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CONNECTION ASSESSMENT & APPROVAL PROCESS

SYSTEM IMPACT ASSESSMENT REPORT

For the Generation Projects in the 2nd Sarnia-Windsor Cluster

Enron Project	*CAA ID No. 2001-048*
Calpine Project	*CAA ID No. 2000-027*
Imperial Oil Project	*CAA ID No. 2000-029*

Consistent Information Set Department, and
Long Term Forecasts & Assessments Department

FINAL Version

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System Impact Assessment Report

For the Generation Projects in the 2nd Sarnia-Windsor Cluster

Acknowledgement

The IMO wishes to acknowledge the assistance of Hydro One in completing some of the studies for this assessment.

Disclaimers

IMO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the IMO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether the IMO should issue a notice of approval or disapproval of the proposed connection under Chapter 4, Section 6 of the Market Rules. This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. In particular, this report does not address any other Market-related or any commercial aspects of the connection proposal. This report has been prepared solely for use by the connection applicant and the IMO in accordance with Chapter 4, Section 6 of the Market Rules. The IMO assumes no responsibility to any third party for any use which it makes of this report. Any liability which the IMO may have to the connection applicant in respect of this report is governed by Chapter 1, Section 13 of the Market Rules. The IMO reserves the right to revise this report at any time, at its sole discretion, without notice to the connection applicant. Although the IMO will use its best efforts to advise the connection applicant of such changes, it is the responsibility of the connection applicant to ensure that the most recent version of this report is being used.

Hydro One

Special Notes and Limitations of Study Results

The results reported in this system assessment study are based on the information available to Hydro One, at the time of the study, suitable for a System Impact Assessment of a new interconnection.

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 System Impact Study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection.

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

The additional facilities or upgrades which are required to incorporate the proposed connection have been identified to the extent permitted by a System Impact Assessment under the current IMO Connection Assessment and Approval process. At more advanced stages of the project development, additional studies may identify the need for other facilities or upgrades not covered under this System Impact Assessment. Further studies may also be required to confirm constructability and the time required for construction.

SYSTEM IMPACT ASSESSMENT REPORT

For the Three Generation Projects in the 2nd Sarnia-Windsor Cluster

EXECUTIVE SUMMARY

This System Impact Assessment has examined the impact that the incorporation of the following generation projects would have on the IMO-controlled grid:

- The Enron Project: with a scheduled in-service date of Q2-2004
- The Calpine Project: with a scheduled in-service date of Q3-2004
- The Imperial Oil Project: with a scheduled in-service date of Q2-2004

Incorporation Arrangement for each Project

Enron Project

This Project, which is to consist of two gas-turbine generating units and a single steam-turbine unit, each rated at 210MVA, is to be connected on to the 230kV busbar at Lambton TS via a single 230kV circuit, approximately 3.2km in length. It is proposed to terminate the new circuit on to the existing 230kV diameter, at the southern end of the switchyard.

The IMO has made it a requirement for connection, that instead of installing a 230kV in-line circuit breaker at the Lambton end of the new 230kV circuit, it be installed in the existing diameter. With this breaker located in the diameter, together with the breaker that Enron was originally proposing to install in the diameter so as to establish a termination position for their new 230kV connection, the final arrangement would then comprise two breakers connected in series.

Instead of having a single breaker located between the termination of the L4D Ontario-Michigan Interconnection and the termination of the Enron circuit, this change would result in two breakers separating the two connections. This would therefore avoid the possible simultaneous loss of both connections for a breaker-failure condition.

Calpine Project

This Project, which is to consist of three gas-turbine units, each rated at 225MVA, and a single steam-turbine unit, rated at 300MVA, is to be connected via taps on to the 230kV circuits L23N, L25N & L27N. The connections to circuits L25N & L27N are to made locally, via the existing taps to the Nova (Corunna) TS. The connection to circuit L23N is to be made via a new tap, approximately 1.5km in length, to the main right-of-way between Lambton TS and Sarnia-Scott TS.

A new 3-diameter 230kV switching station is to be installed at the generating facility. This has been configured so that should there be a future requirement to operate with the 230kV busbar at Lambton TS split, then normally-open points can be established at this switching station to distribute the new generating capacity between the two halves of the split busbar.

Since the output from the Calpine Project can be injected at three separate points on the IMO-controlled grid, offers will need to be submitted for each injection point. While it is recognised that the offers would need to be inter-dependent to allow the inherent efficiencies of combined-cycle generating facilities to be exploited, the IMO's tools for dispatching generation capacity are presently unable to accommodate such coupled offers.

Imperial Oil Project

This Project consists of a single 112MVA gas-turbine unit connected to the 27.6kV busbar at Imperial Oil Substation 2A via a 0.8km cabled-busbar. Two overhead line circuits, 0.9km in length, connect Substation 2A to the new 230/27.6kV DESN station that has recently been established at the Imperial Oil Complex.

The new generating unit is expected to displace most of the existing load at the Complex and Imperial Oil has indicated that they do not expect to produce surplus power beyond their local requirements.

Load Flow Analysis

The existing transmission facilities are considered to be sufficient to accommodate the following:

- full output of the existing generation facilities in the Sarnia-Windsor area, including the recently commissioned TransAlta Project
- the full output of the ATCO Project when it comes into service in the Spring-2004, and
- a maximum transfer of 1500MW into Ontario across the Ontario-Michigan Interface.

Any further generation development will result in congestion unless additional transmission facilities are installed. However, the extent of the congestion will depend on the actual generation capacity that is dispatched, as well as the magnitude of the transfers into Ontario.

Fault Level Analysis

Fault level studies were performed for all combinations of the three new projects in the 2nd Sarnia-Windsor Cluster, both with and without the proposed 1050MW generating facility in China Township, Michigan.

The impact of the increased fault levels on the existing breakers at Lambton TS and Sarnia-Scott TS are summarised in the following Tables.

No. of 230kV breakers at Lambton TS whose fault interrupting capacity would be exceeded		
	Without the China Township Project	*With the China Township Project*
With the Imperial Oil Project	0	0
With the Calpine Project	2	2
With the Enron Project	2	***10***
With the Imperial Oil & Calpine Projects	2	2
With the Imperial Oil & Enron Projects	2	***10***
With the Calpine & Enron Projects	***13***	***13***
With the Imperial Oil, Calpine & Enron Projects	***13***	***13***

The shaded cells indicate conditions that have been assumed to justify reconfiguring the Lambton 230kV busbar so as to allow it to be operated split and thereby avoid replacing an excessive number of breakers.

No. of 230kV breakers at Sarnia-Scott TS whose fault interrupting capacity would be exceeded		
	Without the China Township Project	*With the China Township Project*
With the Imperial Oil Project	0	0
With the Calpine Project	5	6
With the Enron Project	0	0
With the Imperial Oil & Calpine Projects	6	6
With the Imperial Oil & Enron Projects	0	0
With the Calpine & Enron Projects	6	6
With the Imperial Oil, Calpine & Enron Projects	6	6

These results can be summarised as follows:

At Lambton TS:

- If the Enron Project were to be developed together with either the Calpine Project, or the China Township Project, then the 230kV busbar at Lambton TS would need to be reconfigured and operated split.
- Developing the Imperial Oil Project in isolation would require no breakers to be replaced at Lambton TS.
- Developing the Calpine Project, either in isolation or with the Imperial Oil Project, would require the two lower-rated breakers at Lambton TS to be replaced.

At Sarnia-Scott TS:

- Developing the Calpine Project in isolation of the China Township Project or either of the other two Projects in the Cluster would require five of the 230kV breakers at Sarnia-Scott TS to be replaced.
- If either of the other two Projects or the China Township Project were also to be developed (in addition to the Calpine Project) then the number of 230kV breakers that would need to be replaced would increase to six.
- In the absence of the Calpine Project, the remaining three Projects (Enron, Imperial Oil and the China Township Project) could all be developed without triggering the need to replace any of the 230kV breakers at Sarnia-Scott TS.

It should be noted that this assessment has been limited to a review of the impact that the increased fault levels would have on the existing circuit breakers in the local area.

The impact that the increased fault levels may have on the remaining station equipment (buswork, disconnect switches, etc.) would require a detailed review that is beyond the scope of this assessment. It is expected that this detailed review would be undertaken as part of the engineering design required to prepare the Connection & Cost Recovery Agreement (CCRA) that the Proponent is required to sign with the transmitter.

Generation Rejection/Runback Schemes

Calpine Project

The Calpine Project would need to be integrated into both the Lambton G/R Scheme and the Sarnia-Scott G/R Scheme. Furthermore, since many of the same contingency conditions would need to be covered by both Schemes, it is expected that they would need to be integrated into a single scheme.

Enron Project

Similar to the Calpine Project, the Enron Project would need to be integrated into both the Lambton G/R Scheme and the Sarnia-Scott G/R Scheme, and these two Schemes would also need to be integrated into a single entity.

Furthermore, if the China Township Project were also to be developed, then the 230kV busbar at Lambton would need to be operated split. This would necessitate further enhancements to the Lambton G/R Scheme to recognise the revised configuration of the 230kV circuits and the two Ontario-Michigan Interconnections, as well as the association of the Lambton generating units with a particular half of the split busbar.

Imperial Oil Project

Although Imperial Oil is planning to operate their new generating unit so that it supplies only their local requirements, there could be occasions when net transfers are made to the IMO-controlled. The new generator is therefore to be integrated into the Sarnia-Scott G/R Scheme.

A functional specification for the revised scheme was produced and agreed with Imperial Oil.

Transient Stability Analysis

Since the data provided for the exciters for the Enron & Calpine Projects failed to meet the requirements of the Market Rules, appropriate replacement models with assumed data were used.

In addition, assumed data were used for the models for the following facilities:

- The Enron Project: The governor on the steam-turbine unit.
- The Calpine Project: The governors on both the gas-turbine and the steam-turbine units.
  The power system stabilisers on both the gas-turbine and the steam-turbine units (with positive gain).

Where data for the machine parameters were missing, appropriate values were assumed, and these have been detailed in the Report.

In each of these instances, the respective Proponents will need to provide suitable data or confirm that the values that were assumed are adequate for modelling the new facilities. It is also recommended that revised models for the various exciters for the Enron and Calpine Projects be submitted to the IMO as soon as possible so that they can be assessed for compliance with the Market Rules.

Using the assumed data and equipment models, the results of the transient stability studies that were performed for a selected number of fault conditions on the system, showed that all of the generating units would remain stable, with acceptable machine damping. In addition, the voltages at all of the monitored busbars were restored to within 10% of their pre-contingency values within the 10-second simulation period.

Equipment Nomenclature

Typical designations for the major items of switchgear at the Calpine and Enron Projects have been indicated on the appropriate Diagrams of the Report. It is recommended that the Proponents consult with Hydro One to establish suitable equipment designations as soon as possible in the design phase so that they can be included in their drawings.

Approximate Cost Estimates

Approximate cost estimates have been provided for all the work that has been identified for the incorporation of the individual Projects have been provided.

Identification of 'Sole Beneficiary'

Any changes to existing facilities or the installation of new facilities that are 'triggered by and for the sole benefit of' a particular Project, have been identified.

Customer Impact Assessments

Customer Impact Assessments are required to be completed by the transmitter (Hydro One Networks Inc.) before this Report can be finalised.

Any adverse impacts that are identified in these Assessments for the individual generation projects will be captured in the final version of this Report.

Notification of Approval

Subject to the results of the Customer Impact Assessments and the implementation of the specific requirements identified by the IMO for the connection of each project, it has been recommended that a *Notification of Approval for the Connection* be issued for each Project.

SYSTEM IMPACT ASSESSMENT REPORT

For the following Projects in the 2nd Sarnia-Windsor Cluster:

The Enron 630MVA Project

The Calpine 975MVA Project

The Imperial Oil 112MVA Project

SYSTEM IMPACT ASSESSMENT REPORT

For the three generation Projects in the 2nd Sarnia-Windsor Cluster

1. Introduction

1st Sarnia-Windsor Cluster

The System Impact Assessment for the 1st Sarnia-Windsor Cluster was issued on 1st December 2000 and this examined the impact of the following four Projects on the IMO-controlled grid:

- the 580MVA Project by TransAlta Energy Corp. at the Dow Chemical Complex, in Sarnia
- the 610MVA Project by Enron Canada Corp. at Lambton TGS, in Sarnia
- the 625MVA Project by AES Endeavor Inc. near Leamington
- the 680MVA Project by ATCO Canada Corp. at Keith TS, in Windsor

The TransAlta Project is now in full commercial operation.

The ATCO Project, which is presently under construction, is expected to start full commercial operation in the spring-2004.

The AES Project is scheduled to commence full commercial operation in the spring-2005.

The Enron Project, which was originally designed to be a straight gas-turbine development, has since been redesigned as a combined-cycle facility, with a rated capacity of 630MVA. This Project is therefore being reassessed as part of this new cluster.

2nd Sarnia-Windsor Cluster

The three Projects that are to be assessed as part of the 2nd Sarnia-Windsor Cluster are therefore as follows:

- the 630MVA Project by Enron Canada Corp. at Lambton TGS, in Sarnia
- the 975MVA Project by Calpine Canada Power Holdings in Nova Township, Sarnia
- the 112MVA Project by Imperial Oil at their Complex, in Sarnia

As the basis for the assessment of this 2nd Sarnia-Windsor Cluster, the three Projects from the 1st Cluster, with the exception of the Enron Project, were all included in the baseline system model.

Scheduled In-service Dates

The scheduled in-service dates for these Projects are as follows:

- The Enron Project Q2-2004
- The Calpine project Q3-2004
- The Imperial Oil Project Q2-2004

2. Connection Arrangements

The connection arrangements that have been proposed by the individual applicants for the incorporation of their Projects into the IMO-controlled grid are shown in the following Diagrams:

- Diagram 1 - Enron Project
- Diagram 2 & 3 - Calpine Project
- Diagram 4 & 5 - Imperial Oil Project

Comments on the Connection Arrangements

2.1 Enron Project

The original proposal for the Enron Project consisted of four gas-turbine units with no 230kV circuit breakers installed at the new development. This facility was to have been incorporated, via a 3.2km single-circuit transmission line, directly into an existing 230kV diameter at Lambton 230kV switchyard. A 230kV in-line circuit breaker was to have been installed at Lambton TGS, with a second breaker installed in the existing diameter, as shown in the upper portion of Diagram 6.

When the SIA Report was prepared for the 1st Sarnia-Windsor Cluster, the IMO had recommended that measures should be implemented to allow the 230kV busbar at Lambton TGS to be operated split to address the fault level problems that had been identified in the assessment. One of these measures would have involved the relocation of one of the Ontario-Michigan Interconnections to balance the two halves of the split busbar. Because of its position at the extreme south-end of the switchyard, it was assumed that the L4D Interconnection would be selected for retermination on to the northern half of the split busbar.

