

CONNECTION ASSESSMENT & APPROVAL PROCESS

PRELIMINARY ASSESSMENT REPORT

*For the Proposed Development by Imperial Oil at their Complex in Sarnia.
230kV Incorporation Option*

CAA ID No. 2000-029:

<i>Phase I</i>	<i>115.6MVA</i>
<i>Phase II</i>	<i>115.6MVA</i>

Long Term Forecasts & Assessments Department

FINAL Version

Date: 12th July 2001

Preliminary Assessment Report

For Phases I & 2 of the Proposed Development by Imperial Oil at their Complex in Sarnia.

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, on a preliminary basis, whether the connection applicant's proposed connection with the IMO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether a System Impact Assessment of the proposed connection should be conducted under Chapter 4, section 6 of the Market Rules. This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. This report has been prepared solely for use by the connection applicant, Hydro One and the IMO in accordance with Chapter 4, Section 6 of the Market Rules. The IMO assumes no responsibility to any third party for any use which it makes of this report. Any liability which the IMO may have to the connection applicant in respect of this report is governed by Chapter 1, Section 13 of the Market Rules. In the event that the IMO provides a draft of this report to the connection applicant, you must be aware that the IMO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IMO will use its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that it is using the most recent version of this report. The IMO expects the connection applicant and affected transmitter to discuss the connection project with any persons located in the vicinity of the project and to advise the IMO of any concerns they might express about the impact of the project on system reliability.

Hydro One

Special Notes and Limitations of Study Results

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

The short circuit and thermal loading levels have been computed based on the information provided by the connection proponent at the time of the study. These levels may be higher or lower if the connection information changes as a result of, but not limited to, subsequent design modifications or when more accurate test measurement data is available.

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

In this preliminary feasibility study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent upon request.

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

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

PRELIMINARY ASSESSMENT REPORT

For the 230kV Option for Incorporating New Generating Capacity

EXECUTIVE SUMMARY

Introduction

Imperial Oil is proposing to incorporate two new 115.6MVA generating units into their Complex at Sarnia.

The scheduled in-service date for the first unit is the 3rd Quarter of 2004, and
The scheduled in-service date for the second unit is the 4th Quarter of 2007.

Incorporation of the new generating units into either the existing 230kV system or the 27.6kV system is being considered. This Preliminary Assessment has examined the impact of implementing the 230kV Incorporation Option.

Incorporation Arrangement

The arrangement proposed by Imperial Oil for the incorporation of the two new generating units will involve the installation of four, in-line 230kV circuit breakers. In addition, each generating unit is to have its own 13.8kV synchronising circuit breaker.

While the arrangement that has been proposed for the incorporation of the two generating units would be acceptable to the IMO, under contingency conditions it could result in one of the units being connected via the LV busbars at the two Imperial Oil DESN stations. An alternative Assessment has been proposed that would avoid this situation.

Furthermore, in order to ensure that any comparison of the costs for the 230kV and 27.6kV incorporation options is equitable, the IMO has attempted to identify the minimum switching facilities that would need to be installed for compliance with the Transmission System Code. Two arrangements, that each involve the installation of two new 230kV breakers, have been presented for consideration. However, it is emphasised that Hydro One would have the final decision regarding the actual switching facilities that would need to be installed to comply with the code.

Incorporation of the TransAlta Project

The 580MVA development by TransAlta Energy Corp. at the Dow Chemical Complex is to be incorporated on to circuits N6S & N7S (formally L23N). These circuits have only a limited thermal capacity and it is unlikely that this can be increased in the immediate future. TransAlta is therefore proposing to install a generation rejection scheme to address possible overloading of the companion 230kV circuit under contingency conditions involving circuit N6S or N7S.

Ability of the Transmission System to accommodate excess output from Imperial Oil

Due to the limited thermal ratings for the two 230kV circuits N6S & N7S, restrictions would need to be imposed on the amount of output that could be accommodated from the Imperial Oil facilities whenever the TransAlta Project is operating at, or close to, its maximum output. The possible use of the idle section of circuit N6S to increase the transfer capability into Scott TS was examined.

If, at some future date, it is decided to reconductor circuits N6S & N7S to increase their thermal rating, then the impact that specific increases in the thermal rating for these circuits would have on allowing different levels of output from the TransAlta and Imperial Oil facilities to be accommodated has been provided. In addition, the effect that these increases would have on the amount of generation capacity that would need to be rejected under contingency conditions has also been provided.

Requirements for Generation Rejection

If transfers are expected to be made from the Imperial Oil facility to the IMO-controlled grid, then it would be necessary for a generation rejection scheme to be installed to initiate rejection of generating capacity at the Imperial Oil facility for contingencies involving circuit N6S or N7S.

In addition it may be necessary for capacity at the Imperial Oil Complex to be incorporated into the Lambton Generation Rejection Scheme.

Impact on Fault Levels

On the assumption that the 230kV busbar at Lambton TGS will have been reconfigured to allow it to be operated 'split', then the busbar on which the additional generators at the Imperial Oil Complex will have the greatest impact will be at Sarnia-Scott TS. However, the analysis indicates that the Imperial Oil Project, *in isolation*, would not be sufficient to result in an increase in the fault level that would trigger the need for the replacement of individual circuit breakers on either the 230kV or the 115kV busbars at Sarnia-Scott TS.

Impact on Transfer Capabilities

While the new generating facilities would increase congestion within the area as a result of displacing load at the Imperial Oil Complex, they will not, *in isolation*, result in any reduction in the existing operating limits or transfer capabilities.

Since Imperial Oil has indicated that the *maximum* transfer to the IMO-controlled grid, with both generating units in-service, would be 62MVA (56MW), no examination has been made of the potential impact that the new generation would have with zero load at the Imperial Oil Complex *and* with circuits N6S & N7S reconducted so that there would be no restrictions of the output from the Imperial Oil generating facilities, while the TransAlta Project is operating at maximum output.

Preliminary Assessment Report for the Imperial Oil Project in Sarnia

1. Introduction

Imperial Oil is proposing to install two 115.6MVA gas-turbine generating units at their facility in Sarnia. The first unit is scheduled to be installed in the 3rd Quarter of 2004 and the second unit in the 4th Quarter of 2007.

These units are to be incorporated into the existing transmission system at the Imperial Oil Complex via two, 2km extensions of the existing 230kV circuits N6S & N7S (formally circuit L23N). Diagram 1 shows the proposed arrangement.

Associated Work at the Imperial Oil Complex

Currently, the Imperial Oil Complex is supplied from the 115/27.6kV St Andrews TS and from the DESN (Dual-Element Spot Network) station at their Complex, that consists of the two 230/28kV step-down transformers, T3 & T4. A third step-down transformer, T2, is also available as a switchable spare unit that can be placed in-service within a period of between two & four hours.

In order to address voltage decline concerns upon the loss of either of the transformers T3 or T4, and to avoid overloading the remaining transformer, Imperial Oil is proposing to permanently connect transformer T2 and to install a fourth step-down transformer (T1).

A separate application for a Connection Assessment for this work has been submitted to the IMO by Imperial Oil.

The four step-down transformers are to be configured as two DESN stations with each pair of transformers T1/T2 and T3/T4 supplying approximately half the load at the Complex. The proposed arrangement of the four transformers has also been included in Diagram 1.

The scheduled in-service date for step-down transformers T1 & T2 is July 2002.

Since the installation of transformers T1 & T2 is scheduled to be complete before the new generators are scheduled to be in-service, all four step-down transformers have been assumed to be in-service in all of the studies performed for this assessment.

Loads at the Imperial Oil Complex

Once all four step-down transformers are in-service at the Imperial Oil Complex there would be sufficient capacity to allow those loads that are currently supplied from the 115/27.6kV St. Andrews TS to be transferred to the new facilities. On the assumption that this transfer will occur, loadings of 74MVA on the T1/T2 transformer combination, and 65MVA on the T3/T4 combination have therefore been assumed in this assessment.

2. Incorporation of the TransAlta Project at the Dow Chemical Complex

The 580MVA development at the Dow Chemical Complex that is currently under construction for TransAlta Energy Corp., is to be incorporated into the IMO-controlled grid via a new 230kV double-circuit line, approximately 3.5km in length, that is to connect to the existing 230kV circuits N6S & L23N. The point of connection is to be close to the terminal point of circuits N6S & L23N at the Imperial Oil Complex. Diagram 2 shows the detailed arrangement.

Circuit L23N is currently a three-ended circuit that is terminated at Lambton TGS, Scott TS and the Imperial Oil Complex. As part of the modifications required to incorporate the TransAlta Project, the section of this circuit between Scott TS and Imperial Oil is to be terminated on to a new position on the 230kV busbar at Scott TS. This will separate the two portions of this circuit. The radial section between Scott TS and Imperial Oil TS will then be re-designated as circuit N7S.

Incorporation Options available to TransAlta

Circuits N6S and N7S currently have the following operating characteristics and ratings:

<i>Circuits N6S & N7S Line Section:</i>	<i>Conductor</i>	<i>Max. Operating Temperature for specified loading condition</i>		<i>Continuous Rating: at specified temperature for a wind speed of 0-4km/hr</i>	
		<i>continuous loading</i>	<i>emergency loading *</i>	<i>10°C</i>	<i>30°C</i>
Scott TS to Bayer Junction	795kcmil	93°C	150°C	424MVA	362MVA
Bayer Junction to Imperial Oil		60°C	60°C	308MVA	233MVA

Note: The Emergency loading* temperature of 150°C corresponds to the maximum operating temperature to which the conductors have been sagged.

This higher temperature has been employed for calculating the 15-minute limited-time-rating of the conductors that would be used under contingency conditions. The table below provides the 15-minute limited-time-ratings for two specific ambient temperatures.

