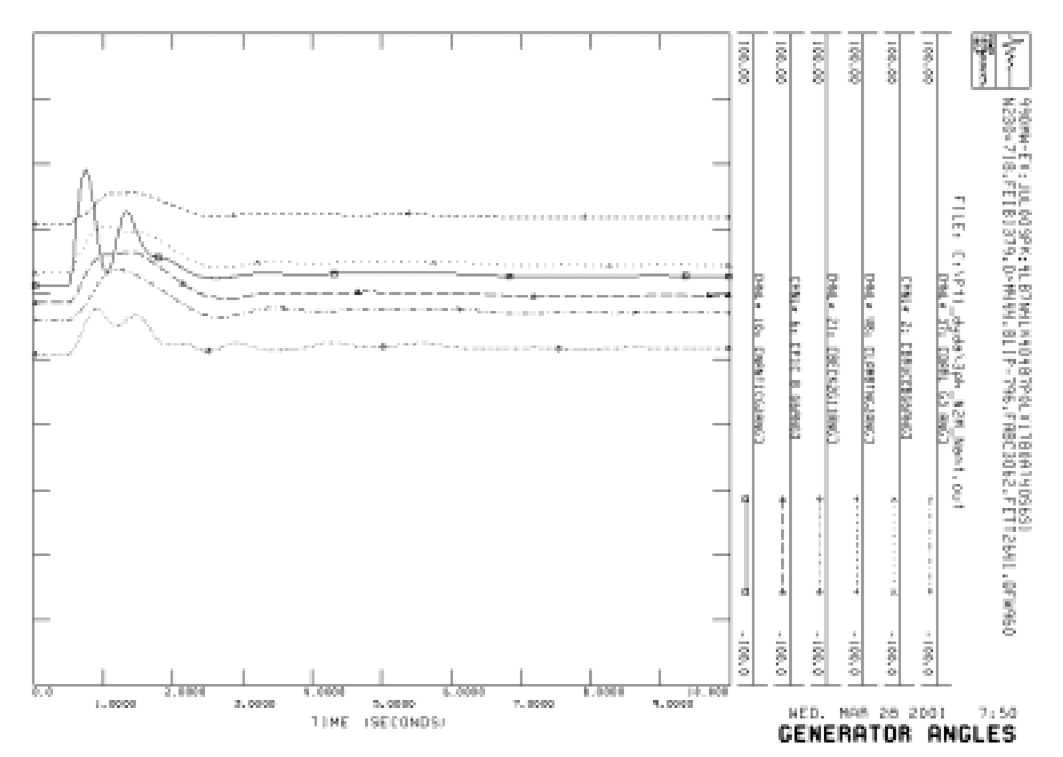


Figure 5b. 230 kV Voltages