Relocating the L4D Interconnection would have had the added benefit of physically separating the L4D Interconnection from the adjacent termination for the Enron facility. With the arrangement shown in the upper portion of Diagram 6, a breaker-failure condition involving the new 230kV breaker would have resulted in the simultaneous loss of both the L4D Interconnection and the entire Enron facility.

A subsequent review by Hydro One indicated that it would be better to relocate the L51D Interconnection to the northern half of the split busbar. Furthermore, since each diameter can accommodate four circuit breakers, the termination arrangement for the connection to the Enron Project at Lambton TGS was subsequently revised as shown in the lower half of Diagram 6. Instead of installing the new in-line breaker, it was recommended that it be installed within the existing diameter. With two breakers located between the L4D connection and the Enron connection, a breaker-failure condition involving either of the new breakers would no longer result in the simultaneous loss of both the L4D Interconnection and the entire Enron facility.

The new arrangement proposed by Enron includes an in-line breaker at the new facility, installed in the new transmission line, together with individual 230kV breakers for each generating unit. A new 230kV breaker is also to be installed in the existing diameter at Lambton TGS, to provide a termination point for the new transmission line from the Enron project.

The 230kV breakers that are to be installed on the HV side of the generator transformers will normally be used for the isolation of transformer faults. However, in the event that Enron receives approval to install a separate connection to the Detroit Edison System they would also be used, together with their associated disconnect switches, to isolate specific generating units from the Ontario system.

Since the new arrangement that has been proposed by Enron, involving the installation of a single new 230kV breaker at Lambton TGS, would leave the system exposed to the possible loss of both the L4D Interconnection and the entire Enron facility as a result of a breaker-failure condition, the IMO will require the new 230kV overhead line from the Enron facility to be terminated on to the 230kV busbar at Lambton TGS using the arrangement that is shown in Diagram 7.

230kV Circuit Breakers

The particulars provided by Enron in their SIA Application quote a rated voltage of 242kV and a rated symmetrical short circuit capability of 63kA.

It should be noted that the circuit breakers (and all associated facilities) should be suitable for a maximum continuous voltage of 250kV - Reference 2 of Appendix 4.1 of the Market Rules.

The existing air-blast circuit breakers at Lambton TGS, with the exception of the two breakers, KL4 & PL4, are all rated at 70.0kA symmetrical and 92.0kA asymmetrical. Breakers KL4 & PL4 are rated at 65.0kA symmetrical and 78.0kA asymmetrical. Furthermore, depending on the particular sequence in which future generation Projects are developed, it is possible that breakers KL4 & PL4 may be replaced with higher-rated units before it becomes necessary to proceed with the splitting of the Lambton 230kV busbar.

If breakers KL4 & PL4 were to be replaced, then the 70.0kA symmetrical and 92.0kA asymmetrical rating of the remaining breakers would become the 'reference' fault level for operating this portion of the system. It would therefore be necessary to ensure that any new facilities that are installed for the Enron Project would not impose a lower fault level limit to which the system would have to be operated. The two new breakers that are required to be installed within the existing 230kV diameter at Lambton TGS should therefore be rated at least 70.0kA symmetrical and 92.0kA asymmetrical. For the remaining breakers at the actual Enron Project, a rating of 63.0kA may be adequate due to the attenuating effect of the overhead line, and the distribution of fault infeeds from the individual generating units. However, in the event that Enron decides to proceed with their Project the adequacy of the breakers that they are proposing to install should be verified prior to purchase.

The IMO therefore requires that, prior to ordering any 230kV equipment for this Project, Enron must consult with Hydro One regarding appropriate ratings.

2.2 Calpine Project

As shown in Diagrams 2 & 3, the Calpine Project is to be connected to circuits L23N, L25N & L27N between Lambton TGS and Sarnia-Scott TS. The new facility would be connected to the existing tapped connections to circuits L25N and L27N, that supply Nova Corunna TS, and via a new 1.5km tap that would need to be established on to circuit L23N.

Calpine is proposing to establish a full 230kV switching station so that, should the Lambton 230kV busbar eventually be reconfigured and operated split, it would then be possible to dedicate specific generating units to the three 230kV circuits between Lambton TGS and Sarnia-Scott TS. Until the Lambton 230kV busbar is split, (and subject to the two lower-rated 230kV breakers at Lambton TGS having been replaced as identified in Section 5.2.1 of this Report) it would be possible for the 230kV busbar at the Calpine facility to remain closed.

Once it becomes necessary to operate with the Lambton 230kV busbar split, it is the intention that the two breakers, identified as 'A' & 'B' in Diagram 2, would be operated normally-open. This would result in the two gas-turbine units, GT2 & GT3 being connected to circuit L23N, while the steam-turbine unit ST1, and the remaining gas-turbine unit GT1, would be associated with circuits L25N & L27N. With the 230kV busbar at Lambton TGS reconfigured and operated split, circuit L23N would be associated with the northern-half of the split busbar while circuits L25N & L27N would be associated with the southern-half of the busbar (refer to Diagram 3). Operating with breakers 'A' & 'B' open at the Calpine facility would then become a requirement to avoid 'bridging' the split busbar at Lambton TGS.

It should also be noted that the proposed busbar arrangement at the Calpine facility would provide the flexibility to change the location of the normally-open points to allow different generating units to be dedicated to the various circuits. It is expected that this feature could be used whenever circuits are out-of-service and the prevailing ambient conditions result in favourable thermal ratings that would allow more units than normal to be connected to the remaining circuits.

It should, however, be noted that if Calpine Canada wants to have the flexibility to associate different generating units with particular transmission circuits, then this feature would need to be incorporated into the generation rejection scheme that is a requirement for the incorporation of the Calpine Project into the IMO-controlled grid.

[For further details on the requirements for generation rejection, refer to Section 6.]

Since the station service supply for the Calpine Project is to be obtained from the LV terminals of two of the generator step-up transformers, these two generating units are to be equipped with LV synchronising breakers, as shown in Diagram 2. Synchronising of the remaining two generating units would be performed via the 230kV circuit breakers at the new switching station. However, because of the various synchronising arrangements that could be employed, it is recommended that *all* of the 230kV circuit breakers that are to be installed at the new switching station, as well as the two LV synchronising breakers, should be capable of withstanding at least a 2 p.u. voltage across their open terminals.

Furthermore, although it is the intention to operate the 230kV busbar at Lambton TGS permanently 'split' once it has been reconfigured, there may be occasions when conditions would allow the Lambton busbar to be operated 'closed'. (This situation is more likely to arise under line outage conditions when less generation capacity would be dispatched and the projected fault levels would be lower.)

It is expected that a rating of 63.0kA would be adequate for the equipment to be installed at the Calpine facility, due to the attenuating effect of the overhead line connections and the distribution of fault infeeds from the individual generating units. However, in the event that Calpine should decide to proceed with their development, then before ordering any equipment, they should verify that the breakers and associated facilities would be adequate for the expected fault interrupting duty.

The IMO therefore requires that, prior to ordering any 230kV equipment for this Project, Calpine must consult with Hydro One regarding appropriate ratings.

Coupled Offers

The tools that the IMO presently has available for determining the dispatch of generation facilities requires separate offers to be submitted for each injection point. Since there is the potential for the Calpine Project to inject at three separate points, then separate offers would be required for each of these injection points.

It is recognised that to fully exploit the inherent efficiencies of combined-cycle generating facilities, the offers for each injection point on the IMO-controlled grid would need to be inter-dependent. However, the existing IMO tools for dispatching generation capacity are presently unable to accommodate such coupled offers.

Auto-reclosure Requirements

Reference 4 of Appendix 4.4 of the Market Rules requires all transmission circuits to be equipped with timed, single-shot automatic reclosing facilities.

Since the 230kV switching station at the Calpine Project will become an integral part of the transmission system, auto-reclosure facilities will need to be installed on the 230kV breakers at the Calpine switching station.

While auto-reclosure of the Lambton TS to Sarnia-Scott TS circuits is presently initiated from either Lambton TS or from Sarnia-Scott TS, and it is unlikely that auto-reclosure will need to be initiated at any of the Calpine terminals, future changes in either the system configuration or the manner in which the system is operated, could require auto-reclosure to be initiated from the Calpine switching station.

The IMO therefore requires that auto-reclosure facilities be installed on the 230kV circuit breakers that are to be installed at the Calpine switching station.

2.3 Imperial Oil Project

After completing Preliminary Assessments that examined both a 230kV and a 27.6kV incorporation arrangement for their proposed generation development, Imperial Oil has decided to proceed with the 27.6kV option.

Diagram 4 shows the proposed arrangement for incorporating a single 112MVA gas-turbine generating unit on to the 27.6kV busbar of the new 230/27.6kV DESN station that Imperial Oil is presently developing.

The existing DESN station at the Imperial Oil Complex in Sarnia, which consists of step-down transformers T3 & T4, presently supplies Substations 2A, 2B & 3B. Transformer T2 is used as a switchable spare for any protracted outages involving transformers T3 or T4.

A new step-down transformer, T1, is to be connected in parallel with transformer T2 to establish a second DESN station. The two 27.6kV overhead line circuits, M1 & M2, that presently connect Substation 2A to the existing DESN station are to be reterminated on to the new DESN station so that it will become the point of supply for Substation 2A.

The new generating unit is to be connected to the 27.6kV busbar at Substation 2A via a new cabled-busbar connection, approximately 800 metres in length, that is to comprise three or four 750kcmil cables per phase. The new 27.6/13.8kV generator step-up transformer is to be connected directly to the new cabled connection, with switching for the step-up transformer and the 27.6kV cabled connection being performed at Substation 2A via two 27.6kV circuit breakers connected in parallel. While these two breakers and the bus-section breaker at Substation 2A are to be operated normally-closed, this arrangement would allow the generator to be connected to either side of the 27.6kV busbar whenever the busbar needs to be operated split.

Synchronising of the generating unit would normally be performed using the local 13.8kV generator circuit breaker. However, Imperial Oil is planning to install facilities that would permit synchronising to be performed via either of the 27.6kV breakers on the M1 and M2 feeders at Substation 2A, or via either of the LV breakers that are associated with the step-down transformers T1 & T2. All of these breakers, which have been identified in Diagrams 4 & 5, will need to be capable of sustaining a voltage of at least 2 p.u. across their open terminals.

By equipping the four 27.6kV breakers with facilities that would allow them to be used for synchronising, it is Imperial Oil's intention to avoid having to 'collapse' any island that might be formed with the new generating unit supplying the load, before reconnecting the island to the main system.

Faults associated with the new generating unit would normally be cleared via its 13.8kV generator breaker, but in the event that this should malfunction, a breaker-failure scheme is to initiate tripping of the two breakers at Substation 2A that are directly associated with the cabled connection to the new generating facility.

Faults associated with either the generator step-up transformer or the 27.6kV cabled connection between the generating facility and Substation 2A would normally be cleared by the two parallel-connected breakers at Substation 2A. Should either of these breakers malfunction, then a breaker-failure scheme is to initiate clearance of the associated section of the 27.6kV busbar at Substation 2A.

Consequently, any faults associated with the new generating facility are expected to be isolated locally within the Imperial Oil Complex and therefore have no adverse impact on the 230kV system between Sarnia-Scott TS and the Imperial Oil Complex.

Loads at the Imperial Oil Complex

The present peak load at the Imperial Oil Complex is approximately 103MVA. A further 36MVA of load is supplied from St. Andrews TS.

During peak load periods the output of the new generating unit would therefore displace most of the existing load at the Imperial Oil Complex. However, during light load periods there could be occasions when the normal output from the new generating unit would exceed the available, local load.

Imperial Oil is therefore proposing to install facilities to control the output of their generating facility so that it 'follows the local load'. These facilities are intended to avoid the export of any surplus output from their new generating facility to the IMO-controlled grid.

Furthermore, if the load that is presently supplied from St. Andrews TS were to be transferred to the two DESN stations at the Imperial Oil Complex then this would help reduce the likelihood of there being excess output from the new generating unit.

However, to address those occasions when exports may occur, Imperial Oil has agreed to integrate their new generating facility into the Sarnia-Scott G/R Scheme. This is discussed later in Section 6.3.

Reactive Power Requirements

Since the new generating facility is intended to displace a large portion of the load at the Imperial Oil Complex, the amount of load remaining to be supplied from the system would be reduced accordingly. The power factor at which this remaining load is to be supplied is required to be within the range of 0.9 lagging to 0.9 leading (Reference 1 of Appendix 4.3 of the Market Rules). This will mean that the reactive power demand of the load at the IOL Complex together with the reactive losses on the IOL system will have to be supplied locally, either from the new generating unit or from local capacitor banks.

As part of their 4th Transformer Project, Imperial Oil had indicated that two new 14.3MVAr (29kV) capacitor banks are to be installed at the new DESN station to complement the two existing 18MVAr (30kV) capacitor banks at the existing DESN station.

Since the combined impedance of the facilities connecting the new 13.8kV generator to the 230kV system is expected to exceed 35% (on 100MVA$_{base}$) it will not be possible to comply with the Market Rules which limit the maximum impedance to approximately 13% (calculated on the generator voltage and MVA$_{base}$).
[References 1 & 2 of Appendix 4.2.]

Consequently, the incorporation arrangement that has been proposed will exclude Imperial Oil from participating in the electricity market.

Voltage declines at the Imperial Oil Facility in response to generator trips

Studies were performed to examine the impact on the Imperial Oil 27.6kV busbars of the loss of the new generating unit. The studies examined two scenarios: one with both 14.3MVAr capacitor banks at the new DESN station in-service and the other with only a single capacitor bank in-service.

For each study, the reactive power output of the generator was adjusted so that the reactive power flows at the 230kV terminals of transformers T1 & T2 were approximately zero. This was intended to ensure that the power factor of the net load at the Imperial Oil Complex would comply with the requirements of the Market Rules.

The power factor of the load at Substation 2A was assumed to be 0.9 lagging.

With both 14.3MVAr capacitor banks in-service, a voltage decline of 1.44% at the 27.6kV busbar at Substation 2A was recorded in response to a trip of the new generating unit.

With one of the 14.3MVAr capacitor banks out-of-service and with the reactive power output from the generator adjusted so as to continue to maintain zero reactive power flows at the HV terminals of the DESN transformers, the voltage decline at the 27.6kV busbar at Substation 2A in response to a generator trip, increased to 5.54%.

Should there be a limit on the voltage decline that can be tolerated at the Imperial Oil facility, then this could require the maximum reactive power output of the generating unit to be restricted during these periods when a capacitor bank is out-of-service.

However, even with the generator operating with its reactive power output increased to compensate for the loss of one of the 14.3MVAr capacitor banks, the voltage decline on the IMO-controlled grid resulting from a trip of the new generator at the Imperial Oil facility would be well within the 4% limit for switching operations involving capacitor banks (the nearest equivalent operation). It would therefore meet the requirements of the Market Rules.