<i>Ambient Temperature</i>	<i>Pre-load Conditions: Limiting value to respect a maximum continuous operating temperature of 93°C</i>		<i>15-minute limited-time-rating: Based on a maximum conductor operating temperature of 150°C</i>	
	<i>Current</i>	<i>MVA at 240kV</i>	<i>Current</i>	<i>MVA at 240kV</i>
10°C	1020 amps	424MVA	1506 amps	626MVA
30°C	870 amps	362MVA	1420 amps	590MVA

For the incorporation of the TransAlta Project, the IMO required that one of the following options be implemented:

- i. *Upgrade* the section of circuits N6S & N7S between Bayer Junction and Imperial Oil to increase the maximum continuous operating temperature of its conductors to 93°C.

AND

Install a generation rejection scheme to initiate rejection of sufficient capacity at the TransAlta facility, under contingency conditions involving either circuit N6S or circuit N7S, to allow the *continuous* rating of the companion circuit to be respected.

- ii. *Reconductor* circuits N6S & N7S so that the continuous rating of each circuit would be sufficient to accommodate the full output of the TransAlta project.

It is understood that TransAlta is proposing to adopt Option i.

Developments since the original System Impact Assessment was completed

Following the completion of the System Impact Assessment for the initial Sarnia-Windsor cluster, that included the TransAlta Project, consideration has been given to the possible modification of the requirements under Option i.

With both 230kV circuits between Scott TS and Imperial Oil ‘sagged’ for a maximum conductor operating temperature of 150°C, then it would allow the 15-minute limited-time-rating that corresponds to this temperature, rather than that for the more-limiting temperature of 93°C to be employed, following a system contingency.

With net loads of 0MW at the Imperial Oil Complex and at Bayer Rubber, and with the generating facilities at TransAlta and Bayer Rubber operating at full output, the analysis for the original SIA indicated that the maximum transfer on each circuit would be 383MVA. Under contingency conditions involving one of the circuits, the flow on the companion circuit would more than double. The flow on the companion circuit would therefore be approximately 770MVA. This would exceed the 15-minute limited-time-rating for ambient temperatures of both 30°C and 10°C, which have been provided in the Table above.

However, in the event that no transient stability issues are identified in the System Impact Assessment for the next cluster of Projects, this could allow generation run-back, or a combination of generation rejection and run-back, rather than generation rejection to be employed to reduce the output from the TransAlta Project. If the run-back option were to be employed, then it would need to ensure that the flow on the remaining circuit is reduced to the continuous rating, or lower, within a maximum interval of 15 minutes.

This possible change in the IMO's requirements is currently under discussion with TransAlta.

3. Comments on the Connection Arrangement

With the arrangement that has been proposed by Imperial Oil, the in-line circuit breakers, 52-N6S & 52-N7S, located at the termination point of circuits N6S and N7S at the Imperial Oil Complex, would be used to isolate faults within the Complex from the system. Breaker-failure protection to initiate tripping at Scott TS; at Bayer Rubber; and at the new TransAlta facility would also need to be installed to cater for the possible mal-operation of either of these circuit breakers.

Imperial Oil is proposing to install two additional in-line circuit breakers, 52-T5-N6S & 52-T6-N7S, at the terminals of the 2km double-circuit line to the that is to be constructed for the incorporation of the new generating facilities into their system. These breakers are intended to ensure that faults on either of the generator step-up transformers or on the new transmission line would not adversely affect the supply to the Imperial Oil Complex. Breaker failure protection would need to be installed to trip the corresponding circuit breaker 52-N6S or 52-N7S in the event that circuit breaker 52-T5-N6S or 52-T6-N7S should fail to operate.

With the arrangement proposed, any contingency involving circuit N6S or N7S would result in the generator that is associated with the IOL section of the faulted circuit being connected through to the circuit that remains in-service via the LV busbars at the two Imperial Oil DESN stations. This is not considered to be an ideal arrangement, even though, under normal conditions, it is expected to continue for a very short interval. With the TransAlta Project fully dispatched, and with two generating units in-service at the Imperial Oil Complex, automatic rejection of one of the Imperial Oil generating units would be necessary to avoid overloading the circuit that remains in-service. To avoid the 'back-feed' situation, the unit that is associated with the IOL section of the faulted circuit should be the one that is tripped. Once this particular unit is tripped, the 'back-feed' condition would cease.

However, there could be occasions when the TransAlta facility has not been fully dispatched, that would allow both generating units at the Imperial Oil Complex to remain in-service post-contingency. The 'back-feed' condition would therefore be maintained indefinitely, and while it is unlikely that the transfers through the transformers would be sufficient to result in overloading, particularly if the loads at the Imperial Oil Complex are at their normal level, it would be preferable if it could be avoided.

Alternative Switching Arrangement at the Imperial Oil Complex

Diagram 3 shows an alternative arrangement using the four circuit breakers that Imperial Oil is proposing to install at their Complex. This arrangement would avoid the possibility of one of the generators remaining connected via the LV busbars at the Imperial Oil DESN stations, following a contingency condition involving either of the 230kV circuits, N6S or N7S. In addition it would provide greater flexibility for performing maintenance on the individual 230kV breakers.

It would also have the advantage of minimising possible transfers, via the LV busbar, that could occur through the transformers, T1 & T2, at Bayer Rubber, for a 'line-end-open' condition on the terminals of circuit N6S or circuit N7S at Scott TS. Should this LEO condition arise when the 230kV busbar at the TransAlta Facility is open, or either of the TransAlta incorporation circuits is out-of-service, then the output from the Imperial Oil generator that is associated with the circuit that is 'line-end-open' would need to flow via the LV busbars at the Imperial Oil DESN stations and that at the Bayer Rubber DESN station. Since there would be three parallel paths available for the output of the generator associated with the circuit that is 'line-end-opened', it is very unlikely that overloading would occur. However, as for the situation addressed earlier, it would be preferable if it could be avoided.

3.1 Minimum Switching Requirements for Compliance with the Transmission System Code

The Transmission System Code requires that:

Schedule F - General Technical Requirements

1.2 Isolation from the Transmission System

'The Customer shall provide an isolating disconnect switch or device at the point or junction between the Transmitter and the Customer.....' *Clause 1.2.1*

'when the device is used as part of the High Voltage Interrupting Device failure protection system, it shall be motor-operated and equipped with appropriate control circuitry.' *Clause 1.2.2.4*

The Customer must be able to isolate (self-contain) his internal problems without having a major impact on the transmission system. Under certain circumstances, HV breakers may not be required for Load Customer step-down transformers, provided that a motorised disconnect switch and redundant communication channels and paths are provided to isolate the transformer at the terminal stations if the fault occurs in the transformer zone of protection. *Exhibit F.2*

Schedule G - Technical Requirements for Generators

1.1 Supply Considerations

A High Voltage Interrupting Device shall provide a point of isolation for the Generator's station from the transmission system. The High Voltage Interrupting Device shall be a circuit breaker unless the Transmitter authorises another device. *Clause 1.1.1*

Our interpretation of these requirements would require that the following facilities be installed (if not already available) at the Imperial Oil Complex (the final decision regarding what needs to be installed would however be with Hydro One):

For the two DESN stations (in isolation) -

Redundant communication channels and paths for Remote Trip/Transfer Trip signals to the terminal breakers associated with circuits N6S & N7S,

AND

- i. a motorised disconnect switch for each step-down transformer.
In addition, in order to be able to isolate the two 230kV Jitney busbars, a (manually-operated) disconnect switch would be required in each 230kV circuit at the point where circuits N6S & N7S terminate at the IOL Complex.
It is understood that these latter disconnect switches already exist, and that they are motorised.

OR

- ii. a motorised disconnect switch in each 230kV circuit at the point where circuits N6S & N7S terminate at the IOL Complex.

Since it is understood that these motorised disconnect switches already exist, no additional switching facilities would be required.

For the new 230kV generating facilities (in isolation) -

Redundant communication channels and paths for Remote Trip/Transfer Trip signals to the terminal breakers associated with circuits N6S & N7S,

AND

A High Voltage Interrupting Device, together with a motorised disconnect switch for each generator connection.

The breaker and its associated disconnect switch could be located either at the termination of the 2km connections to each new generating facility, or at the point where circuits N6S & N7S terminate at the IOL Complex.

The arrangements shown in Diagrams 4 & 5 are the result of combining the requirements for the DESN stations with those for the 230kV generating facilities. In both these Diagrams, it has been assumed that the arrangement proposed by Imperial Oil, involving the installation of separate motorised disconnect switches for each step-down transformer, will be implemented because of its superior operational performance.

Diagram 4 shows the arrangement with the two 230kV breakers located at the termination of the 2km connections to each new generating facility, while Diagram 5 shows the breakers located at the point where circuits N6S & N7S terminate at the IOL Complex.

The arrangement shown in Diagram 4 would help minimise the potential impact on the supply to the DESN stations at the Imperial Oil Complex of any contingencies that occur on either of the generator step-up transformer or on the associated 230kV connections. The arrangement shown in Diagram 5 would help minimise the impact on the supply to the DESN stations and also on the generating facilities at the Imperial Oil Complex of any contingencies that occur on circuits N6S & N7S.

In each Diagram, an optional 230kV circuit breaker has been included for the following reasons:

In Diagram 4: A contingency involving circuit N6S or N7S would result in the automatic loss of the particular generating unit associated with the faulted circuit. If the operating conditions on the system are such that automatic rejection of a generating unit at the Imperial Oil Complex is *not* required under contingency conditions, then the optional breaker would allow the generator to remain in-service.

In Diagram 5: A contingency involving circuit N6S or N7S would result in the generator associated with the faulted circuit being connected to the companion circuit via the LV busbars at each of the DESN stations. Assuming that automatic rejection of one of the generating units at the Imperial Oil Complex is *not* required under contingency conditions, then having the generator connected in this manner may be acceptable, particularly under normal load conditions. If it were not acceptable, then the optional 230kV breaker would avoid this possible constraint.

The facilities shown in Diagrams 4 & 5, with the exception of the optional 230kV breaker, would therefore represent the minimum facilities that would be required for the connection of the new DESN station and the new 230kV generating units in order to comply with the Transmission System Code.

3.2 Comments on the Facilities that Imperial Oil is Planning to Install

Step-up Transformers

The new step-up transformers that Imperial Oil is proposing to install are to have a turns-ratio of 242:13.8 and are to be equipped with a suitable tap-range to accommodate the possible variations in the system voltage as stated in Appendix 4.1 of the Market Rules.

In addition, in order to comply with the requirements of Market Rule: Reference 2 of Appendix 4.2, the impedance of the step-up transformer should be 13% or less on $100\text{MVA}_{\text{base}}$ & $220\text{kV}_{\text{base}}$. A value of 13% was assumed in all the analysis.

Proposed Staged Development of the New Generating Facilities

While Imperial Oil has tentatively scheduled the installation of the first new generating unit for the third quarter of 2004, the installation of the second unit is not scheduled until the fourth quarter of 2007. Furthermore, they have indicated to the IMO that the installation of the second unit could be dependent on the ability of the connections from the Imperial Oil Complex into Scott TS to accommodate any output in excess of their load requirements. This is addressed in the next section.

Data for the Generating Units, Exciters & System Stabilisers

While it is appreciated that some of the data provided by Imperial Oil are of a preliminary nature, more accurate data will be required for the System Impact Assessment, should Imperial Oil elect to proceed with this phase of the process.

In particular, the following aspects of the Imperial Oil proposal need to be reviewed/augmented:

- *Reactive Capability Curves*

The curve provided for an inlet air temperature of 15°C shows the generator having an output of only 84MW at a power factor of 95% leading. This would not comply with the Market Rule that defines the Reactive Power Capability requirements for new synchronous generators that are to be connected to the IMO-controlled grid.

Appendix 4.2 Reference 1 of the Market Rules requires that:

“Synchronous generation facilities connected to the IMO-controlled grid shall have the capability to supply reactive power within the range between 90% lagging (over-excited) and 95% leading (under-excited) power factor based on rated active power at rated voltage.”

- *Generator Data*

The inertia constant has not been provided.

- *Excitation System Model*

The information for the model has not been provided.

- *Power System Stabiliser*

The information for the model has not been provided.

4. Ability of the Transmission System to Accommodate Excess Output from Imperial Oil

In the event that the proposed transfer of the Imperial Oil load that is currently supplied from St. Andrews TS to the new DESN stations at the Imperial Oil Complex should occur, then the total loading on the T1/T2 transformer combination would be 74MVA, while that on the T3/T4 combination would be 65MVA.

As part of the project for the installation of the new transformers, Imperial Oil is planning to install two new 10.8MVA capacitor banks. Each bank is to be capable of eventual expansion to 21.6MVA. The installation of these new capacitor banks will reduce the loading on the two step-down transformer combinations to 62MVA for the T1/T2 combination and 57MVA for the T3/T4 combination. The combined load at the Imperial Oil complex would therefore be expected to total approximately 119MVA.

With only a single new generator installed (Phase 1), the Imperial Oil facility would still represent a net load and there would be no net transfers to the system, *under normal conditions*. Upon completion of Phase 2 of the proposed development, when both generating units have been installed, the Imperial Oil Complex would become a net exporter to the system of *approximately 80MVA*.

As discussed earlier, with net loads at the Imperial Oil Complex and at Bayer Rubber of 0MW, and with the generating facilities at TransAlta and Bayer Rubber operating at full output, the individual flows on circuits N6S & N7S are expected to be 383MVA. As shown in the Table in Section 2 above, the *continuous* rating of each of these circuits once the work at Bayer Junction has been completed, will be 362MVA and 424MVA for ambient temperatures of 30°C and 10°C, respectively.

The impact of these continuous ratings on the two Projects that are to be incorporated via circuits N6S & N7S would be as shown below:

Ambient Temperature	Continuous Rating of circuits N6S & N7S	Output that can be accommodated	
		From TransAlta	From Imperial
30°C	362MVA	Maximum output restricted by ≈40MVA	Zero
10°C	424MVA	Full output	Restricted to approximately 80MVA

This would suggest that for ambient temperatures of 10°C and lower, there should be sufficient line capacity to accommodate the full output of the TransAlta generating facility together with the surplus output from the Imperial Oil facility, with both generating units in Phases I & 2 of the Imperial Oil development in-service. Furthermore, for every 1MW of additional load at either Bayer Rubber or at the Imperial Oil Complex, there would be a 1MW increase in the amount of output that could be accommodated on circuit N6S & N7S, from the two generating Projects.

The algorithm employed by the IMO to dispatch generating capacity will automatically respond to changes in those loads that are supplied from circuits N6S & N7S, as well as changes in the rating of these circuits, depending on the prevailing ambient conditions. It will therefore determine the maximum permissible output from the generating facilities at the TransAlta and Imperial Oil facilities that can be accommodated while respecting the continuous thermal rating of these circuits.

Possible Use of the Idle Section of Circuit N6S

The System Impact Assessment Report for the initial Sarnia-Windsor cluster detailed two alternatives; either of which would satisfy the IMO's requirements for the incorporation of the TransAlta Project into the IMO-controlled grid. Option ii. involved the reconductoring of circuits N6S & N7S in order to achieve a higher thermal rating so that these circuits would not impose restrictions on the output that could be accommodated (under normal system conditions) from the TransAlta facility. While this Option is still under consideration, there are known to be some external issues that could hinder its implementation. Furthermore, additional work would need to be performed to determine what would be the realistic maximum, and economic, rating that could be achieved through the use of larger conductors.

One other possible Option would involve incorporating the idle section of circuit N6S between Scott TS and the Dow Chemical Complex into the system configuration as a permanent connection. This would require establishing a new terminal position for this connection at both Scott TS and the 230kV busbar at the TransAlta generating facility.

Preliminary analysis indicates that the use of the idle section of circuit N6S would increase the maximum flow into Scott TS from approximately 724MVA (via circuits N6S & N7S) to approximately 825MVA (via all three circuits), for an ambient temperature of 30°C.

This approximate increase in the continuous rating of 100MVA, that the use of the idle section of circuit N6S would be expected to provide, would not only be sufficient for the assumed surplus output of 80MVA from the Imperial Oil facility, but would also allow more of the output from the TransAlta Project to be accommodated, during periods of minimum load and high ambient temperatures.

In addition, the use of the idle section of circuit N6S would increase the 15-minute limited-time-rating of the two remaining circuits for a contingency involving either N6S or N7S, from approximately 590MVA to approximately 900MVA, for an ambient temperature of 30°C and a maximum conductor operating temperature of 150°C. Since the four-breaker connection arrangement proposed by Imperial Oil will not result in the automatic loss of a generating unit at their facility for contingencies involving either circuit N6S or N7S, the increase in the 15-minute limited-time-rating could be beneficial by allowing generation run-back rather than generation rejection to be employed for the Imperial Oil generating units in response to contingencies.

5. Response to Contingency Conditions

Under contingency conditions involving either of the 230kV circuits, N6S or N7S, the entire pre-contingency flow on the two circuits would appear on the remaining circuit, less any reduction in output at the TransAlta Project that might be automatically initiated by the generation run-back or generation rejection scheme.

If the Imperial Oil Project were also to be transferring surplus output to the system when the contingency occurs, then it would aggravate the post-contingency loading situation on the remaining 230kV circuit.

Consequently, if there are ever going to be occasions when the Imperial Oil Project is expected to transfer surplus output to the system, then it will be an IMO requirement for the connection of this Project that a generation rejection scheme be installed to initiate rejection of generation capacity at the Imperial Oil facility for contingencies involving either circuit N6S or N7S.

Voltage Response under Contingency Conditions

Studies were performed to determine the impact on the voltages at the 230kV busbars at Scott TS; at the Imperial Oil Complex; and at Bayer Rubber, for a contingency involving one of the 230kV circuits, N6S or N7S. The situation selected assumed that only Phase 1 of the Imperial Oil development was complete, and that rejection of the single generating unit would be initiated in response to the loss of the 230kV circuit. In addition it was assumed that the generation rejection scheme would initiate simultaneous rejection of two of the generating units at the TransAlta facility.

The voltage declines that were recorded were all less than 2%, which is within the IMO criterion of 10%.

6. Implementation of Option ii. from the SIA for the initial Sarnia-Windsor cluster

Should it be decided to implement Option ii from the System Impact Assessment for the initial Sarnia-Windsor cluster, and proceed with the reconductoring of circuits N6S & N7S to obtain a higher continuous thermal rating, then this would have an impact on the amount of surplus power that could be delivered to the system from the Imperial Oil Complex and on the response required under contingency conditions.

The extent to which the continuous rating of these circuits can be increased will be a function of many factors, including cost. However, for the TransAlta and Imperial Oil Projects the following represent the ratings that would be expected to have the most impact/benefit:

<i>Continuous Rating at 30^o C & a wind speed of 0-4km/hr</i>	<i>Required Impact</i>		<i>Required Response under contingency conditions</i>
	<i>On the TransAlta facility</i>	<i>On the Imperial Oil facility</i>	
423MVA 1018 amps (at 240kV)	To accommodate the full output from the TransAlta/ Dow Chemical Complex & from the generators at Bayer Rubber with zero local load.	To accommodate the projected surplus of 80MVA from the Imperial Oil facility	Initiate a combined reduction of 423MVA in the output from the two facilities. This is equivalent to the pre-contingency loading on the faulted circuit
	383MVA/circuit	40MVA/circuit	<i>Reject: 383MVA + 40MVA</i>
766MVA 1843 amps (at 240kV)	To accommodate the full output from the TransAlta/ Dow Chemical Complex & from the generators at Bayer Rubber under outage/ contingency conditions, with zero local load.	To accommodate the full output (200MVA) from the Imperial Oil generators, with zero load at the Complex	Reduce the surplus output from the Imperial Oil facility to zero. The full output of the TransAlta Project could then be accommodated on the remaining circuit
	383MVA/circuit	100MVA/circuit	<i>Reject: Up to 2 x 100MVA</i>
846MVA 2035 amps (at 240kV)	To accommodate the full output from the TransAlta/ Dow Chemical Complex & from the generators at Bayer Rubber under outage/ contingency conditions, with zero local load.	To accommodate the projected surplus of 80MVA from the Imperial Oil facility under outage/contingency conditions	No response is necessary
	383MVA/circuit	40MVA/circuit	<i>Reject: 0MW</i>

7. Fault Level Analysis

Fault level studies were performed to determine the impact of each Phase of the proposed Imperial Oil Development at their Complex in Sarnia on the existing transmission facilities.