Imperial Oil has subsequently confirmed that they will be installing sufficient shunt capacitors to supply all the reactive power demands of the Complex and that their new generator will therefore only be required to supply the reactive power losses of the generator step-up transformer. Consequently, under normal operating conditions there will be a zero reactive power flow at the 27.6kV terminal of the generator step-up transformer.

3. Load Flow Analysis

Other than the possible post-contingency overloading of the companion circuits due to contingencies involving the 230kV circuits between Lambton TGS and Sarnia-Scott TS, the studies that had been performed for the Preliminary Assessments for each of the three Projects that constitute the 2nd Sarnia-Windsor Cluster had shown that none of these Projects would be expected to have an adverse impact on the IMO-controlled grid.

To address the post-contingency over-loading of the 230kV circuits between Lambton TGS and Sarnia-Scott TS resulting from the incorporation of the Calpine Project on to these circuits it was proposed to use a generation rejection scheme, and this is discussed later in this Report.

In addition, both the Calpine and Enron Projects would need to be incorporated into the existing Lambton G/R Scheme to allow the units at the new facilities and at Lambton TGS to be selected for rejection in the event of contingencies at Lambton TGS (breaker-failure conditions) or involving the Ontario-Michigan Interconnections L4D and L51D.

Furthermore, the new Imperial Oil generating facility would need to be incorporated into the Sarnia-Scott G/R Scheme to address possible transfers to the IMO-controlled grid in the event of a sudden loss of load at their Complex.

Apart from a general requirement for the new generation Projects to be incorporated into new or existing G/R Schemes, and the prospect of considerable congestion on the system should a high proportion of the Projects that have been assessed proceed to completion (and this is discussed in the next section), there were no issues identified that would justify further load flow analysis.

Furthermore, with the amount of new generation capacity that has been proposed for incorporation into the system in south-western Ontario, it becomes increasing difficult to establish a reasonable base-case for further analysis unless assumptions are made about possible future transmission enhancements within the area. Again, this is explained further in the next section.

4. Transfer Limits on the Transmission System in the Sarnia-Windsor Area

With the 230kV busbar at Lambton TGS operated ***'closed'*** the transfer capability across the various interfaces that have been established to enable the impact of the proposed generating Projects in south-western Ontario to be assessed, are summarised in the following Table. However, it should be noted that the limits quoted for both the Sarnia-London Interface and the London-Import Interface are particularly sensitive to the generation Projects that were assumed to be in-service, since these influence the flow distribution on the various circuits that comprise each of these Interfaces.

Limiting Transfers Across the Principal Interfaces with the Lambton busbar operated 'closed'		
Import Condition		
Interface:	*Transfer Limit*	*Limiting Condition*
Ontario-Michigan Interface	***1505MW ****	*Lambton PL51 Breaker Failure* Interface transfers are restricted by the 15-minute limited-time-rating of the L4D Interconnection (1170MVA)
Sarnia-London Interface	***2650MW***	*Pre-Contingency flow on circuits L24L & L26L* Interface transfers are restricted by the continuous rating of these two circuits (579MVA/per circuit).
London Import Interface	***2865MW***	
Export Condition		
Ontario-Michigan Interface	***2409MW ****	*Lambton L51L29 Breaker Failure* (with rejection of one Lambton unit) Interface transfers are restricted by the 15-minute limited-time-rating of the B3N Interconnection (482MVA)

** Note: These limits may need to be revised should Michigan not agree to the Interconnections being operated to their 15-minute limited-time-rating.*

Diagram 8 shows the Load and Generation Balance for the peak load condition with all of the proposed generation facilities in south-western Ontario in-service. In addition, the limiting transfers across each of the Interfaces have also been included in the Diagram.

The principal conclusions that can be drawn from the information presented in this Diagram are as follows:

- For the Sarnia area, with all of the following projects in-service, the net transfer across the Sarnia-London Interface would be approximately 3200MW, with zero imports across the B3N, L4D & L51D Interconnections. Since the transfer capability of the Sarnia-London Interface is 2650MW, then transfers of approximately 550MW to Michigan would need to be made across these three Interconnections if all five generating facilities are to be fully dispatched:
    - TransAlta Project
    - Calpine Project
    - Enron Project
    - Imperial Oil Project, and
    - The four units at Lambton TGS

  During off-peak periods, with lighter system loads, the extent of the congestion is expected to worsen, even after making allowance for possible higher thermal ratings due to lower ambient temperatures.

- Since the net output from the Windsor area would only be approximately 100MW with both the ATCO and AES Projects fully dispatched, then with zero imports across all four Ontario-Michigan Interconnections the net transfer across the London-Import Interface would increase to approximately 3300MW. This would exceed the transfer capability of the London-Import Interface by approximately 430MW. Consequently, in order for all the generating facilities in the Sarnia and Windsor areas to be fully dispatched and to respect the transfer capability of this Interface, a combined transfer to Michigan of approximately 430MW would need to be made via the four Interconnections.

  Since the Sarnia-London Interface is more limiting than the London-Import Interface, then the higher transfer of 550MW to Michigan would be required for all the generating facilities in the Sarnia and Windsor areas to be fully dispatched.

- After allowing for the load in the London area, the net transfer across the Negative-BLIP (Bruce-Longwood Input) Interface would be 2100MW. Since this would exceed the 1500MW transfer capability of this Interface then transfers to Michigan of approximately 600MW would be required to allow all the generating facilities in south-western Ontario to be fully dispatched while respecting the operating limit for this Interface.

  [It has been assumed that any flows from the Bruce Complex into Longwood TS, via circuits B562L & B563L, would be off-set by the combined transfers away from Longwood TS, via circuit N582L, and away from Buchanan TS, via circuits D4W, D5W, M31W, M32W & M33W. These flows would therefore not contribute to the Negative-BLIP flow.]

4.1 Incremental Changes in Flow Distribution

Diagram 9 shows the incremental flow changes that would be expected to occur with the incorporation of the Calpine, Enron and Imperial Oil Projects. While the actual flows that will appear on the individual circuits will depend on the 'normal' flows without these Projects in-service, these incremental flows do provide an indication of where the heaviest flows are expected to appear. Since the incremental changes in flow are not evenly distributed, they also provide an indication of where thermal limitations are expected to influence generation dispatch, or alternatively where system reinforcement would be the most effective.

Diagram 9 shows that the highest proportion of the flow from the new facilities would be expected to appear on circuits L24L and L26L, between Lambton TGS and Longwood TS. Of the remaining flow from the new facilities, slightly more would appear on circuits N21W & N22W, between Sarnia-Scott TS and Buchanan TS, than on circuits W44LC & W45LC, between Chatham TS and Buchanan TS. However, since the Sarnia area is expected to have a significantly larger excess of generation over the local load than the Windsor area, then even without the new generation facilities in this cluster, circuits L24L, L26L, N21W & N22W would normally be much more heavily loaded than circuits W44LC & W45LC. Consequently, the highest flows resulting from the incorporation of the new generating facilities into the system in the Sarnia-Windsor area are expected to occur on circuits L24L & L26L, while slightly lower flows are expected to appear on circuits N21W & N22W.

This leads to the general conclusion that, in the event that a number of the proposed generation Projects in the Sarnia-Windsor area are developed, the most effective transmission reinforcement to help relieve the resulting congestion, would be between Lambton TGS and Longwood TS. Installing additional transmission between these locations would also be expected to reduce the flows on circuits N21W & N22W, making them less susceptible to overloading.

Furthermore, the prevailing value for the Negative-BLIP limit varies depending on the number of generating units that are in-service at Lambton TGS and Nanticoke TGS and therefore able to provide reactive support to the Longwood and Middleport busbars. Should new transmission facilities be installed between Lambton TGS and Longwood TS, then these, together with any additional generating units that may be installed in the Sarnia-Windsor area, would provide additional voltage support to the Longwood busbar. These facilities would therefore be expected to enhance the Negative-BLIP limit. While this would need to be confirmed through additional analysis, any improvement in the Negative BLIP limit would help reduce congestion.

5. Fault Level Analysis

Fault level studies were performed to determine the impact of the three generation Projects in the 2nd Sarnia-Windsor Cluster on the existing transmission facilities.

The following system conditions were assumed when preparing the system model that was used for these studies:

- All existing transmission facilities, together with those facilities that have been 'committed', were incorporated into the model.
- The four Interconnections with Michigan reflect their final arrangement following the installation of the new phase-shifters.
- The generators at the Bruce 'A' station were considered to be out-of-service
- The generators at the Pickering 'A' station were considered to be in-service
- The two 500/230kV auto-transformers at Lennox TS, together with units G1 to G4 at Lennox GS were considered to be in-service.
- The 230kV busbars at Richview TS were assumed to be split.
- The 230kV busbars at Cherrywood North TS & Cherrywood South TS were assumed to be split.
- The TransAlta Project at the Dow Chemical Complex in Sarnia was assumed to be in-service.
- The ATCO Project at Keith TS in Windsor was assumed to be in-service.
- The AES Project near Leamington was assumed to be in-service.
- The 230kV busbar at Lambton TGS was assumed to be closed.
- All of the 20kA circuit breakers on the 115kV busbar at Sarnia-Scott TS were assumed to have been replaced with higher rated units.
- The two 115kV series-connected reactors on the two 230/115kV auto-transformers at Sarnia-Scott TS were assumed to have been removed.
- *The original (1995) representation for the Detroit Edison Company in the year-2000 was used to model that system*.

The full, quoted fault interrupting capability of the circuit breakers on the 230kV and 115kV systems was used when assessing the adequacy of the equipment for the projected fault interrupting duty that is likely to be imposed on it.

5.1 CME North America 1050MW Facility in China Township, Michigan

St Clair Energy Projects LLC, a subsidiary of CME North America Merchant Energy LLC, is proposing to develop a 1050MW generating facility in China Township, close to the 345kV Belle River SS on the Detroit Edison System.

The scheduled in-service date is summer-2004.

Should this facility be developed, then due to its proximity to the two Ontario-Michigan Interconnections between St Clair SS and Lambton TGS, it is expected to have an impact on the fault levels within the Sarnia area.

Fault Level studies were therefore performed with, and without, this new generating facility in-service.

5.2 Fault Level Results

The results from the fault level studies have been summarised in the following Tables:

Table 1: Lambton TGS: 230kV busbar
Table 2: Sarnia-Scott TS: 230kV busbar
Table 3: Sarnia-Scott TS: 115kV busbar
Table 4: Keith TS: 230kV & 115kV busbar
Table 5: Other principal busbars in the area

The convention that has been employed in the above Tables to distinguish between the various fault level results is to shade those cells that contain the symmetrical fault level values and ratings, and to leave those cells that contain the asymmetrical values unshaded.

Where the projected fault level at the main busbars exceed the fault interrupting capability of the existing breakers, the relevant figures in the summary tables have been shown in ***bold-italic.***

5.2.1 Fault levels at Lambton TGS

The upper portion of Table 1 shows the fault levels at Lambton TGS for the various generation scenarios that were studied, with the new generating facility in China Township, Michigan assumed to be in-service. The lower portion of the Table shows the corresponding results with the new Michigan development assumed to be out-of-service.

Comparison of the two sets of results shows that the China Township development would be expected to increase fault levels by approximately 1.6kA symmetrical and between 2.1kA & 2.8kA asymmetrical. In addition, the three new Projects, should they all proceed, would increase fault levels by approximately 11.9kA symmetrical and 15.3kA asymmetrical.

The Table also indicates that the *total* fault levels at the Lambton 230kV busbar for all of the development scenarios that were studied are expected to exceed the breaker ratings. Since the fault interrupting duty that is imposed on the individual breakers will vary depending on the actual fault infeeds at the busbar, separate diagrams have been produced to identify the particular breakers whose fault interrupting capability would be exceeded.

The following Tables provide details regarding the number of breakers that are expected to be affected for each generation development scenario, together with the reference number of the corresponding diagram. The first Table is for the situation with a new 1050MW generating facility developed in China Township, Michigan, while the second Table corresponds to the situation with no new generation in Michigan.

It should be noted that since the fault levels experienced at Lambton TGS would be lower without the China Township facility in-service, that it was therefore only necessary to produce diagrams for this condition for those particular development scenarios from the first Table for which it had been established that one, or more, breakers would be affected.

No. of breakers that would need to be replaced at Lambton TGS: *With new generation capacity in-service in China Township, Michigan*				
	For 3-phase faults	*Diagram No.*	*For Single-line-to-ground faults*	*Diagram No.*
'Existing'	0	**-**	0	**-**
With Imperial Oil	0	10	0	11
With Calpine	0	12	2	13
With Enron	0	14	***10***	15
With Imperial Oil & Calpine	0	16	2	17
With Imperial Oil & Enron	0	18	***10***	19
With Calpine & Enron	1	20	***13***	21
With all 3 new Projects I/S	2	22	***13***	23

*Note: For those situations where the number of breakers have been shown in **bold-italic**, it is assumed the Lambton 230kV busbar would be reconfigured to allow it to be operated split*

No. of breakers that would need to be replaced at Lambton TGS: *With no new generation capacity in China Township, Michigan*				
	For 3-phase faults	*Diagram No.*	*For Single-line-to-ground faults*	*Diagram No.*
'Existing'	0	-	0	-
With Imperial Oil	0	-	0	-
With Calpine	0	-	2	13-1
With Enron	0	-	2	15-1
With Imperial Oil & Calpine	0	-	2	17-1
With Imperial Oil & Enron	0	-	2	19-1
With Calpine & Enron	2	20-1	***13***	21-1
With all 3 new Projects I/S	2	22-1	***13***	23-1

*Note: For those situations where the number of breakers have been shown in **bold-italic**, it is assumed the Lambton 230kV busbar would be reconfigured to allow it to be operated split*

The results shown in these Tables can also be summarised, as follows:

- The impact of the Imperial Oil Project on the fault levels at Lambton TGS is minimal, and if it is developed in isolation of either of the other Projects in the cluster, the ratings of all of the existing breakers at Lambton TGS would be adequate.