The following system conditions were assumed when conducting the studies:

- All existing transmission facilities, together with those facilities that have been 'committed' are assumed to be in-service.
- The three Interconnections with Michigan reflect their final arrangement following the installation of the new phase-shifters.
- The generators at the Bruce 'A' station are out-of-service
- The generators at the Pickering 'A' station are in-service
- The two 500/230kV auto-transformers at Lennox TS, together with units G1 to G4 at Lennox GS are in-service.
- The 230kV busbars at Richview TS are operated 'split', while Cherrywood TS is operated with a separate North & South switchyard.
- All of the generators that were specified for each Project in the original Sarnia-Windsor cluster were assumed to be in-service and incorporated into the system in accordance with the arrangements detailed in the System Impact Assessment Report for this cluster.
- The circuits terminating at the Lambton 230kV busbar have been reconfigured in accordance with the requirements detailed in the System Impact Assessment for the original Sarnia-Windsor cluster, and the 230kV busbar is operated permanently 'split'.
- All of the 20kA circuit breakers on the 115kV busbar at Sarnia-Scott TS have been replaced with higher rated units.
- The two 115kV series-connected reactors on the two 230/115kV auto-transformers at Sarnia-Scott TS 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.

7.1 Detroit Edison Company

In discussions with the Detroit Edison Company (DECO) we were made aware of a major new development in the Belle River/St. Clair area of the Detroit Edison Transmission System. This Project, which is to have a capacity of 950MW, is scheduled to be in-service in the Spring 2003.

A Facilities Study, to establish a detailed specification for the incorporation equipment, has recently been completed, and since Detroit Edison is still of the opinion that this Project will proceed, it was therefore decided to include it in the system model for the fault level analysis for this assessment.

7.2 Representation of the Detroit Edison System

The expected model for the year-2000, that was provided by Detroit Edison in 1995, has been used in all of the fault level studies that were performed for this Assessment. The IMO has concerns regarding the accuracy of this representation as it could affect the study results, and the conclusions that have been drawn from them.

Prior to commencing the System Impact Assessment for those Projects in the next cluster, which is to include the Imperial Oil Project, the IMO will confirm the validity of the model that is to be used for the Detroit Edison System and the Ontario-Michigan Interconnections.

7.3 Fault Level Results

The results for the three most-critical locations are shown on the following Diagrams:

At Lambton TGS

- Diagram 6 For a 3-phase Fault on the 230kV busbar
- Diagram 7 For a Line-to-Ground Fault on the 230kV busbar

At Sarnia-Scott TS

- Diagram 8 For a 3-phase Fault on the 230kV & 115kV busbar
- Diagram 9 For a Line-to-Ground Fault on the 230kV & 115kV busbar

At Keith TS

- Diagram 10 For a 3-phase Fault on the 230kV & 115kV busbar
- Diagram 11 For a Line-to-Ground Fault on the 230kV & 115kV busbar

7.3.1 Fault levels at Lambton TGS

The maximum fault levels for Phase 2, with both generating units in-service, are also summarised in the Table below:

Fault levels on the 230kV busbars at Lambton TGS for a Pre-fault Voltage of 250kV									
		Symmetrical		Asymmetrical		Breaker Ratings			
		3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical	
<i>With the four Sarnia-Windsor Projects in-service</i>	<i>North</i>	35.69kA	40.20kA	46.33kA	53.47kA	<i>B</i>	70.0kA	<i>B</i>	92.0kA
	<i>South</i>	41.98kA	46.55kA	54.49kA	61.91kA	<i>A</i> <i>B</i>	65.0kA 70.0kA	<i>A</i> <i>B</i>	78.0kA 92.0kA
<i>With the four Sarnia-Windsor Projects & both units of the Imperial Oil Project</i>	<i>North</i>	36.34kA	40.83kA	47.17kA	54.30kA	<i>B</i>	70.0kA	<i>B</i>	92.0kA
	<i>South</i>	43.07kA	47.56kA	55.95kA	62.78kA	<i>A</i> <i>B</i>	65.0kA 70.0kA	<i>A</i> <i>B</i>	78.0kA 92.0kA

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

The results in the above table indicate that with the Lambton 230kV busbar operated 'split' all of the existing circuit breakers will be adequate for the expected fault interrupting duty that could be imposed on them with both generating units at the Imperial Oil Complex in-service.

Since there is a considerable margin between the projected fault levels and the fault interrupting capability of the existing breakers the results with just the single generator in Phase 1 have not been presented.

7.3.2 Fault levels at Sarnia-Scott TS

The maximum fault levels are also summarised in the Table below:

Fault levels on the 230kV busbar at Scott TS for a Pre-fault Voltage of 250kV							
	Symmetrical Fault		Asymmetrical Fault		Breaker Capability		
	3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical
<i>With all four Sarnia-Windsor Projects In-service</i>	36.75kA	33.57kA	45.16kA	38.67kA	38.4kA		46.2kA
<i>With all four Sarnia-Windsor Projects in-service plus both units at Imperial Oil</i>	38.66kA	36.23kA	47.90kA	42.39kA			
	+1.91kA	+2.66kA	+2.74kA	+3.72kA			
<i>With all four Sarnia-Windsor Projects in-service plus only one unit at Imperial Oil</i>	37.65kA	34.89kA	46.72kA	40.79kA	38.4kA		46.2kA
	+0.90kA	+1.32kA	+1.56kA	+2.12kA			

Fault levels on the 115kV busbar at Scott TS for a Pre-fault Voltage of 127kV								
	Symmetrical Fault		Asymmetrical Fault		Breaker Capability			
	3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical	
<i>With all four Sarnia-Windsor Projects In-service</i>	16.22kA	18.74kA	21.41kA	25.43kA	A B	31.4kA 38.8kA	A B	34.1kA 45.5kA
<i>With all four Sarnia-Windsor Projects In-service plus both units at Imperial Oil</i>	19.92kA	23.82kA	24.87kA	31.61kA				
	+3.70kA	+5.08kA	+3.46kA	+6.18kA				

Note: The 'A' rating applies to breaker KL1; & the 'B' rating to breakers KL7, L1L6, L5L7, & PL5.

230kV Facilities

The following conclusions can be drawn from the Table above:

The Table above indicates that with both generating units in Phases 1 & 2 of the proposed Imperial Oil development in-service, the *total* symmetrical and asymmetrical fault levels for three-phase faults on the Scott 230kV busbar will exceed the rating of the existing breakers. However, after allowing for the *minimum* symmetrical & asymmetrical fault infeeds of 2.19kA & 2.71kA, respectively (on the Buchanan circuits), the actual duty imposed on the breakers would be 36.47kA (symmetrical) & 45.19kA (asymmetrical), or lower. This means that with the two Imperial Oil generators in-service, together with all four Projects in the original Sarnia-Windsor cluster, the existing 230kV breakers would have a margin of approximately 1kA with respect to the maximum fault interrupting duty that is expected to be imposed on them.

With only a single new generating unit at the Imperial Oil Complex, the margin between the maximum fault interrupting duty that would be expected to be imposed, and the rating of the existing breakers would increase to approximately 2kA

The incremental increase in the fault level on the 230kV & 115kV busbars at Scott TS, that is expected to be contributed by the two Phases of the Imperial Oil Project have also been indicated in the above Table.

115kV Facilities

Since none of the 115kV circuits at Scott TS contribute to the fault levels on the 115kV busbar at that station, the fault interrupting duty that would be imposed on each individual breaker would be the same as the fault level on the busbar. However, with all of the 20kA breakers replaced with higher-rated units, the maximum symmetrical (23.8kA) & asymmetrical (31.6kA) fault currents for a line-to-ground fault would be within the rating of the critical KL1 breaker with a rating of 31.4kA symmetrical and 34.1kA asymmetrical.

7.3.3 Fault levels at Keith TS

Fault levels on the 230kV busbar at Keith TS for a Pre-fault Voltage of 250kV								
	Symmetrical Fault		Asymmetrical Fault		Breaker Capability			
	3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical	
<i>With all four Sarnia-Windsor Projects In-service</i>	20.25kA	20.94kA	25.37kA	25.27kA	38.4kA		46.2kA	
<i>With all four Sarnia-Windsor Projects in-service plus both units at Imperial Oil</i>	20.25kA	20.94kA	25.37kA	25.28kA				
<i>With all four Sarnia-Windsor Projects in-service plus only one unit at Imperial Oil</i>	20.25kA	20.94kA	25.37kA	25.28kA				
Fault levels on the 115kV busbar at Scott TS for a Pre-fault Voltage of 127kV								
	Symmetrical Fault		Asymmetrical Fault		Breaker Capability			
	3-phase	L-G	3-phase	L-G	Symmetrical		Asymmetrical	
<i>With all four Sarnia-Windsor Projects In-service</i>	25.14kA	29.31kA	31.65kA	36.73kA	A B	31.4kA	A B	34.1kA
<i>With all four Sarnia-Windsor Projects In-service plus both units at Imperial Oil</i>	25.14kA	29.32kA	31.65kA	36.73kA		38.8kA		45.5kA

The results summarised in the Table above show that the new generating facilities at the Imperial Oil facility will have a negligible impact on the fault levels on either the 230kV or the 115kV busbars at Keith TS.