- Similarly, the China Township Project in Michigan, should it be developed in isolation of either the Calpine or Enron Projects, would not cause the ratings of any of the existing breakers to be exceeded. This is also true if the China Township Project and just the Imperial Oil Project were to be developed

- The Calpine Project, if it were to be developed either in isolation or together with the Imperial Oil Project would only affect the two lower-rated breakers, KL4 & PL4, at Lambton TGS, *regardless of the development status of the China Township Project.*

- The Enron Project, whether it is developed in isolation or together with the Imperial Oil Project would also only affect the two lower-rated breakers, KL4 & PL4, at Lambton TGS, *as long as the China Township Project is NOT developed.*

- For all of the other development scenarios that are listed below, the ratings of at least ten of the breakers at Lambton would be exceeded. However, for this number of breakers it was concluded in the System Impact Assessment for the 1st Sarnia-Windsor Cluster that the appropriate response would involve reconfiguring the Lambton 230kV busbar to allow it to be operated permanently split:

Development Scenarios that would require the 230kV busbar at Lambton TGS to be split	
1. With no new generation capacity in China Township, Michigan	*No. of breakers affected*
1.1 With both the Calpine & Enron Projects developed	***13***
1.2 With all three Projects in the 2nd Sarnia-Windsor Cluster developed	***13***
2. With the new generation capacity in China Township, Michigan in-service	*No. of breakers affected*
2.1 With the Enron Project developed in isolation	***10***
2.2 With both the Enron & Imperial Oil Projects developed	***10***
2.3 With both the Calpine & Enron Projects developed	***13***
2.4 With all three Projects in the 2nd Sarnia-Windsor Cluster developed	***13***

5.2.2 Fault Levels at Sarnia-Scott TS

230kV Facilities

Table 2 shows the fault levels on the 230kV busbar at Sarnia-Scott TS. As before, the upper portion of this Table corresponds to the situation with the new generation capacity that has been proposed in China Township assumed to be in-service. The lower portion is for the situation without this generation facility in-service.

A comparison of the two sets of results on Table 2 shows that the effect of the China Township development in Michigan on the 230kV busbar at Sarnia-Scott TS is significantly lower than that at Lambton TGS, contributing only about 0.2kA symmetrical and 0.4kA asymmetrical to the fault levels.

Table 2 indicates that for 3-phase faults, the *total* fault levels on the 230kV busbar at Sarnia-Scott TS, for the majority of the development scenarios that were studied, are expected to exceed the fault interrupting capability of the existing breakers. Separate diagrams have been produced in order to determine the actual breakers for which the fault interrupting duty is expected to exceed the breaker rating, and these have been identified in the following Table. This Table also shows the number of breakers that would be affected for each development scenario.

[Since the minimum infeed is approximately 2.66kA asymmetrical and the breakers are rated at 46.2kA asymmetrical, the existing breakers would be adequate for all of those cases for which the *total* fault level at the 230kV busbar would be less than 48.86kA.]

No. of breakers that would need to be replaced at Sarnia-Scott TS: *With new generation capacity in-service in China Township, Michigan*		
	For 3-phase faults	*Diagram No.*
'Existing'	0	**-**
With Imperial Oil	0	**-**
With Calpine	***6***	24
With Enron	0	25
With Imperial Oil & Calpine	***6***	**-**
With Imperial Oil & Enron	0	**-**
With Calpine & Enron	***6***	**-**
With all 3 new Projects I/S	***6***	26

Two additional diagrams were also produced for the condition with no new generation capacity in China Township, Michigan so as to determine the number of breakers that would be affected for each of the development scenarios under this condition. The results are summarised in the Table below:

No. of breakers that would need to be replaced at Sarnia-Scott TS: *With no new generation capacity in-service in China Township, Michigan*		
	For 3-phase faults	*Diagram No.*
'Existing'	0	**-**
With Imperial Oil	0	**-**
With Calpine	***5***	24-1
With Enron	0	**-**
With Imperial Oil & Calpine	***6***	27
With Imperial Oil & Enron	0	**-**
With Calpine & Enron	***6***	**-**
With all 3 new Projects I/S	***6***	**-**

The results shown in the two Tables above can be summarised, as follows:

- The Calpine Project, if it were to be developed in isolation of either the China Township Project in Michigan, or any of the other Projects in the cluster, would trigger the replacement of five of the existing 230kV breakers at Sarnia-Scott TS.

- If, in addition to the Calpine Project, one of the other Projects should also be developed (the Imperial Oil Project; the Enron Project; or the China Township Project in Michigan), then one additional 230kV breaker at Sarnia-Scott TS would also need to be replaced.

- If the Calpine Project were not to be developed, then all three of the other Projects (the Imperial Oil Project, and the Enron Project, and the China Township Project in Michigan) could be developed without triggering the replacement of any of the existing 230kV breakers at Sarnia-Scott TS.

115kV Facilities

Table 3 shows the fault levels on the 115kV busbar at Sarnia-Scott TS. As before, the upper portion of this Table corresponds to the situation with the new generation capacity that has been proposed in China Township assumed to be in-service. The lower portion is for the situation without this generation facility in-service.

This Table shows that for all of the development scenarios that were considered, the contributions to the fault levels on the 115kV busbar at Sarnia-Scott TS are negligible. Since none of the 115kV circuits at Sarnia-Scott TS contribute to the fault levels on the 115kV busbar, the maximum fault interrupting duty that will be imposed on each breaker will be the same as the *total* fault level at the 115kV busbar. However, even with all three Projects in the 2nd Cluster developed, as well as the China Township Project in Michigan, the *total* fault level has been shown to remain approximately 7.5kA below the rating of the two lowest-rated breakers (KL1 & L1L6). Consequently, all of the existing 115kV breakers at Sarnia-Scott TS would be adequate for the projected increase in fault levels.

5.2.3 Fault levels at Keith TS

Table 4 shows the fault levels on both the 230kV busbar and the 115kV busbar at Keith TS for the situation with the proposed China Township development in-service.

The fault levels for the condition with no new generation capacity in China Township have not been separately tabulated. However, for comparison, the values corresponding to the 'existing' system with the new generation capacity assumed to be in-service in Michigan, have been included in this Table (directly under the values for the 'existing' system). These sets of values confirm that the proposed generating facility in Michigan will have only a negligible effect on the fault levels on either the 230kV busbar (+ 0.02kA) or the 115kV busbar (+ 0.01kA).

The results in this Table show that even if all three Projects in this cluster were to be developed, the fault level on the 230kV busbar at Keith TS would be expected to increase by a maximum of only 0.05kA. On the 115kV busbar the maximum increase would be expected to be only 0.02kA. These very small increases would not cause any of the ratings of the existing breakers at Keith TS to be exceeded.

5.2.4 Fault Levels at the other Principal Busbars in the Sarnia-Windsor Area

Table 5 provides a summary of the fault levels at the other principal busbars in the Sarnia-Windsor area. Only the results for the 'existing' system and those for the 'extreme' condition with all three Projects in the cluster assumed to be in-service, together with the China Township Project, have been tabulated.

[Fault levels were not obtained for either Longwood TS (which is equipped with 63kA breakers) or Chatham TS (which is equipped with 40kA breakers) since earlier studies had indicated that there was more than sufficient margin between the existing fault levels and the breaker ratings to accommodate the expected increases in fault level from the Projects in this cluster.]

As shown in this Table the largest increases in fault level, of those transformer stations that were examined, occurred at Buchanan TS. However, since the contributions to the fault levels on the 230kV and 115kV busbars were only 0.40kA and 0.15kA, respectively, the increased fault levels would remain well within the breaker ratings.

The effect of all of the proposed developments on the local 115kV system in the Windsor area would also be negligible (0.02kA).

6. Generation Rejection/Runback Schemes

6.1 Existing & Proposed Schemes

i. Lambton Generation Rejection Scheme

The Lambton G/R Scheme, which has been in-service for at least 20-years, was installed to increase the maximum transfers that can be made across the two Ontario-Michigan Interconnections, L4D & L51D. The original Scheme was subsequently upgraded so that it now has the capability of initiating instantaneous rejection of one of the four generating units at Lambton TGS in response to any of the following contingency conditions:

- An L4D contingency condition
- An L4D line-end-open (LEO) condition - detected at either the Lambton or the St Clair (Michigan) terminal.
- An L51D contingency condition
- An L51D LEO condition - detected at either the Lambton or the St Clair (Michigan) terminal.
- A breaker-failure condition involving any of the following breakers at Lambton TGS:
    - L51L29 - which would result in the simultaneous loss of circuit L29C & Interconnection L51D
    - L27L28 - which would result in the simultaneous loss of circuits L27N & L28C
    - L25L26 - which would result in the simultaneous loss of circuits L25N & L26L
    - L23L24 - which would result in the simultaneous loss of circuits L23N & L24L

ii. Sarnia-Scott Generation Rejection Scheme

This is a new Scheme that is in the process of being installed as part of the connection requirements for the new TransAlta Generation project at the Dow Chemical Complex in Sarnia.

This Scheme will initiate rejection and/or run-back of specific generating units at the TransAlta facility in response to contingencies involving the following circuits:

- 230kV circuits N6S or N7S - Sarnia-Scott TS to Imperial Oil
- 230kV circuits N21W &/or N22W - Sarnia-Scott TS to Buchanan TS
- 230kV circuits L23N &/or L25N &/or L27N - Sarnia-Scott TS to Lambton TGS
- The Ontario-Michigan Interconnection B3N

iii. Windsor Area Overload & G/R Scheme

As a requirement for the incorporation of the proposed ATCO Generation Project at Keith TS, the existing Windsor Area Overload Protection and Load Rejection Scheme is to be enhanced.

The existing Scheme initiates cross-tripping of the 115kV circuits to split the 115kV system at Essex TS in response to overloads that are detected on the 230/115kV auto-transformers at Keith TS or on the 115kV circuits Z1E and Z7E, between Lauzon TS and Essex TS. These overloads can occur as a result of various contingencies involving the local 230kV or 115kV systems, or either of the auto-transformers at Keith TS.

In addition, this Scheme can initiate load rejection at Kingsville TS and Tilbury TS/Tilbury West DS in response to contingencies involving the 230kV circuits C23Z and/or C24Z, or the two 230/115kV auto-transformers at Lauzon TS. This part of the Scheme is connectivity-based, using the status of the circuit breakers and disconnect switches at Lauzon TS to identify when the 230/115kV connection is broken at that location. Furthermore, since single-element contingencies in the Lauzon TS/Kingsville TS/Tilbury area can result in excessive voltage declines on the 115kV busbar at Kingsville TS, this Scheme can also initiate load rejection at that TS in response to sustained low voltages.

With the introduction of the new ATCO generation facility at Keith TS, the portion of the Scheme that presently responds to overloads will need to become connectivity-based. This would then allow different responses to be initiated for different contingency conditions under various system operating conditions; specifically with different levels of transfers on the J5D Ontario-Michigan Interconnection. In addition, the existing Scheme will need to be expanded so that it can also address contingencies involving the Ontario-Michigan Interconnection, J5D.

It is proposed to enhance the existing Windsor Area Overload & Load Rejection Scheme in two discrete phases. Phase I would be completed for the incorporation of the ATCO Project at Keith TS, and Phase II would be completed once either AES or AGSTAR confirm that they are to develop their respective projects near Leamington and Tilbury.

Once Phases I & II have been completed the Scheme would then be able to initiate splitting of the local 115kV system and/or rejection of the generating units of the ATCO, AES & AGSTAR Projects, in response to contingencies involving the following system elements:

- 230kV circuits C21J &/or C22J - Chatham TS to Keith TS
- 230kV circuits C23Z &/or C24Z - Chatham TS to Lauzon TS
- Auto-transformers T11 &/or T12 at Keith TS
- Auto-transformers T1 &/or T2 at Lauzon TS
- 115kV circuits in the Windsor Area
- The Ontario-Michigan Interconnection J5D

6.2 Splitting of the 230kV busbar at Lambton TGS

Once fault levels on the 230kV busbar at Lambton TGS increase to approximately 93kA (asymmetrical), it is expected that the 230kV busbar will need to be reconfigured to allow it to be operated split.

With the 230kV busbar operated split, changes would also need to be made to the existing Lambton G/R Scheme to allow specific generating units at Lambton TGS to be rejected for contingencies involving each particular Interconnection:

- For a contingency involving the L51D Interconnection, which is to be reterminated on to the northern half of the Lambton 230kV busbar, only units G1 & G2 which would remain connected to the same section of busbar would need to be selectable for rejection,

and similarly,

- For a contingency involving the L4D Interconnection, which is to remain connected to the southern half of the Lambton 230kV busbar, only units G3 & G4 would need to be selectable for rejection.

In addition, with the rearrangement of the terminations on to the 230kV busbar, the particular circuits affected by the critical breaker failure conditions that are addressed by the existing Scheme would change. Furthermore, circuit breaker L25L26 would no longer be a critical breaker, since one of the terminations associated with this breaker would become vacant.

The existing Scheme would therefore need to be revised to allow specific generating units to be selected for rejection in response to each of the critical breaker failure conditions that remain. These changes would be similar to those required for contingencies affecting the L4D & L51D Interconnections.

6.3 Changes Required to the Existing/Proposed Schemes for the Projects in the 2nd Cluster

Diagram 28 is an attempt to show the existing/proposed Schemes and the expansion/integration that is expected to be required to incorporate the new Projects in the 2nd Sarnia-Windsor Cluster into the system.

Although the specific requirements will depend on the actual sequence in which the proposed Projects are developed, the changes that are expected to be required for the incorporation of each Project are as follows,

i. Imperial Oil Project

Although Imperial Oil is planning to operate their new generating unit so that it supplies only their local requirements, there could be occasions when net transfers are made to the IMO-controlled. The new generator is therefore to be integrated into the Sarnia-Scott G/R Scheme.

A functional specification for the revised scheme, which has been agreed with Imperial Oil, is shown in Diagram 28A.

Since the generating unit at the Imperial Oil Complex is only to be armed when transfers are being made from the Complex to the IMO-controlled grid, additional features are to be incorporated into the supervisory controls for the Sarnia-Scott G/R Scheme at the Clarkson System Control Centre.

These features will monitor the flows on circuits N6S & N7S at the Imperial Oil Complex and whenever they exceed a set threshold AND if any of the TransAlta generating units are also armed for rejection, an alarm will be initiated. This will notify the System Operators that the G/R selections need to be reviewed and that the Imperial Oil unit should be selected for rejection.

Once the flows on circuits N6S & N7S decline and fall below an appropriate threshold, AND if the Imperial Oil unit has been selected for rejection, a separate alarm will be initiated to notify the System Operators that the Imperial Oil unit should be de-selected.

ii. Calpine Project

While the fault level studies have shown that the Calpine Project, either in isolation or together with the Imperial Oil and the China Township Project in Michigan, would increase fault levels sufficiently to trigger the replacement of the two lower-rated breakers at Lambton TGS, it would not be sufficient to trigger the splitting of the 230kV busbar.

On the assumption that it is decided to replace just these two breakers and not advance the proposed reconfiguration of the 230kV busbar at Lambton TGS to allow it to be operated split, then the changes described earlier for a split busbar would not be required. However, because of its proximity to Lambton TGS, the Calpine Project would need to be integrated into the *existing* Lambton G/R Scheme.

In addition, because of its direct affect on the flows on the three 230kV circuits between Lambton TGS and Sarnia-Scott TS, facilities would be required to allow rejection of the generating units at the Calpine Project in response to contingencies involving these circuits.

The relevant section from the Preliminary Assessment for the Calpine Project has been reproduced in Appendix A. This provides details of the ratings for the 230kV circuits between Lambton TGS and Sarnia-Scott TS and the rationale for requiring generation rejection to be initiated for contingencies involving these circuits.