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

The Table below provides a summary of the fault levels at the principal busbars in the Sarnia-Windsor area, with the two generating units in Phases 1 & 2 of the proposed Imperial Oil development in-service.

<i>Busbar</i>		<i>Symmetrical</i>		<i>Asymmetrical</i>		<i>Breaker Ratings</i>		
		<i>3-phase</i>	<i>L-G</i>	<i>3-phase</i>	<i>L-G</i>	<i>Symmetrical</i>	<i>Asymmetrical</i>	
<i>Buchanan TS</i>	230kV	A	29.71kA	25.22	32.59kA	28.15kA	39.0kA to 74.0kA	
		B	29.80kA	25.27kA	32.69kA	28.20kA		
<i>Chatham TS</i>	230kV	A	23.28kA	14.65kA	25.54kA	14.76kA	36.4kA & 48.6kA	
		B	23.32kA	14.67kA	25.14kA	14.77kA		
<i>Lauzon TS</i>	C23Z 230kV	A	9.23kA	8.90kA	10.81kA	10.27kA	No 230kV breakers	
		B	9.23kA	8.90kA	10.82kA	10.27kA		
	C24Z 230kV	A	9.17kA	8.87kA	10.88kA	10.23kA		
		B	9.17kA	8.87kA	10.88kA	10.23kA		
	115kV	A	20.69kA	23.16kA	23.48kA	25.84kA	39.3kA	45.5kA
		B	20.69kA	23.16kA	23.48kA	25.85kA		
<i>Essex TS</i>	115kV	A	22.31kA	22.90kA	25.75kA	26.43kA	39.3kA	45.5kA
		B	22.32kA	22.90kA	25.75kA	26.43kA		

Note: The 'A' values correspond to the fault levels without the two new generators at the Imperial Oil Complex, while the 'B' values correspond to those with the new generators in-service.

The values in the Table above show that the additional generators at the Imperial Oil complex would be expected to have very little impact on the fault levels at those busbars that are not within the immediate vicinity of Sarnia.

7.3.5 Summary of the Impact of the New Generators on Fault Level

On the assumption that the 230kV busbar at Lambton TGS will have been reconfigured to allow it to be operated 'split', then the busbar on which the additional generators at the Imperial Oil Complex will have the greatest impact will be Sarnia-Scott. However, the analysis indicates that the Imperial Oil Project, in isolation, would not be sufficient to result in an increase in the fault level that would trigger the need for the replacement of individual circuit breakers on either the 230kV or the 115kV busbars at Sarnia-Scott TS.

8. Impact on System Transfers

The System Impact Assessment Report for the four generation projects in the initial Sarnia-Windsor cluster addressed the potential for congestion on the 500kV and 230kV systems in the south-west, assuming all four projects proceed to completion.

Diagram 16 from that Report, which showed the approximate generation-load balance for the three principal centres in the Sarnia-Windsor study area, with all four of the new Projects in-service, has been reproduced as Diagram 12.

This Diagram shows the net transfers from the three principal load and/or generation areas with the expected peak loads for the summer-2004. This Diagram has been amended from its original version to show the impact that an additional 200MW of generating capacity at the Imperial Oil Complex would have. In particular, with no transfers being made into Ontario across the Ontario-Michigan Interface, the net transfer across the London-Import Interface would increase to approximately 2690MW. Since the eastward transfer limit for the London-Import Interface is approximately 2815MW, the maximum transfer that could occur across the Ontario-Michigan Interface, with all the generating facilities in the area fully dispatched, would be limited to approximately 125MW. Conversely, with maximum transfers of 1500MW across the Ontario-Michigan Interface, approximately 1375MW of the generating capacity in the area would be constrained. During periods with reduced loads in the area, there would be further restrictions on the amount of generating capacity that could be dispatched and on the level of transfers that could be made into Ontario across the Ontario-Michigan Interface.

For the situation when transfers are being made to Michigan across the Ontario-Michigan Interface, then as long as there was a minimum transfer eastwards across the London-Import Interface of at least 290MW, it would be possible to dispatch all of the generating capacity in the Sarnia and Windsor area and respect the transfer limit of approximately 2400MW. Again, during periods with reduced loads, there would have to be a comparable increase in the transfer eastwards across the London-Import Interface, to allow all of the generating capacity to be dispatched.

For the Sarnia-Windsor study area the dispatch of generating capacity could also be restricted by a requirement to respect the Negative BLIP (Bruce-Longwood Input) Interface limit of 1500MW. As shown in Diagram 12, with all the generating facilities in the area fully dispatched and with no transfers into Ontario across the Ontario-Michigan Interface, the net transfer across the Negative BLIP Interface would be approximately 1490MW. Since this is essentially the same value as the Negative BLIP limit, there would be no opportunity for simultaneous transfers into Ontario across the Ontario-Michigan Interface when all the generation capacity within the area is dispatched.

As before the restrictions would be more severe during those periods when the loads are lighter, requiring a 1MW increase in the westward transfer across the Ontario-Michigan Interface, or a reduction of 1MW in the amount of generating capacity that could be dispatched, for every 1MW reduction in the load that has been assumed.

Lambton TGS Generation Rejection Scheme

The existing Lambton Generation Rejection Scheme (with the Lambton busbar operated 'closed') provides the capability to reject a single generating unit for a contingency condition involving the loss of one of the Ontario-Michigan Interconnections that terminate on the Lambton 230kV busbar, when transfers are being made to Michigan. The purpose of the Scheme is to reduce the post-contingency loading on the companion Interconnection.

Once the Lambton 230kV busbar has been reconfigured to allow it to be operated 'split', the existing Generation Rejection Scheme will need to be modified to allow either of those two generators that are associated with a specific Interconnection to be rejected in the event of a contingency.

Since, the transfer capability of the Ontario Michigan Interface is limited by the post-contingency flow on the B3N Interconnection, then it might be possible to maintain or even increase the transfer capability of the Interface by rejecting generation capacity at the TransAlta and/or Imperial Oil installations, in addition to that at Lambton TGS, for contingencies involving the L4D or L51D Interconnections.

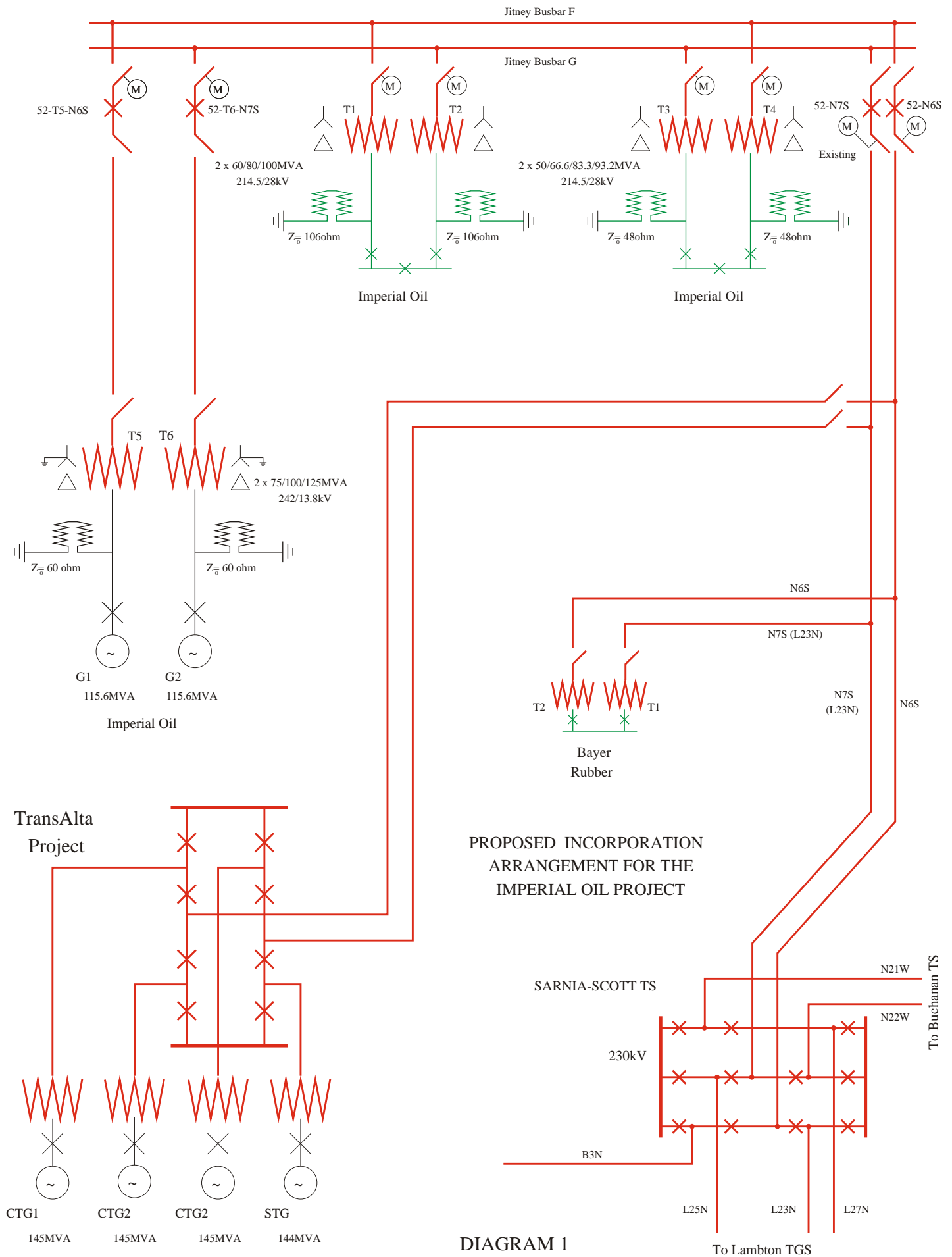
It is proposed to examine this issue in more detail in the System Impact Assessment.

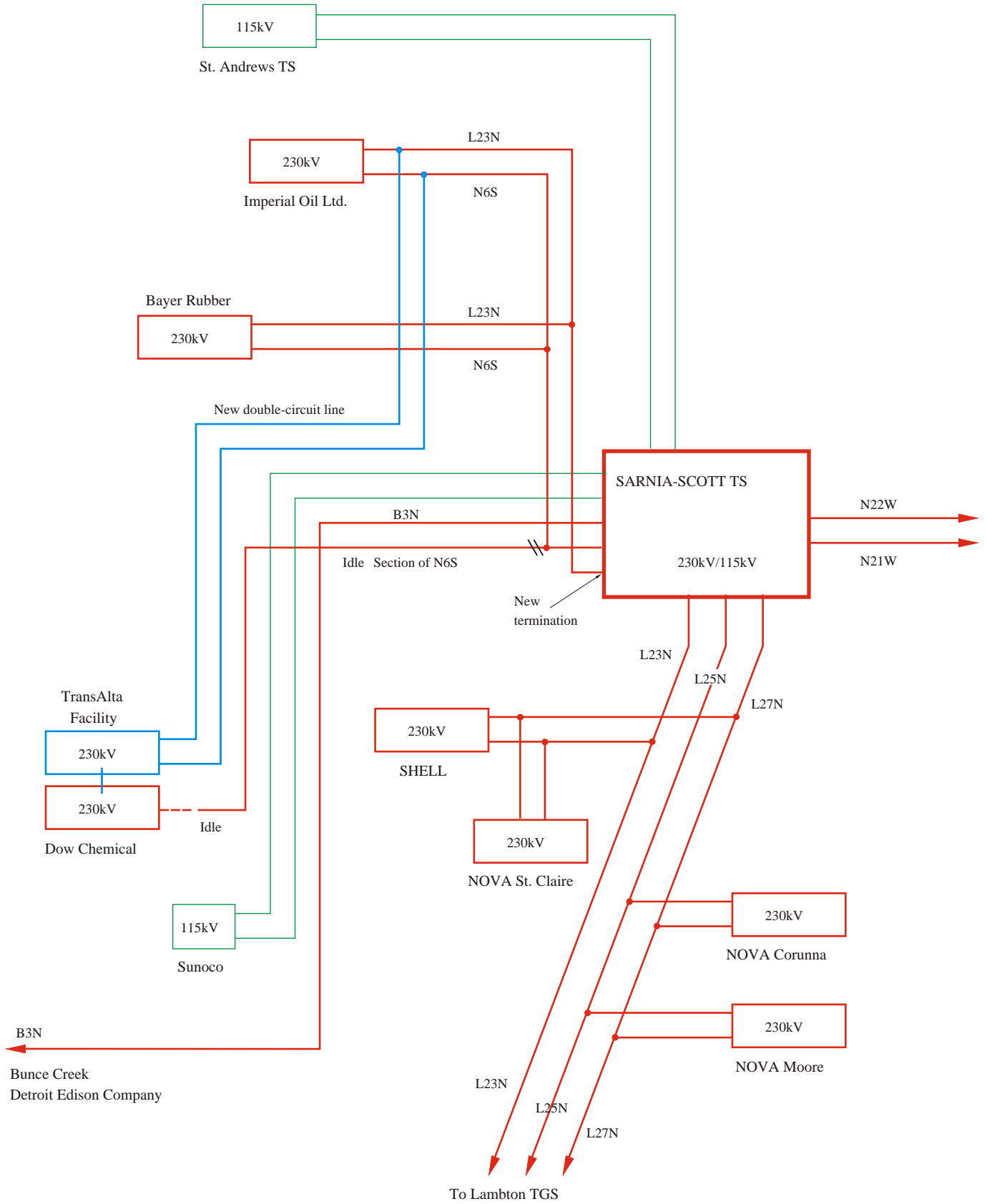
9. Conclusions

The Preliminary Assessment has examined the effect of incorporating the additional generating capacity that Imperial Oil is proposing to install at their Complex in Sarnia into the IMO-controlled grid, and the following conclusions have been reached:

- The proposed connection of the single generating unit in Phase 1 will have no adverse impact on reliability, as long as there are no net transfers to the system.
- If there are net transfers to the system from Phase 1, then the IMO will require a generation rejection scheme to be installed for contingencies involving either circuit N6S or N7S. This would also apply if Phase 2 were to proceed and net transfers were to be made to the system from the larger development.
- On the assumption that the Lambton 230kV busbar will be reconfigured and operated 'split', the impact of the new generating facilities at the Imperial Oil Complex, in isolation, will not be sufficient to increase the fault level at Sarnia-Scott TS, to require remedial action to be taken.
- While the new generating facilities will increase congestion within the area, they will not, in isolation, result in any reduction in the existing operating limits or transfer capabilities.

- Apart from possible system constraints (congestion), there will also be local restrictions on the amount of generating capacity that it will be possible to dispatch at the Imperial Oil Complex, and this will vary depending on the following factors:
 - i. The ambient temperature & wind speed conditions (which effect the circuit ratings)
 - ii. The combined, local load at Imperial Oil, Bayer Rubber & Dow Chemical
 - iii. The output from the TransAlta, Dow Chemical & Bayer Rubber generating facilities
- If circuits N6S & N7S are re-conducted and their continuous ratings are increased, then there could be a relaxation in the requirements for generation rejection depending on the extent of the uprating achieved. Similarly the local restrictions on the amount of generating capacity that could be dispatched would also be relaxed.
- Should Imperial Oil elect to proceed to the System Impact Assessment phase of the Connection Process, then additional data will need to be supplied. If these data are unavailable, then Imperial Oil would have the option of instructing the IMO to proceed with the analysis using typical values. The onus would then be on Imperial Oil to ensure that the equipment supplied meets, or surpasses, the capability of the assumed values.
- An alternative switching arrangement has been proposed, that while employing the same number of circuit breakers, would avoid possible 'back-feed' situations involving the transformers at the DESN stations at Imperial Oil and Bayer Rubber.
- An attempt has also been made to identify the minimum switching facilities that would need to be installed to ensure compliance with the Transmission System Code. (However, it is emphasised that Hydro One would have the final decision regarding the switching facilities that would need to be installed to comply with the Code.)