Although contingencies involving circuits L23N, L25N & L27N are initially to be addressed by the Sarnia-Scott G/R Scheme, it is expected that the initiating signal will also need to be derived at the Lambton terminals. This would then allow possible LEO (line-end-open) conditions involving these circuits to be addressed by either Scheme as a result of breaker-failure conditions at either Lambton TGS or Sarnia-Scott TS.

There is also a requirement to be able to select the generating units at the Calpine facility for contingencies involving the Ontario-Michigan Interconnections (and also possibly for contingencies involving the 230kV circuits to Longwood TS and Chatham TS). Furthermore, since the Calpine Project will also affect the flows on circuits N21W & N22W between Sarnia-Scott TS and Buchanan TS, it will therefore be necessary to provide a capability to reject generating units at the Calpine facility, as well as those at the TransAlta facility, to address overloads resulting from contingencies involving these circuits.

Since the status of some of the circuits for which generation rejection is to be initiated is to be monitored at Lambton TGS, while that of some of the other circuits is to be monitored at Sarnia-Scott TS, it will therefore become necessary for the two Schemes to be integrated.

iii. Enron Project

The fault level analysis has shown that if the Enron Project were to be developed in isolation, it would not trigger the splitting of the Lambton 230kV busbar. However, this busbar would need to be split if the China Township Project in Michigan were also to be developed.

Similarly, if both the Enron and Calpine Projects were to be developed, with or without the China Township Development in Michigan, the Lambton 230kV busbar would need to be split.

If the Lambton 230kV busbar were split, then the changes to the Lambton G/R Scheme that were discussed earlier would need to be completed.

In addition, regardless of whether the busbar is to be operated split, facilities would need to be installed to allow the generating units at the Enron Project to be rejected for those contingency conditions that are presently covered by the Lambton G/R Scheme, together with the following additional contingency conditions:

- 230kV circuits L24L and/or L26L
- 230kV circuits L28C and/or L29C
- 230kV circuits N21W and/or N22W
- 230kV circuits L23N and/or L25N and/or L27N

As before, for the Calpine Project, this would mean integrating the Lambton and Sarnia-Scott G/R Schemes.

iv. Calpine, Enron, AES & AGSTAR Projects

Should either the Calpine or Enron Project be developed in the Sarnia area, and either the AES or AGSTAR Project be developed in the Leamington/Tilbury area, then the post-contingency flows on the 230kV circuits W44LC & W45LC, between Chatham TS and Buchanan TS, are expected to become critical.

This is expected to require contingencies involving one or both of these circuits to be addressed by the G/R Schemes. As shown in Diagram 28, this would require the Lambton G/R Scheme and the Windsor Area Overload & G/R Scheme to be integrated. With the Lambton and Sarnia-Scott G/R Schemes already integrated, this would then mean that all three G/R Schemes in the area would become integrated. This would then provide a capability to arm generating units at any of the Projects in the Sarnia-Windsor area for rejection in response to a comprehensive range of contingencies.

Standard Requirements for Special Protection Systems

Any new Special Protection Systems (G/R, L/R and Cross-Tripping Schemes) or enhancements to any existing SPSs must comply with the following criteria:

- All facilities are to be fully duplicated
- The logic used for detecting a contingency condition is to be connectivity-based, and
- The SPSs are to be capable of being pre-armed with the appropriate selections to ensure a rapid response to a contingency.

7. Transient Stability Analysis

Market Rules Requirement: Excitation System Performance

Reference 12 of Appendix 4.2 of the Market Rules states:

> *Each synchronous generating unit that is rated at 10MVA or larger shall be equipped with an excitation system with a voltage response time not longer than 50msec, and a ceiling voltage at least twice the rated field voltage.*

Open-circuit Response Tests were conducted for each of the exciters proposed for the individual Projects to determine whether they would be able to comply with this requirement.

7.1 Enron Project

Exciter

Diagram 29 shows the data that were provided for the EX2000 bus-fed IEEE AC2 exciter that Enron is proposing to install on all three units at their Project.

For the generating units proposed for this Project, the rated field voltage, at rated output, would be 2.58 p.u.

Diagram 30 shows the results that were obtained for the open-circuit response test. In order to comply with the requirements of the Market Rule, the exciter field voltage would need to exceed a value of approximately 5.2 (twice the rated field voltage of 2.58 p.u.) in 50msec.

Since the exciter was only able to achieve a field voltage of approximately 2.0 p.u. in 50msec. it would not comply with the Market Rules and would therefore be unacceptable.

A Simplified Excitation System (SEXS) model was therefore used to represent the exciters on the Enron units, and Diagram 31 shows the typical values that were used for the model.

Diagram 32 shows the typical response that this exciter, which has a gain of 200, would provide. [In the actual case shown, the exciter is associated with the gas-turbine unit of the Imperial Oil Project.]

Stabiliser

Diagram 33 shows the data that were provided for the PSS2A model of the Power System Stabiliser that is to be installed on all three generating units.

Governor

Diagram 34 shows the data that were provided for the GAST model of the governor that Enron is proposing to install on the two gas-turbine units.

Diagram 35 shows the typical response that this governor would provide. [In the actual case shown, the governor is associated with the gas-turbine unit of the Imperial Oil Project.] This response would be acceptable.

Since no data were provided for the governor that is to be installed on the steam-turbine unit, a typical IEEEG1 model was assumed with the data values shown in Diagram 36.

The expected response of this governor would be similar to that shown in Diagram 37 for the identical governor fitted to the steam-turbine unit of the Calpine Project.

7.2 Calpine Project

Exciter

Diagrams 38 & 39 show the data that were provided for the IEEE models representing the excitation systems that are to be installed on the gas-turbine units and the steam-turbine unit, respectively:

Diagram 38: IEEE ESAC2A model for the 8TE3008S brushless exciter to be installed on the gas-turbine units.
Diagram 39: IEEE ESAC5A model for the brushless exciter to be installed on the steam-turbine unit.

For these generating units, the rated field voltage, at rated output, would be as follows:

2.64 p.u. for the gas-turbine units, and
2.73 p.u. for the steam-turbine unit

Diagrams 40 & 41 show the results obtained for the open-circuit response test for an increase of 5% in the generator terminal voltage. Neither exciter was able to achieve a field voltage of twice the rated value within the 50msec. interval as specified in the Market Rules, and they would therefore not be acceptable.

As before for the Enron units, a Simplified Excitation System (SEXS) model was used to represent the exciters on the Calpine units, and Diagram 31 shows the typical values that were used for the model.

Diagram 32 shows the typical response that this exciter, which has a gain of 200, would provide. [In the actual case shown, the exciter is associated with the gas-turbine unit of the Imperial Oil Project.]

Stabiliser

Data were provided for IEEE PSS1A models to represent the Power System Stabilisers that Calpine is proposing to install on their gas-turbine and their steam-turbine units. The data provided are shown on Diagrams 42 & 43 for the gas-turbine and steam-turbine units, respectively.

Since the IEEE PSS1A model is not recognised by the PTI Programs used by the IMO, IEEEST models where used, with appropriate changes to the respective T_6 time constants.

For both stabilisers, the K_S gain was given as a negative value, and this resulted in sustained oscillations on the Calpine units in response to a three-phase fault on the L4D Interconnection at Lambton TS, as shown in Diagram 44. Changing the K_S gain values to positive values resulted in a damped response.

Diagrams 45 & 46 show the data values that were used in the transient stability studies.

Governor

Since no data were provided for the governors to be installed on the Calpine units, typical GAST models were assumed, having the data values shown in Diagram 47.

7.3 Imperial Oil Project

Exciter

Diagram 48 shows the data that were provided for the EX2000 bus-fed IEEE ST4B exciter that Imperial Oil is proposing to install on their gas-turbine unit.

For this generating unit, the rated field voltage, at rated output, would be 3.03 p.u. of the air gap field voltage. Consequently, in order to comply with the Market Rule governing the required response for exciters, the field voltage would need to achieve a value of approximately 6.0 p.u. within 50msec.

Diagram 49 shows the results that were obtained for the open-circuit response test, in response to an increase of 5% in the generator terminal voltage, using the specified gain of 2.05.

Since the exciter only reaches a maximum field voltage of approximately 2.0 p.u. in 50msec it would not be acceptable.

A Simplified Excitation System (SEXS) model was therefore used to represent the exciter on the Imperial Oil unit, having the values shown in Diagram 31.

Diagram 32 shows the typical response that this exciter, which has a gain of 200, would provide. This would achieve the 6.0 p.u. field voltage (twice the rated field voltage of 3.03 p.u.) that is required by the Market Rules within 50msec.

Imperial Oil subsequently confirmed that their exciter is capable of achieving a ceiling voltage of 9.06 p.u. of the air gap field voltage and that it can be operated at higher gain settings.

Additional studies were therefore performed using a gain setting of 15 for the EX2000 exciter. The following Diagrams show the response of the proposed generator at the Imperial Oil Complex to a 3-phase fault on the 230kV circuit N6S at the TransAlta generating facility for different exciter models:

Diagram 32A	With a SEXS Model for the Exciter with a gain of 200
Diagram 32B	With an EXPIC1 Model for the Exciter, with a gain of 2 - with & without the benefit of a power system stabiliser
Diagram 32C	With an EXPIC1 Model for the Exciter with a gain of 15 - with & without the benefit of a power system stabiliser
Diagram 32D	Comparative responses at the different gain settings, with a power system stabiliser.

From these results it was determined that the exciter with a gain setting of 11, or greater, would meet the requirements of the Market Rules.

Diagram 32E compares the results that were obtained for the open-circuit response test for an increase of 5% in the generator terminal voltage using the EXPIC1 model with a gain of 11, with those obtained using a SEXS model with a gain of 200.

Stabiliser

Diagram 50 shows the data that were provided for the PSS2A model of the EX2000 Power System Stabiliser that is to be installed on the new steam-turbine generating unit.

Governor

Diagram 50A shows the data that were provided for the governor to be installed on the steam-turbine unit

7.4 Transient Stability Results

Transient stability studies were performed for both positive and negative transfer conditions across the BLIP (Bruce Longwood Input) Interface. The transfers were adjusted to correspond to the respective operating limit together with a further 10% margin:

- For the Negative (eastward) BLIP flow condition, for which the operating limit is 1500MW, the transfer was 1650MW.
- For the Positive (westward) BLIP flow condition, for which the operating limit is 3500MW, the transfer was 3850MW.

Missing data

Where machine data were missing, appropriate values were assumed as shown below (the shaded cells indicate where data were assumed):

i. For the Enron Project

Generator Parameters					
	Gas-turbine	***Steam-turbine***		***Gas-turbine***	***Steam-turbine***
X_d	1.92	1.92	T'_{do}	4.767	4.767
X_q	1.832	1.832	T''_{do}	0.033	0.033
X'_d	0.289	0.289	T'_{qo}	0.394	0.394
X'_q	0.464	0.464	T''_{qo}	0.074	0.074
X''_d	0.205	0.205	S (1.0)	0.05	0.05
X_l	0.170	0.170	S (1.2)	0.23	0.23
X_2	0.195	0.195	H	5.3kWsec/kVA	5.3kWsec/kVA
X_0	0.126	0.126	D	0.0	0.0

ii. For the Calpine Project

Generator Parameters					
	Gas-turbine	***Steam-turbine***		***Gas-turbine***	***Steam-turbine***
X_d	1.995	2.01	T'_{do}	9.5	7.4
X_q	1.94	1.98	T''_{do}	0.047	0.025
X'_d	0.258	0.292	T'_{qo}	1.12	1.50
X'_q	0.442	0.446	T''_{qo}	0.082	0.04
X''_d	0.195	0.262	S (1.0)	0.077	0.10
X_l	0.166	0.189	S (1.2)	0.267	0.275
X_2	0.193	0.223	H	6.6kWsec/kVA	3.54kWsec/kVA
X_0	0.104	0.136	D	0.0	0.0

iii. For the Imperial Oil Project - all required data were provided

Generator Parameters: Gas-turbine Unit			
X_d	2.20	T'_{do}	7.90
X_q	2.09	T''_{do}	0.040
X'_d	0.255	T'_{qo}	0.590
X'_q	0.465	T''_{qo}	0.080
X''_d	0.185	S (1.0)	0.0731
X_l	0.140	S (1.2)	0.3945
X_2	0.185	H	5.69kWsec/kVA
X_0	0.110	D	0.0

Where data have had to be assumed, the respective Proponent will be responsible for ensuring that the equipment that is eventually installed meets or exceeds the values that are shown in the Tables above (so as to result in a better performance than that shown in the stability plots).

Fault conditions

The performance of the generating units for the following fault conditions at different locations on the system were examine:

- Normally-cleared three-phase faults;
- Normally-cleared line-to-line-to-ground faults; and
- Delayed clearance line-to-ground faults.

Summary of Transient Stability Results

Tables A & B summarise the results of the transient stability studies for east and west transfers across the BLIP Interface, respectively.

The results are ranked in order of their severity, in terms of the rotor angle deviation that was recorded.

Maximum Angular Deviation				
	Direct of Transfer across the BLIP Interface			
	Eastwards: Negative		*Westwards: Positive*	
Three-Phase Fault	30^{o} at Lambton GS	Fault on L4D, L51D or L28C	34^{o} at Lambton GS	Fault on M570V at Claireville TS
			Diagram 54	
	30^{o} at Imperial Oil	Fault on N6S	30^{o} at Calpine GS	Fault on L4D or L51D
	Diagram 51			
Line-to-Line-to-Ground Fault	27^{o} at Lambton GS	Fault on L28C or L29C	25^{o} at Calpine GS	Fault on L28C or L29C
	Diagram 52		*Diagram 56*	
Line-to-Ground Fault: Delayed	70^{o} at Imperial Oil	Fault on N7S	50^{o} at Imperial Oil	Fault on N7S
	Diagram 53		*Diagram 57*	

Individual Plot Diagrams, as indicated above, have also been included for the most severe cases. Instead of including the plots for a Three-Phase Fault on either the L4D or the L51D Interconnection, under Positive BLIP Flow Conditions, those for a Three-Phase Fault on circuit N6S at TransAlta GS have been included - Diagram 55. This allows a direct comparison to be made for the same fault condition with transfers in different directions across the BLIP Interface.

The results from the transient stability studies show that for all fault conditions examined the generating units remained stable, with acceptable machine damping. In addition, the voltages at all of the monitored busbars were restored to within 10% of their pre-contingency values within the 10-second simulation period.

In general, apart from those fault conditions involving 230kV circuit N7S with delayed clearance, three-phase faults represented the most severe of the fault conditions examined, resulting in the greatest rotor angle deviations. While larger rotor angular deviations were recorded for faults on circuit N7S with delayed clearance, they were confined to the Imperial Oil generating unit, having very little impact on the other generating units that were monitored in the area.

Table A: Transient Stability Results - With Negative Flows across the BLIP Interface

Contingency Conditions Examined with a flow (eastwards) of 1650MW across the BLIP Interface. [Equivalent to the Negative BLIP limit of 1500MW (with four units at Lambton TGS in-service) plus a 10% margin.]							
Three-phase fault, cleared in normal time							
Designation of faulted circuit			*Location of applied fault*	Results			
				Stability	*Damping*	*Max δ*	*Voltage*
51	N6S	Scott to Trans Alta GS	TransAlta GS	*Stable*	*Good* > 0.03	30^o at Imperial Oil	*Good* *Recovers to within 10% of Pre-fault value*
	L28C	Lambton to Chatham TS	Lambton TGS			30^o at Lambton	
	L4D	Lambton to St Clair (Michigan)	Lambton TGS			30^o at Lambton	
	L51D	Lambton to St Clair (Michigan): Lambton G2 tripped	Lambton TGS			30^o at Lambton	
	N21W	Scott to Buchanan TS	Scott TS			28^o at Imperial Oil	
	L26L	Lambton to Longwood TS	Lambton TGS			27^o at Lambton	
	M570V	Milton to Claireville 500 kV TS	Claireville TS			27^o at Imperial Oil	
	L23N	Lambton to Scott TS: Calpine GT2 & GT3 tripped	Scott TS			25^o at Imperial Oil	
	B3N	Scott to Bunce Creek (Michigan)	Scott TS			25^o at Imperial Oil	
	N582L	Nanticoke to Longwood 500 kV TS	Longwood TS			15^o at Imperial Oil	

X *Indicates the number of the Diagram showing the results of the transient stability study*

Table A (Continued): Transient Stability Results - With Negative Flows across the BLIP Interface

Contingency Conditions Examined with a flow (eastwards) of 1650MW across the BLIP Interface. [Equivalent to the Negative BLIP limit of 1500MW (with four units at Lambton TGS in-service) plus a 10% margin.]							
Line-to-line-to-ground fault, cleared in normal time							
Designation of faulted circuit			*Location of applied fault*	*Results*			
				Stability	*Damping*	*Max δ*	*Voltage*
52	L28C +L29C	Lambton to Chatham TS	Lambton TGS	*Stable*	*Good* > 0.03	27^{o} at Lambton	*Good* *Recovers to within 10% of Pre-fault value*
	L24L+L26L	Lambton to Longwood TS	Lambton TGS			23^{o} at Calpine	
	N21W+N22W	Scott to Buchanan TS	Scott TS			23^{o} at Imperial Oil	
	N6S+ N7S	Scott to TransAlta GS: TransAlta, Dow & Imperial units tripped	TransAlta GS			19^{o} at Calpine	
	B560V+B561M	Bruce NGS to Claireville TS and to Milton TS	Bruce NGS			17^{o} at Imperial Oil	
	B562L+B563L	Bruce NGS to Longwood TS	Longwood TS			15^{o} at Imperial Oil	
	L23N+L25N	Lambton to Scott TS	Scott TS			13^{o} at Imperial Oil	
	L23N+L27N	Lambton to Scott TS (same as an L23N & L25N contingency)	Scott TS			13^{o} at Imperial Oil	
	L25N+L27N	Lambton to Scott TS: Calpine GT1 & ST1 tripped	Scott TS			13^{o} at Imperial Oil	

X *Indicates the number of the Diagram showing the results of the transient stability study*

Table A (Continued): Transient Stability Results - With Negative Flows across the BLIP Interface

Contingency Conditions Examined with a flow (eastwards) of 1650MW across the BLIP Interface. [Equivalent to the Negative BLIP limit of 1500MW (with four units at Lambton TGS in-service) plus a 10% margin.]							
Line-to-ground fault, delayed clearing (breaker failure time)							
Designation of faulted circuit			*Location of applied fault*	*Results*			
				Stability	*Damping*	*Max δ*	*Voltage*
53	N7S + Imperial M2 feeder	Scott to TransAlta GS: M1 feeder cleared in normal time + 300msec	Imperial Oil 230kV Junction	*Stable*	*Good > 0.03*	70^{o} at Imperial Oil	*Good* *Recovers to within 10% of Pre-fault value*
	L51D + One Lambton unit	Lambton to St Clair GS: 3-phase applied to increase severity. Lambton G2 tripped from breaker failure protection	Lambton TGS			18^{o} at Calpine, Imperial Oil & ENRON	
	L25N+L26L	Lambton to Scott, & Lambton to Longwood TS	Lambton TGS			15^{o} at Lambton	
	N7S+N22W	Scott to TransAlta & Scott to Buchanan TS	Scott TS			15^{o} at Imperial Oil	
	N7S+L25N	Scott to TransAlta & Lambton to Scott TS	Scott TS			13^{o} at Imperial Oil	
	N22W+W44LC	Scott to Buchanan, & Buchanan to Longwood & to Chatham TS	Buchanan TS			12^{o} at Imperial Oil	
	N6S+L23N	Scott to TransAlta & Lambton to Scott TS: L23N contingency trips two units at Calpine	Scott TS			9^{o} at Imperial Oil	

X *Indicates the number of the Diagram showing the results of the transient stability study*

Table B: Transient Stability Results - With Positive Flows across the BLIP Interface

Contingency Conditions Examined with a flow (westwards) of 3850MW across the BLIP Interface. [Equivalent to the Positive BLIP limit of 3500MW plus a 10% margin.]							
Three-phase fault, cleared in normal time							
Designation of faulted circuit			*Location of applied fault*	*Results*			
				Stability	*Damping*	*Max δ*	*Voltage*
54	M570V	Milton to Claireville 500 kV TS	Claireville TS	*Stable*	*Good* > 0.03	34^{o} at TransAlta	*Good* *Recovers to within 10% of Pre-fault value*
	L4D	Lambton to St Clair (Michigan)	Lambton TGS			30^{o} at Calpine	
	L51D	Lambton to St Clair (Michigan)	Lambton TGS			30^{o} at Calpine	
	B3N	Scott to Bunce Creek	Scott TS			26^{o} at Calpine	
	L28C	Lambton to Chatham TS	Lambton TGS			26^{o} at Calpine	
	L23N	Lambton to Scott TS: Calpine GT2 & GT3 tripped	Scott TS			22^{o} at Calpine	
	L26L	Lambton to Longwood TS	Lambton TGS			22^{o} at Calpine	
55	N6S	Scott to Trans Alta GS	TransAlta GS			22^{o} at Calpine	
	N21W	Scott to Buchanan TS	Scott TS			22^{o} at Calpine	ΔV= 3% at Longwood TS
	N582L	Nanticoke to Longwood 500 kV TS	Longwood TS			6^{o} at Calpine	

X *Indicates the number of the Diagram showing the results of the transient stability study*

Table B (Continued): Transient Stability Results - With Positive Flows across the BLIP Interface

Contingency Conditions Examined with a flow (westwards) of 3850MW across the BLIP Interface. [Equivalent to the Positive BLIP limit of 3500MW plus a 10% margin.]							
Line-to-line-to-ground fault, cleared in normal time							
Designation of faulted circuit			*Location of applied fault*	*Results*			
				Stability	*Damping*	*Max δ*	*Voltage*
56	L28C +L29C	Lambton to Chatham TS	Lambton TGS	*Stable*	good	25^{o} at Calpine	*Good* *Recovers to within 10% of Pre-fault value*
	N6S+ N7S	Scott to TransAlta GS: TransAlta, Dow & Imperial Oil units tripped	TransAlta GS			22^{o} at Calpine	
	L23N+L25N	Lambton to Scott TS	Scott TS			15^{o} at Calpine	
	L24L+L26L	Lambton to Longwood TS	Lambton TGS			14^{o} at Calpine	
	L23N+L27N	Lambton to Scott TS: Same as L23N & L25N contingency	Scott TS			12^{o} at Imperial Oil	
	L25N+L27N	Lambton to Scott TS: Calpine GT1 & ST1 tripped	Scott TS			12^{o} at Imperial Oil	
	N21W+N22W	Scott to Buchanan TS	Scott TS			12^{o} at Calpine	
	B562L+B563L	Bruce NGS to Longwood TS	Longwood TS			11^{o} at Calpine	marginal $\Delta V = 10\%$ at Longwood TS
	B560V+B561M	Bruce NGS to Claireville TS and to Milton TS	Bruce NGS			10^{o} at Calpine	*Good*

X *Indicates the number of the Diagram showing the results of the transient stability study*

Table B (Continued): Transient Stability Results - With Positive Flows across the BLIP Interface

Contingency Conditions Examined with a flow (westwards) of 3850MW across the BLIP Interface. [Equivalent to the Positive BLIP limit of 3500MW plus a 10% margin.]							
Line-to-ground fault, delayed clearing (breaker failure time)							
Designation of faulted circuit			*Location of applied fault*	*Results*			
				Stability	*Damping*	*Max δ*	*Voltage*
57	N7S + Imperial Oil M2 feeder	Scott to TransAlta GS: M1 feeder cleared in normal time + 300msec.	Imperial Oil 230kV Junction	*Stable*	*Good* > *0.03*	50^{o} at Imperial Oil	*Good* *Recovers to within 10% of Pre-fault value*
	L51D	Lambton to St Clair GS: 3-phase applied to increase severity. Lambton G2 tripped from breaker failure protection	Lambton TGS			27^{o} at Calpine	
	L25N+L26L	Lambton to Scott, & Lambton to Longwood TS	Lambton TGS			17^{o} at Calpine	
	N6S+L23N	Scott to TransAlta, & Lambton to Scott TS	Scott TS			8^{o} at Calpine	
	N7S+L25N	Scott to TransAlta, & Lambton to Scott TS	Scott TS			8^{o} at Calpine	
	N7S+N22W	Scott to TransAlta, & Scott to Buchanan TS	Scott TS			8^{o} at Calpine	
	N22W+W44LC	Scott to Buchanan, & Buchanan to Longwood & to Chatham TS	Buchanan TS			5^{o} at Calpine	

X *Indicates the number of the Diagram showing the results of the transient stability study*

8. Conclusions

This Assessment has confirmed that apart from their impact on fault levels, the three Projects in the 2nd Sarnia-Windsor Cluster are expected to have no adverse impact on the IMO-controlled grid, subject to the provision of suitable generation rejection facilities.

The specific requirements for the incorporation of each Project have been summarised below:

8.1. The Enron Project

i. Breaker Replacement/Busbar Splitting Requirements

The effect of incorporating the Enron Project, either in isolation or in combination with the other Projects in the cluster, on the number of breakers that would need to be replaced at Lambton TGS and Sarnia-Scott TS is shown in the following Table.

Number of 230kV breakers to be replaced at Lambton TGS & Sarnia-Scott TS					
For the Enron Project		*Status of new generation in China Township, Michigan*			
		With no new capacity		With new capacity	
		Lambton	Sarnia-Scott	Lambton	Sarnia-Scott
i.	In isolation:	2	0	***10***	0
ii.	& with the Calpine Project	***13***	6	***13***	6
iii.	& with the Imperial Oil Project	2	0	***10***	0
iv.	& with the Calpine & Imperial Oil Projects	***13***	6	***13***	6

Note: The shaded cells indicate conditions that have been assumed to justify reconfiguring the Lambton 230kV busbar so as to allow it to be operated split and thereby avoid replacing an excessive number of breakers.

ii. Incorporation Arrangement

The arrangement shown in Diagram 7 would need to be implemented to address the IMO's concerns regarding possible breaker-failure conditions at Lambton TGS.

The specification for the 230kV equipment that Enron is proposing to install will also need to be reviewed to ensure that it is suitable for the expected maximum fault level at which the Lambton 230kV busbar could be operated.

iii. Machine, Exciter & Stabiliser Data

Enron Canada Corp. will need to confirm the inertia constant for their steam-turbine unit, for which a value of 5.3kW-sec/kVA was assumed in the analysis, and also provide revised data for the exciters that they propose to install to allow the IMO to confirm that they will meet the requirements of the Market Rules. Since data were not provided for the governor for the steam-turbine unit, these will also need to be supplied.

iv. Generation Rejection/Run-back Schemes

The Enron Project will need to be incorporated into an enhanced Lambton G/R Scheme and this Scheme will need to be integrated with the Sarnia-Scott G/R Scheme.

Summary of the Incorporation Requirements for the Enron Project

i. Incorporate the new generating facility into the existing 230kV diameter at Lambton TGS using the arrangement shown in Diagram 7.

ii. Consult with Hydro One prior to ordering any equipment to confirm that the ratings that have been specified are appropriate.

iii. Complete the following work at Lambton TGS:

If the new China Township Project is not developed -

- Replace breakers KL4 & PL4 with higher-rated units.

If the new China Township Project is developed -

- Reconfigure the 230kV busbar to allow it to be operated split.

iv. Supply the missing machine data, together with revised data for the exciters, as well as data for the governor to be installed on the steam-turbine unit.

v. Incorporate the Enron Project into the Lambton G/R Scheme and integrate this Scheme with the Sarnia-Scott G/R Scheme.

8.2. The Calpine Project

i. Breaker Replacement/Busbar Splitting Requirements

The effect of incorporating the Calpine Project, either in isolation or in combination with the other Projects in the cluster, on the number of breakers that would need to be replaced at Lambton TGS and Sarnia-Scott TS is shown in the following Table.

Number of 230kV breakers to be replaced at Lambton TGS & Sarnia-Scott TS					
For the Calpine Project		*Status of new generation in China Township, Michigan*			
		With no new capacity		With new capacity	
		Lambton	Sarnia-Scott	Lambton	Sarnia-Scott
i.	In isolation:	2	5	2	6
ii.	& with the Enron Project	***13***	6	***13***	6
iii.	& with the Imperial Oil Project	2	6	2	6
iv.	& with the Enron & Imperial Oil Projects	***13***	6	***13***	6

Note: *The shaded cells indicate conditions that have been assumed to justify reconfiguring the Lambton 230kV busbar so as to allow it to be operated split and thereby avoid replacing an excessive number of breakers.*

ii. Incorporation Arrangement

Although the proposed arrangement for incorporating the new Calpine Project would meet the IMO's requirements, consultation with Hydro One to determine appropriate ratings for any new equipment that is to be installed will be required prior to placing orders.

iii. Machine, Exciter, Stabiliser & Governor Data

Calpine Canada Power Holdings will need to confirm the transient time constant for their gas-turbine units, for which a value of 9.5sec was assumed in the analysis, and also provide revised data for the exciters that they propose to install to allow the IMO to confirm that they will meet the requirements of the Market Rules. In addition, since data for the governors was not provided this will need to be supplied, and the data that was supplied for the power system stabiliser will need to be in a format recognised by the PTI Programs used by the IMO.

iv. Generation Rejection/Run-back Schemes

The Calpine Project will need to be incorporated into an enhanced Lambton G/R Scheme and into the Sarnia-Windsor G/R Scheme. If these two Schemes have not already been integrated, then this will need to be done for the incorporation of this Project.