INCORPORATION ARRANGEMENT FOR THE TRANSALTA PROJECT

DIAGRAM 2

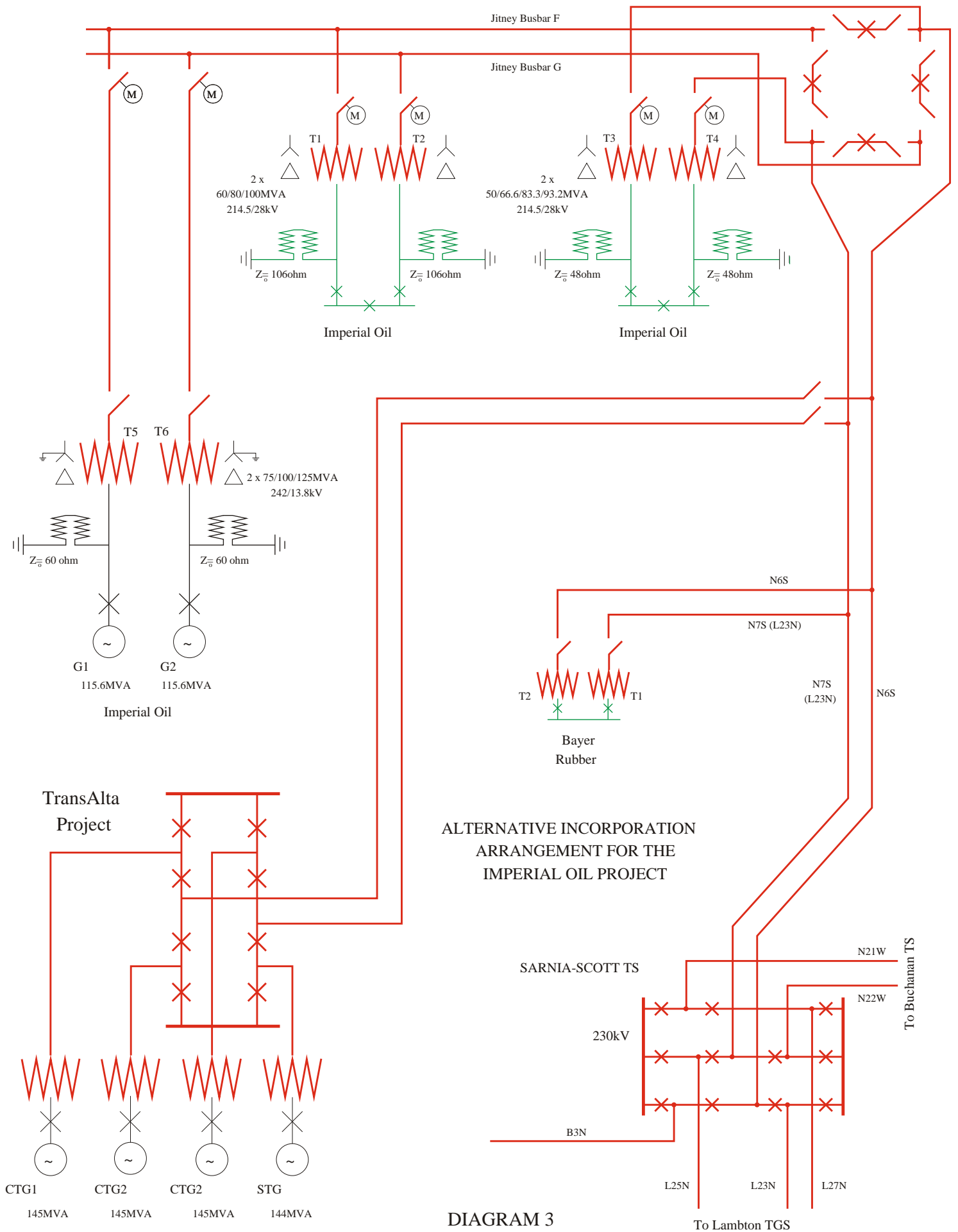


DIAGRAM 3

11th July 2001

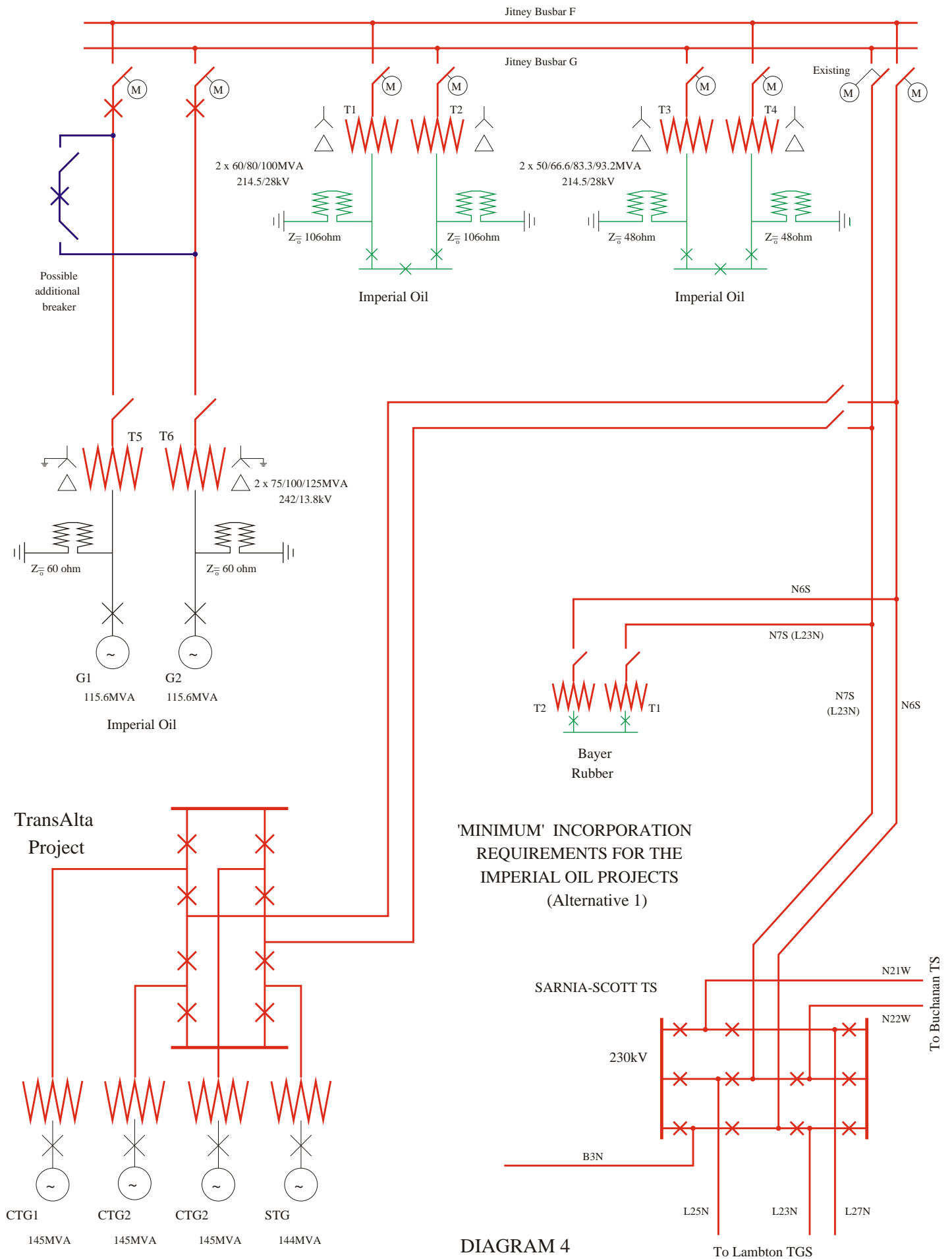


DIAGRAM 4

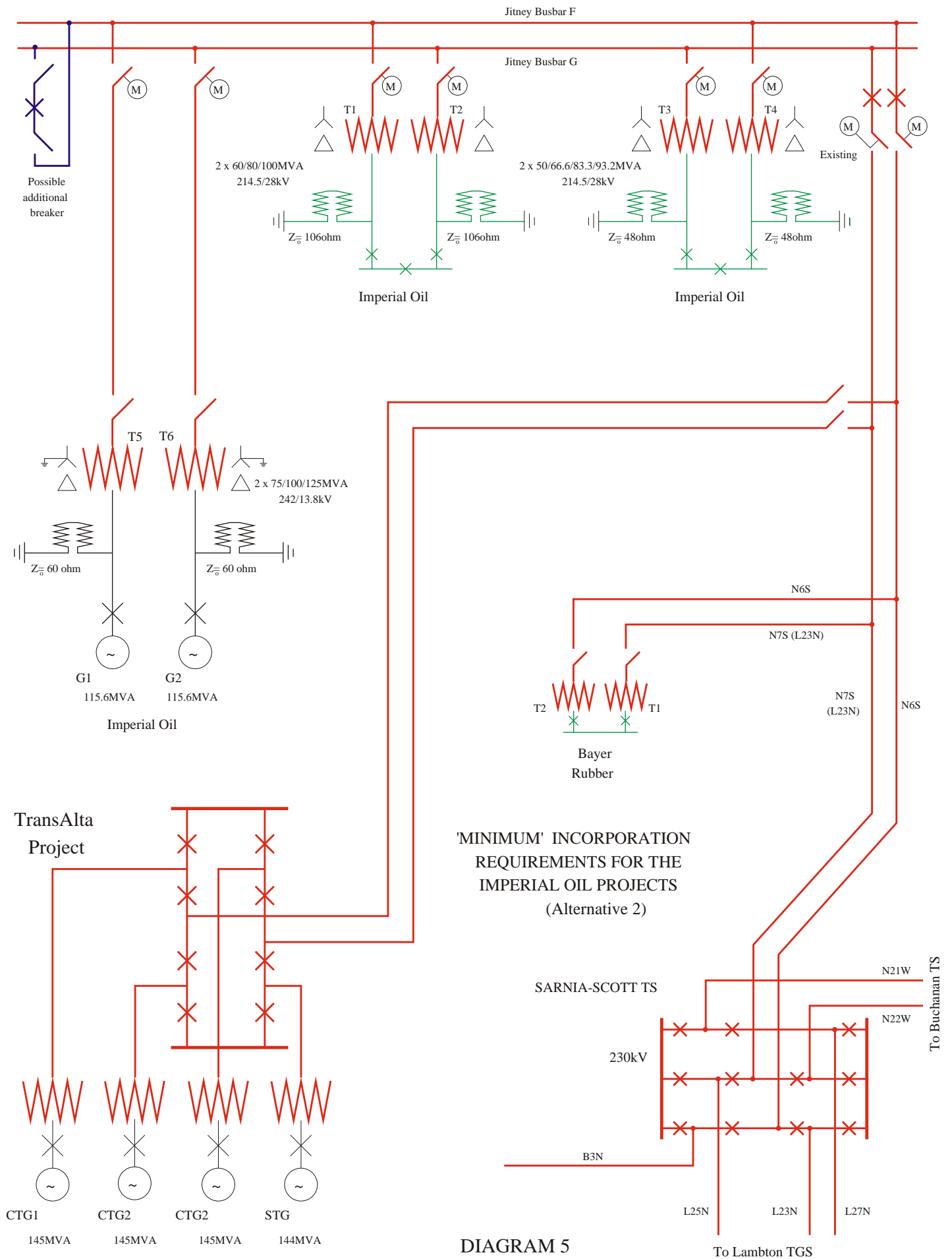