Furthermore, if Calpine Canada wants to have the flexibility to associate different generating units with particular transmission circuits, then this feature would need to be incorporated into the generation rejection scheme.

Summary of the Incorporation Requirements for the Calpine Project

i. Consult with Hydro One prior to ordering any equipment to confirm that the ratings that have been specified are appropriate.

ii. Complete the following work at Lambton TGS:

If the Enron Project has not been developed -

- Replace breakers KL4 & PL4 with higher-rated units.

If the Enron Project has been developed, and the 230kV busbar is not being operated split (i.e. the China Township Project has not been developed) -

- Reconfigure the 230kV busbar to allow it to be operated split.

iii. Complete the following work at Sarnia-Scott TS:

If the new China Township Project is not developed -

- Replace five of the existing 230kV breakers with higher-rated units.

If the new China Township Project is developed -

- Replace six of the existing 230kV breakers with higher-rated units.

iv. Equip all of the 230kV breakers that are to be installed at the Calpine switching station with auto-reclose facilities

v. Supply the missing machine data, together with data for the governors and stabilisers, as well as revised data for the exciters.

vi. Incorporate the Calpine Project into the Lambton G/R Scheme and integrate this Scheme with the Sarnia-Scott G/R Scheme.

8.3. The Imperial Oil Project

i. Breaker Replacement/Busbar Splitting Requirements

The effect of incorporating the Imperial Oil Project, either in isolation or in combination with the other Projects in the cluster, on the number of breakers that would need to be replaced at Lambton TGS and Sarnia-Scott TS is shown in the following Table.

Number of 230kV breakers to be replaced at Lambton TGS & Sarnia-Scott TS					
For the Imperial Oil Project		*Status of new generation in China Township, Michigan*			
		With no new capacity		With new capacity	
		Lambton	Sarnia-Scott	Lambton	Sarnia-Scott
i.	In isolation:	0	0	0	0
ii.	& with the Calpine Project	2	6	2	6
iii.	& with the Enron Project	2	0	***10***	0
iv.	& with the Calpine & Enron Projects	***13***	6	***13***	6

Note: *The shaded cells indicate conditions that have been assumed to justify reconfiguring the Lambton 230kV busbar so as to allow it to be operated split and thereby avoid replacing an excessive number of breakers.*

ii. Incorporation Arrangement

The proposed arrangement for incorporating the new generating unit would meet all of the IMO's requirements.

iii. Machine, Exciter & Governor Data

Since the data provided for the new generating unit and its governor were complete, no further information is required.

It was also confirmed that the Imperial Oil EX2000 exciter, with a revised gain setting of 11 or higher, would meet the requirements of the Market Rules.

iv. Generation Rejection/Run-back Schemes

Although Imperial Oil is proposing to use their new generating facility solely for load displacement and they do not plan to transfer any excess output to the IMO-controlled grid, they have agreed to incorporate their new generating facility into the Sarnia-Scott G/R Scheme.

A functional specification (Diagram 28A) has been provided, detailing the proposed changes

Summary of the Incorporation Requirements for the Imperial Oil Project

i. If the new China Township Project is *not* developed and the Calpine Project is developed -

   Complete the following work at Sarnia-Scott TS:

   - Replace one of the existing 230kV breakers with a higher-rated unit.

ii. Use a gain of 11, or higher, for the exciter on their new generator.

iii. Incorporate the new generating facility into the Sarnia-Scott G/R Scheme

8.4 Congestion

The existing transmission facilities in south-western Ontario are expected to be adequate to accommodate the following facilities during peak-load periods in the summer:

- all of the existing generating facilities in south-western Ontario
- the TransAlta and ATCO Projects (from the 1st Sarnia-Windsor Cluster) that are both currently under construction, and
- maximum transfers of 1500MW into Ontario across the Ontario-Michigan Interconnections.

The incorporation of any additional generation capacity would be expected to result in congestion that would restrict the dispatch of generation facilities in the area, and/or reduce the level of transfers that could be made into Ontario.

Reinforcement of the transmission system would therefore be required if the congestion that would be expected to arise from the incorporation of further generation capacity is to be avoided or limited.

9. Equipment Nomenclature

All three proponents should consult with Hydro One regarding the nomenclature to be used for their equipment to ensure that suitable designations are employed.

An indication of the type of designations that would be appropriate has been included on Diagrams 2 and 7, for the Calpine and Enron Projects, respectively.

10. Approximate Cost Estimates

An attempt has been made to provide approximate costs for the work that will need to be done to incorporate the new generating facilities in the 2nd Sarnia-Windsor Cluster.

These costs are based on available unit costs and do not make any allowance for site conditions. Neither do they take account of outage or construction constraints; associated work that may be triggered by the work identified; or other unforeseen difficulties.

It should also be noted that, for those situations that involve replacement of existing circuit breakers with higher rated units, the extent of any associated upgrades to station buswork or disconnect switches is unlikely to be known until a detailed review of the existing station facilities has been undertaken.

10.1 Work at Lambton TGS:

(The actual requirements will depend on the particular sequence in which the Projects are developed)

i. Replacement of the two lower-rated 230kV breakers KL4 & PL4

   Estimated Cost ≈ $4 to $5 million

ii. Reconfigure the 230kV busbar to allow it to be operated split

   Estimated Cost ≈ $16 to $20 million

iii. Installation of two new 230kV breakers & line termination facilities for the termination of the new 230kV connection for the Enron Project, including modification to the protection, control & monitoring facilities.

   (It has been assumed that the new transmission line is to be constructed as part of the Enron development)

   Estimated Cost ≈ $6 to $7 million

10.2 Work at Sarnia-Scott TS:

(The actual requirements will depend on the particular sequence in which the Projects are developed)

i. Replacement of one 230kV breaker

Estimated Cost ≈ $2 to $2.5 million

ii. Replacement of five 230kV breakers

Estimated Cost ≈ $10 to $13 million

iii. Replacement of six 230kV breakers

Estimated Cost ≈ $12 to $15 million

10.3 The incorporation of the Calpine Project

i. Termination of the tapped connections on to circuits L23N, L25N & L27N and modification to the protection, control & monitoring facilities.

(It has been assumed that the new 1.5km 230kV single-circuit transmission line that is to connect to circuit L23N will be constructed as part of the Calpine Project.)

Estimated Cost ≈ $1 to $2 million

10.4 The installation of generation rejection facilities:

i. To enhance the Lambton G/R Scheme to coincide with the reconfiguration of the Lambton 230kV busbar to allow it to be operated split.

Estimated Cost ≈ $2 to $3 million

ii. To integrate either the Enron or the Calpine Project into the Lambton G/R Scheme.

Estimated Cost ≈ $1 million (each)

iii. To integrate the Imperial Oil Project into the Sarnia-Scott G/R Scheme.

Estimated Cost ≈ $¼ million to $½ million

iv. To integrate the Lambton G/R Scheme and the Sarnia-Scott G/R Scheme (to coincide with the incorporation of either the Enron or Calpine Project).

Estimated Cost ≈ $2 million

v. To integrate the Windsor Area Overload & G/R Scheme with the integrated Lambton & Sarnia-Scott G/R Scheme (to coincide with the incorporation of additional generating capacity in both the Sarnia and Windsor areas).

Estimated Cost ≈ $2 to $3 million

11. Identification of 'Sole Beneficiary'

Section 9.1.3 of the Transmission System Code states:

> *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 the following system modifications to be for the 'sole benefit' of the individual generation Projects:

11.1 The Enron Project would be the 'sole beneficiary' of:

- The installation of two new breakers and associated disconnect switches to establish a new termination point on the existing 230kV busbar at Lambton TGS. This work will also include the installation of a new line disconnect switch and all associated facilities required for the termination of the new 230kV transmission line from the Project on to the new position.
- The incorporation of the Project into the Lambton G/R Scheme.
- The integration of the Sarnia-Scott and Lambton G/R Schemes.

  (The 'sole beneficiary' designation would only apply if the Calpine Project does not proceed. Should both Projects proceed then they would be joint beneficiaries.)

11.2 The Calpine Project would be the 'sole beneficiary' of:

- The connection of the three 230kV taps on to circuits L23N, L25N & L27N, together with the modifications to the protection, control & monitoring facilities.
- The incorporation of the Project into the Lambton G/R Scheme.
- The integration of the Sarnia-Scott and Lambton G/R Schemes.

  (The 'sole beneficiary' designation would only apply if the Enron Project does not proceed. Should both Projects proceed then they would be joint beneficiaries.)

11.3 The Imperial Oil Project would be the 'sole beneficiary' of:

- The incorporation of the Project into the Sarnia-Scott G/R Scheme.

12. Customer Impact Assessments

Customer Impact Assessments are required to be completed by the transmitter (in this case Hydro One Networks Inc.) to identify any adverse impacts that the incorporation of these individual generation projects may have on other customer facilities within the area.

Should these assessments identify possible adverse impacts, then they will be addressed by issuing appropriate Addenda to this Report.

13. Notification of Approval of the Connection Proposal

This System Impact Assessment completes the IMO's review of the three generation Projects in the 2nd Sarnia-Windsor Cluster. This Assessment has identified the IMO's requirements for the connection of the new generating facilities to ensure that they will have no negative impact on the IMO-controlled grid.

Subject to the implementation of these requirements, together with any measures that may be necessary to address any adverse impacts that are identified in the respective Customer Impact Assessments, it is recommended that a *Notification of Approval for Connection* be issued for each of these Projects.

APPENDIX A

Extracted from the Preliminary Assessment Report for the Calpine Project

Ratings of the Incorporation Circuits

The Table below shows the thermal ratings for the existing three 230kV circuits between Lambton TGS and Scott TS.

Since the circuits have adequate line-to-ground clearances for operation at temperatures higher than 93°C, thermal ratings have been provided for continuous operation at the 'normal' conductor temperature of 93°C as well as at the maximum operating temperature to which each individual circuit has been 'sagged'.

The 15-minute limited-time-ratings correspond to the maximum conductor operating temperature for the respective circuits.

It should be noted that since the main sections of the three circuits are equipped with high-aluminum-content conductors (1843.2kcmil: 72/7 stranding) they are restricted to 50 hours of operation in a year at conductor temperatures above 93°C. The cells in the following table with ratings that correspond to this restriction are shown shaded.

Thermal Ratings								
Section	*Lambton TGS to Scott TS*				*Petrosar Junction to Nova Corunna*			
Circuit ID	*L23N, L25N & L27N*				*L25N & L27N*			
Conductor	*1843.2kcmil*				*795kcmil*			
	Continuous rating							
Ambient temperature	*Summer 30°C*		*Winter 10°C*		*Summer 30°C*		*Winter 10°C*	
Conductor temperature	93°C	127°C	93°C	127°C	93°C	150°C	93°C	150°C
Ratings at 240kV	1420amp 590MVA	1840amp 765MVA	1660amp 690MVA	2010amp 836MVA	870amp 362MVA	1250amp 520MVA	1020amp 424MVA	1340amp 557MVA
	15-minute Limited-time-rating							
Ambient temperature	*Summer 30°C*		*Winter 10°C*		*Summer 30°C*		*Winter 10°C*	
Conductor temperature	127°C		127°C		150°C		150°C	
Ratings at 240kV	2473 amp 1028MVA		2800 amp 1164MVA		1498 amp 623MVA		1648 amp 685MVA	
Pre-load	Nominal 1000 amp: 416MVA				650 amp: 270MVA _≈ ½ output from GT + ST			

Operation at this rating is limited to 50 hours/year

The gas-turbine and steam-turbine combination, with a combined output of 525MVA is to be incorporated via the existing tapped connections on to circuits L25N & L27N. Under normal conditions, with both circuits in-service, the tapped connections would only be loaded to approximately 263MVA, which is well within their 93°C thermal rating. However, under outage conditions involving either circuit L25N or circuit L27N, the loading on the companion, tapped connection would be approximately 525MVA.

This post-contingency loading would exceed the *continuous* rating for conductor temperatures of both 93°C and 150°C, when ambient temperatures are at 30°C, or higher. However, it would be within the 15-minute limited-time rating of the remaining tapped connection.

The following options would therefore be available to Calpine Canada for addressing the situation:

i. In the event of a contingency involving circuit L25N or L27N, initiate generation rejection to reduce the output from the gas-turbine/steam-turbine combination to within the continuous rating corresponding to a conductor temperature of 93°C.

ii. Subject to agreement from the transmitter, restrict the output from the gas-turbine/steam-turbine combination under contingency/outage conditions so as to respect the continuous rating corresponding to a conductor temperature of 150°C. Since outage conditions are expected to occur infrequently, operating the circuit to a temperature of 150°C for short periods may be acceptable to the transmitter.

iii. Reconductor the two tapped circuits to provide a continuous summertime rating for each 1.5km connection of 525MVA.

> Implementation of any one of these options would be acceptable to the IMO for the incorporation of the gas-turbine/steam-turbine portion of the new generating facility into the IMO-controlled grid.

For the incorporation of the two gas-turbine generating units, with a combined output of 450MVA, a new 1.5km single-circuit line is to be installed to provide a connection on to circuit L23N. Calpine Canada has confirmed the line is to be equipped with twin 477kcmil conductors which would provide a continuous summertime rating of 515MVA (1240 amp) at a maximum conductor operating temperature of 93°C.

FAULT LEVEL RESULTS

TABLE 1 - Fault Level Results at Lambton TGS

Fault Levels at LAMBTON TGS
With new generation capacity in-service in China Township, Michigan
For a Pre-fault Voltage of 250kV

	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
'Existing'	57.45kA	63.50kA	75.08kA	***84.07kA***				
With Imperial Oil	57.86kA	63.83kA	75.10kA	***84.52kA***				
Increase	*0.41kA*	*0.33kA*	*0.02kA*	*0.45kA*				
With Calpine	62.37kA	***68.40kA***	***81.15kA***	***89.95kA***				
Increase	*4.92kA*	*4.90kA*	*6.07kA*	*5.88kA*				
With Enron	62.42kA	***70.16kA***	***81.96kA***	***93.11kA***				
Increase	*4.97kA*	*6.66kA*	*6.88kA*	*9.04kA*	*A*	65.0kA	*A*	78.0kA
With Calpine & Enron	***67.35kA***	***75.12kA***	***88.03kA***	***99.00kA***	*B*	70.0kA	*B*	92.0kA
Increase	*9.90kA*	*11.62kA*	*12.95kA*	*14.93kA*				
With Calpine & Imperial Oil	62.73kA	***68.68kA***	***81.61kA***	***90.32kA***				
Increase	*5.28kA*	*5.18kA*	*6.53kA*	*6.25kA*				
With Enron & Imperial Oil	62.83kA	***70.51kA***	***81.93kA***	***93.56kA***				
Increase	*5.38kA*	*7.01kA*	*6.85kA*	*9.49kA*				
With all 3 new Projects I/S	***67.70kA***	***75.41kA***	***88.49kA***	***99.38kA***				
Increase	*10.25kA*	*11.91kA*	*13.41kA*	*15.31kA*				

Fault Levels at LAMBTON TGS
With no new generation capacity in China Township, Michigan
For a Pre-fault Voltage of 250kV

	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
'Existing'	56.06kA	61.91kA	72.76kA	***81.28kA***				
With Imperial Oil	56.47kA	62.24kA	73.29kA	***81.72kA***				
Increase	*0.41kA*	*0.33kA*	*0.53kA*	*0.44kA*				
With Calpine	60.99kA	***66.81kA***	***79.35kA***	***87.79kA***				
Increase	*4.93kA*	*4.90kA*	*6.59kA*	*6.51kA*				
With Enron	61.03kA	***68.57kA***	***79.58kA***	***91.00kA***				
Increase	*4.97kA*	*6.66kA*	*6.82kA*	*9.72kA*	*A*	65.0kA	*A*	78.0kA
With Calpine & Enron	***65.96kA***	***73.53kA***	***86.21kA***	***96.91kA***	*B*	70.0kA	*B*	92.0kA
Increase	*9.90kA*	*11.62kA*	*13.45kA*	*15.63kA*				
With Calpine & Imperial Oil	61.34kA	***67.09kA***	***79.81kA***	***88.16kA***				
Increase	*5.28kA*	*5.18kA*	*7.05kA*	*6.88kA*				
With Enron & Imperial Oil	61.44kA	***68.92kA***	***80.12kA***	***90.76kA***				
Increase	*5.38kA*	*7.01kA*	*7.36kA*	*9.48kA*				
With all 3 new Projects I/S	***66.32kA***	***73.82kA***	***86.68kA***	***97.29kA***				
Increase	*10.26kA*	*11.91kA*	*13.92kA*	*16.01kA*				

Note: The 'A' ratings are for breakers PL4 & KL4, while the 'B' ratings are for all the remaining breakers at Lambton TGS

TABLE 2 - Fault Level Results at Sarnia-Scott TS: 230kV busbar

Fault Levels at SARNIA-SCOTT TS: 230kV Busbar
With new generation capacity in-service in China Township, Michigan
For a Pre-fault Voltage of 250kV

	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
'Existing'	37.27kA	33.79kA	45.70kA	38.93kA				
With Imperial Oil	37.98kA	34.18kA	***46.52kA***	39.37kA				
Increase	*0.71kA*	*0.39kA*	*0.82kA*	*0.44kA*				
With Calpine	***41.48kA***	38.07kA	***51.52kA***	43.86kA				
Increase	*4.21kA*	*4.28kA*	*5.82kA*	*4.93kA*				
With Enron	38.44kA	34.52kA	***47.17kA***	39.77kA				
Increase	*1.17kA*	*0.73kA*	*1.47kA*	*0.84kA*	*A*	39.7kA	*A*	46.2kA
With Calpine & Enron	***42.54kA***	38.71kA	***52.23kA***	44.59kA	*B*	63.0kA	*B*	70.0kA
Increase	*5.27kA*	*4.92kA*	*6.53kA*	*5.66kA*				
With Calpine & Imperial Oil	***42.18kA***	38.47kA	***51.76kA***	44.31kA				
Increase	*4.91kA*	*4.68kA*	*6.06kA*	*5.38kA*				
With Enron & Imperial Oil	39.14kA	34.90kA	***47.99kA***	40.20kA				
Increase	*1.87kA*	*1.11kA*	*2.29kA*	*1.27kA*				
With all 3 new Projects I/S	***43.24kA***	39.10kA	***53.06kA***	45.04kA				
Increase	*5.97kA*	*5.31kA*	*7.36kA*	*6.11kA*				

Fault Levels at SARNIA-SCOTT TS: 230kV Busbar
With no new generation capacity in China Township, Michigan
For a Pre-fault Voltage of 250kV

	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
'Existing'	36.89kA	33.56kA	45.22kA	38.66kA				
With Imperial Oil	37.59kA	33.94kA	46.05kA	39.10kA				
Increase	*0.70kA*	*0.38kA*	*0.83kA*	*0.44kA*				
With Calpine	***41.13kA***	37.86kA	***51.04kA***	43.62kA				
Increase	*4.24kA*	*4.30kA*	*5.82kA*	*4.96kA*				
With Enron	38.09kA	34.32kA	***46.74kA***	39.53kA				
Increase	*1.20kA*	*0.76kA*	*1.52kA*	*0.87kA*	*A*	39.7kA	*A*	46.2kA
With Calpine & Enron	***42.22kA***	38.52kA	***52.43kA***	44.38kA	*B*	63.0kA	*B*	70.0kA
Increase	*5.33kA*	*4.96kA*	*7.21kA*	*5.72kA*				
With Calpine & Imperial Oil	***41.83kA***	38.26kA	***51.87kA***	44.07kA				
Increase	*4.94kA*	*4.70kA*	*6.65kA*	*5.41kA*				
With Enron & Imperial Oil	38.79kA	34.69kA	***47.56kA***	39.97kA				
Increase	*1.90kA*	*1.13kA*	*2.34kA*	*1.31kA*				
With all 3 new Projects I/S	***42.92kA***	38.91kA	***52.66kA***	44.83kA				
Increase	*6.03kA*	*5.35kA*	*7.44kA*	*6.17kA*				

Note: The 'B' ratings are assumed values for the two new breakers, while the 'A' are for all the existing breakers

TABLE 3 - Fault Level Results at Sarnia-Scott TS: 115kV busbar

Fault Levels at SARNIA-SCOTT TS: 115kV Busbar
With new generation capacity in-service in China Township, Michigan
For a Pre-fault Voltage of 127kV

	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
'Existing'	16.27kA	18.78kA	21.48kA	25.65kA				
With Imperial Oil	16.34kA	18.84kA	21.57kA	25.73kA				
Increase	*0.07kA*	*0.06kA*	*0.09kA*	*0.08kA*				
With Calpine	16.65kA	19.23kA	22.18kA	26.42kA				
Increase	*0.38kA*	*0.45kA*	*0.70kA*	*0.77kA*				
With Enron	16.38kA	18.88kA	21.62kA	25.79kA				
Increase	*0.11kA*	*0.10kA*	*0.14kA*	*0.14kA*	*A*	31.4kA	*A*	34.1kA
With Calpine & Enron	16.73kA	19.31kA	22.29kA	26.53kA	*B*	38.8kA	*B*	45.5kA
Increase	*0.46kA*	*0.53kA*	*0.81kA*	*0.88kA*	*C*	50.0kA	*C*	60.0kA
With Calpine & Imperial Oil	16.71kA	19.28kA	22.25kA	26.49kA				
Increase	*0.44kA*	*0.50kA*	*0.77kA*	*0.84kA*				
With Enron & Imperial Oil	16.45kA	18.94kA	21.83kA	25.87kA				
Increase	*0.18kA*	*0.16kA*	*0.35kA*	*0.22kA*				
With all 3 new Projects I/S	16.79kA	19.35kA	22.36kA	26.59kA				
Increase	*0.52kA*	*0.57kA*	*0.88kA*	*0.94kA*				

Fault Levels at SARNIA-SCOTT TS: 115kV Busbar
With no new generation capacity in China Township, Michigan
For a Pre-fault Voltage of 127kV

	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
'Existing'	16.23kA	18.74kA	21.43kA	25.60kA				
With Imperial Oil	16.30kA	18.80kA	21.52kA	25.69kA				
Increase	*0.07kA*	*0.06kA*	*0.09kA*	*0.09kA*				
With Calpine	16.62kA	19.20kA	22.14kA	26.38kA				
Increase	*0.39kA*	*0.46kA*	*0.71kA*	*0.78kA*				
With Enron	16.35kA	18.85kA	21.58kA	25.75kA				
Increase	*0.12kA*	*0.11kA*	*0.15kA*	*0.15kA*	*A*	31.4kA	*A*	34.1kA
With Calpine & Enron	16.71kA	19.28kA	22.26kA	26.49kA	*B*	38.8kA	*B*	45.5kA
Increase	*0.48kA*	*0.54kA*	*0.83kA*	*0.89kA*	*C*	50.0kA	*C*	60.0kA
With Calpine & Imperial Oil	16.68kA	19.25kA	22.22kA	26.45kA				
Increase	*0.45kA*	*0.51kA*	*0.79kA*	*0.85kA*				
With Enron & Imperial Oil	16.41kA	18.91kA	21.78kA	25.83kA				
Increase	*0.18kA*	*0.17kA*	*0.35kA*	*0.23kA*				
With all 3 new Projects I/S	16.77kA	19.33kA	22.33kA	26.56kA				
Increase	*0.54kA*	*0.59kA*	*0.90kA*	*0.96kA*				

Note: The 'A' ratings are for breakers KL1 & L1L6; the 'B' ratings are for breakers KL7 & L5L7; while the 'C' ratings are assumed values for all the remaining breakers

TABLE 4 - Fault Level Results at Keith TS: 230kV & 115kV busbars

Fault Levels at KEITH TS: 230kV Busbar
With new generation capacity in-service in China Township, Michigan
For a Pre-fault Voltage of 250kV

	Symmetrical		Asymmetrical		Breaker Ratings			
	3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical	
'Existing'	21.14kA	22.45kA	27.29kA	28.74kA				
['Existing' without China Township]	*21.13kA*	*22.44kA*	*27.27kA*	*28.72kA*				
With Imperial Oil	21.14kA	22.45kA	27.30kA	28.74kA				
Increase	*0.00kA*	*0.00kA*	*0.01kA*	*0.00kA*				
With Calpine	21.16kA	22.47kA	27.32kA	28.76kA				
Increase	*0.02kA*	*0.02kA*	*0.03kA*	*0.02kA*				
With Enron	21.16kA	22.47kA	27.32kA	28.76kA				
Increase	*0.02kA*	*0.02kA*	*0.03kA*	*0.02kA*	*A*	41.1kA	*A*	46.2kA
With Calpine & Enron	21.18kA	22.48kA	27.34kA	28.77kA	*B*	63.0kA	*B*	70.0kA
Increase	*0.04kA*	*0.03kA*	*0.05kA*	*0.03kA*				
With Calpine & Imperial Oil	21.16kA	22.47kA	27.32kA	28.76kA				
Increase	*0.02kA*	*0.02kA*	*0.03kA*	*0.02kA*				
With Enron & Imperial Oil	21.16kA	22.47kA	27.32kA	28.76kA				
Increase	*0.02kA*	*0.02kA*	*0.03kA*	*0.02kA*				
With all 3 new Projects I/S	21.18kA	22.48kA	27.34kA	28.77kA				
Increase	*0.04kA*	*0.03kA*	*0.05kA*	*0.03kA*				

Note: The 'A' ratings are for breakers AL5, C21J & HL5, while the 'B' ratings are assumed values for the two new breakers

Fault Levels at KEITH TS: 115kV Busbar
With new generation capacity in-service in China Township, Michigan
For a Pre-fault Voltage of 127kV

	Symmetrical		Asymmetrical		Breaker Ratings			
	3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical	
'Existing'	24.41kA	29.03kA	31.34kA	37.89kA				
['Existing' without China Township]	*24.40kA*	*29.03kA*	*31.33kA*	*37.88kA*				
With Imperial Oil	24.41kA	29.03kA	31.34kA	37.89kA				
Increase	*0.00kA*	*0.00kA*	*0.00kA*	*0.00kA*				
With Calpine	24.42kA	29.04kA	31.35kA	37.90kA				
Increase	*0.01kA*	*0.01kA*	*0.01kA*	*0.01kA*				
With Enron	24.42kA	29.04kA	31.35kA	37.90kA				
Increase	*0.01kA*	*0.01kA*	*0.01kA*	*0.01kA*	*A*	39.3kA to 42.0kA	*A*	45.5kA
With Calpine & Enron	24.43kA	29.05kA	31.36kA	37.91kA	*B*	50.0kA	*B*	56.8kA
Increase	*0.02kA*	*0.02kA*	*0.02kA*	*0.02kA*				
With Calpine & Imperial Oil	24.42kA	29.04kA	31.35kA	37.90kA				
Increase	*0.01kA*	*0.01kA*	*0.01kA*	*0.01kA*				
With Enron & Imperial Oil	24.42kA	29.04kA	31.35kA	37.90kA				
Increase	*0.01kA*	*0.01kA*	*0.01kA*	*0.01kA*				
With all 3 new Projects I/S	24.43kA	29.05kA	31.36kA	37.91kA				
Increase	*0.02kA*	*0.02kA*	*0.02kA*	*0.02kA*				

Note: The 'B' rating is for breaker SC11SC, while the 'A' ratings are for all the remaining breakers

TABLE 5 - Fault Level Results at the other Principal Busbars

Fault Levels at other busbars ***With new generation capacity in-service in China Township, Michigan*** ***For a Pre-fault Voltage of 250kV or 127kV***								
	Symmetrical		***Asymmetrical***		***Breaker Ratings***			
	3-phase	***L-G***	***3-phase***	***L-G***	***Symmetrical***		***Asymmetrical***	
Buchanan 230kV								
'Existing'	29.18kA	24.96kA	32.01kA	27.86kA	*A*	31.6kA	*A*	46.2kA
With all 3 new Projects I/S	29.54kA	25.14kA	32.41kA	28.06kA	*B*	39.7kA	*B*	46.2kA
Increase	*0.36kA*	*0.18kA*	*0.40kA*	*0.20kA*	*C*	63.0kA	*C*	70.3kA
Buchanan 115kV								
'Existing'	23.34kA	27.52kA	29.25kA	33.22kA	*A*	39.3kA	*A*	45.5kA
With all 3 new Projects I/S	23.46kA	27.63kA	29.40kA	33.35kA	*B*	40.0kA	*B*	45.5kA
Increase	*0.12kA*	*0.11kA*	*0.15kA*	*0.13kA*				
Lauzon 115kV								
'Existing'	19.93kA	22.52kA	22.62kA	25.13kA	*A*	39.3kA	*A*	45.5kA
With all 3 new Projects I/S	19.95kA	22.54kA	22.64kA	25.15kA	*B*	40.0kA	*B*	45.5kA
Increase	*0.02kA*	*0.02kA*	*0.02kA*	*0.02kA*				
Essex 115kV								
'Existing'	21.14kA	22.07kA	24.40kA	25.47kA		39.3kA		45.5kA
With all 3 new Projects I/S	21.16kA	22.09kA	24.42kA	25.49kA				
Increase	*0.02kA*	*0.02kA*	*0.02kA*	*0.02kA*				

Note:

Buchanan TS - 230kV	A	Breaker L4L22
	B	Breakers DL5, HL37 & L5L37
	C	All the remaining breakers
Buchanan TS - 115kV	B	Breakers SC11K1 & SC11SC
	A	All the remaining breakers
Lauzon TS - 115kV	B	Breakers T2K, SC12K 7 & SC12SC
	A	All the remaining breakers