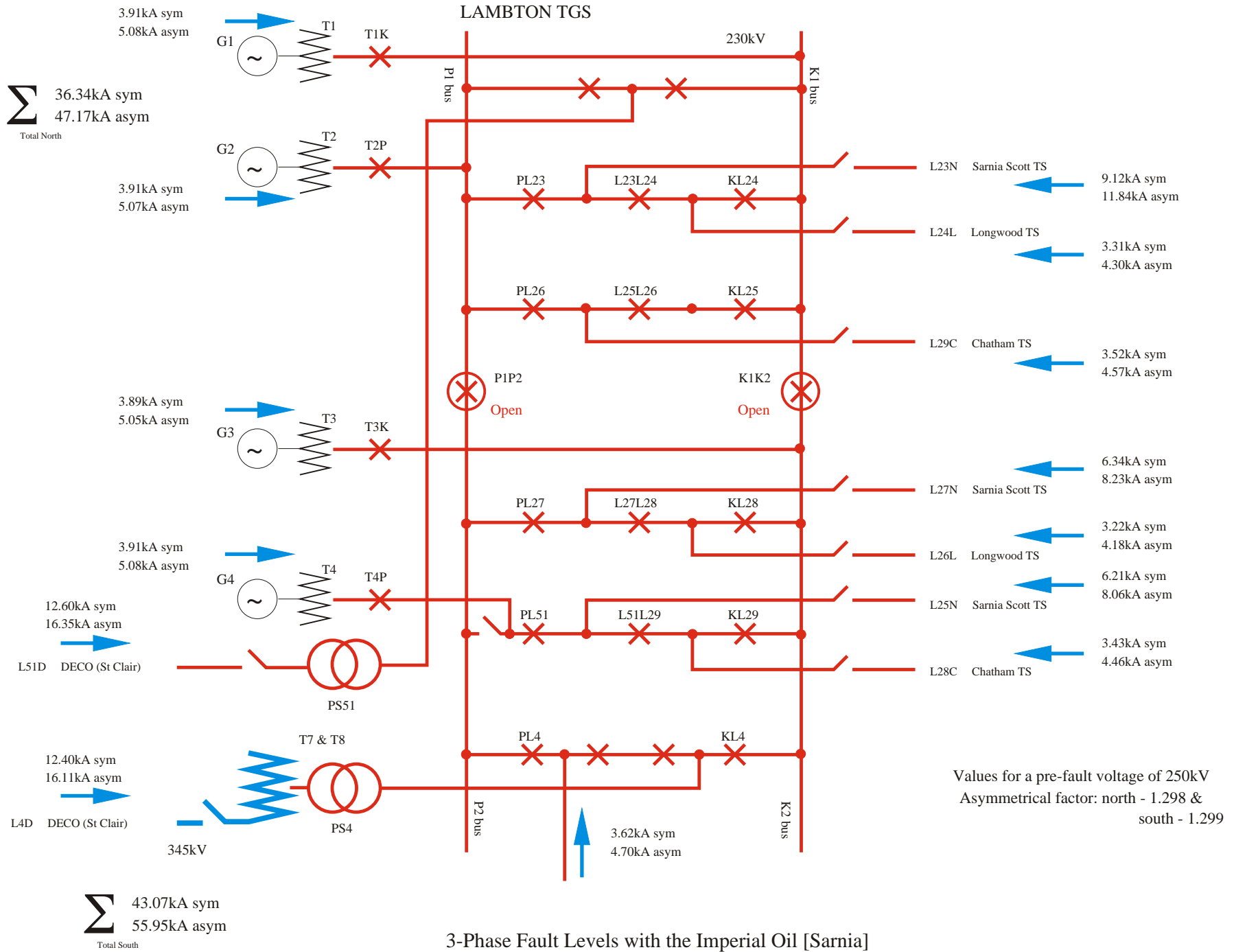
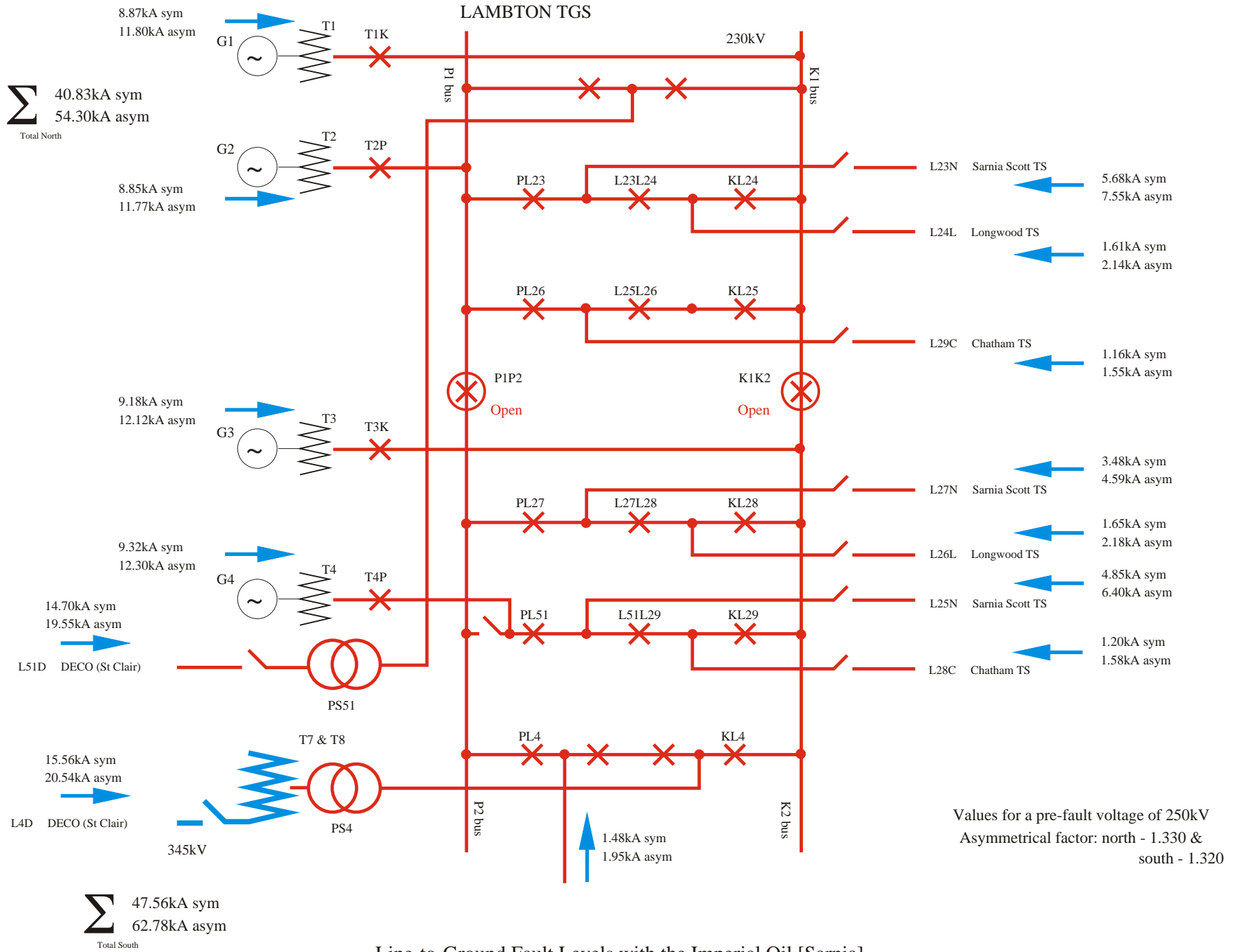


DIAGRAM 5

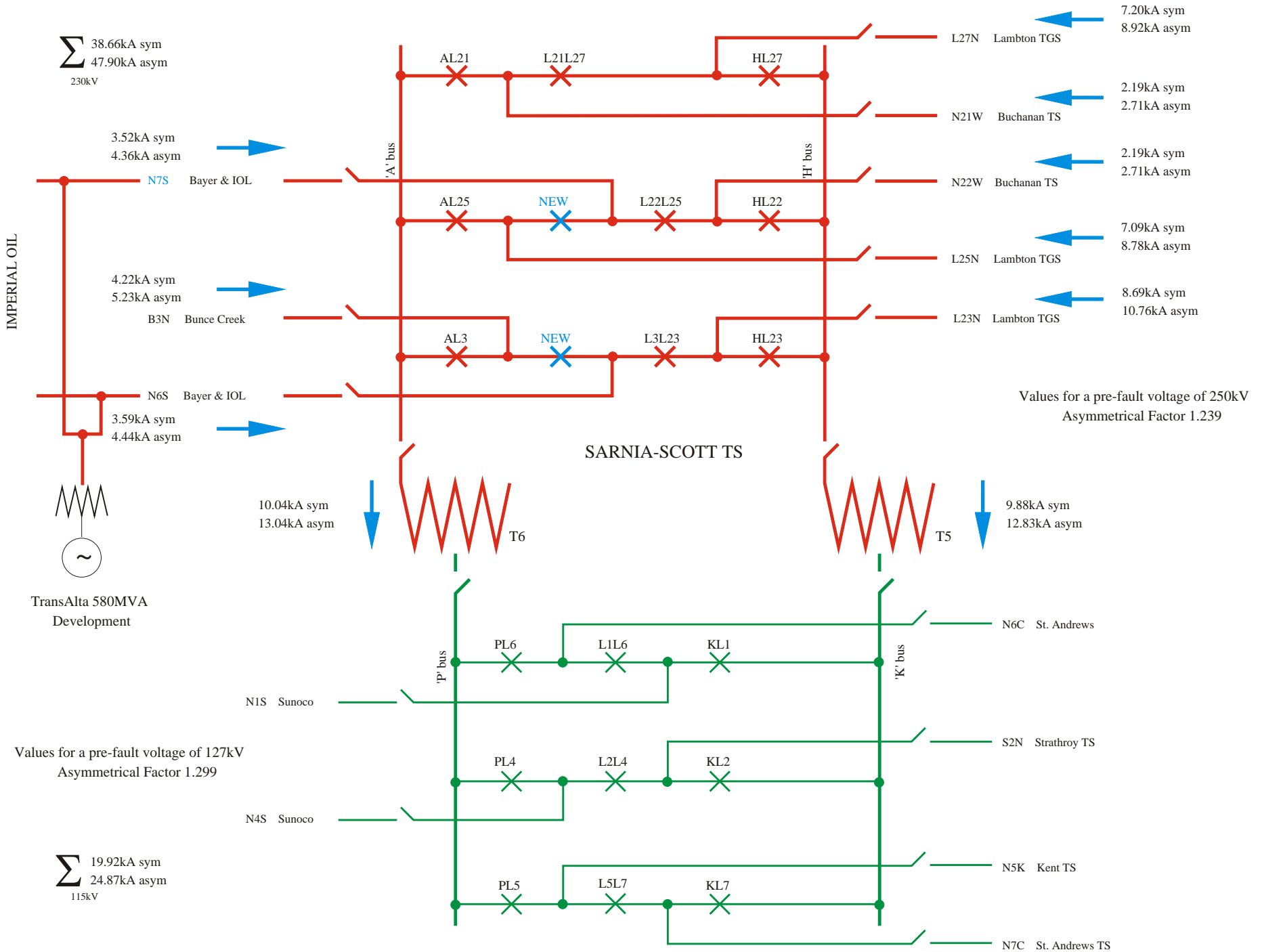


3-Phase Fault Levels with the Imperial Oil [Sarnia] Project Incorporated & the Lambton Busbar 'Split'

DIAGRAM 6



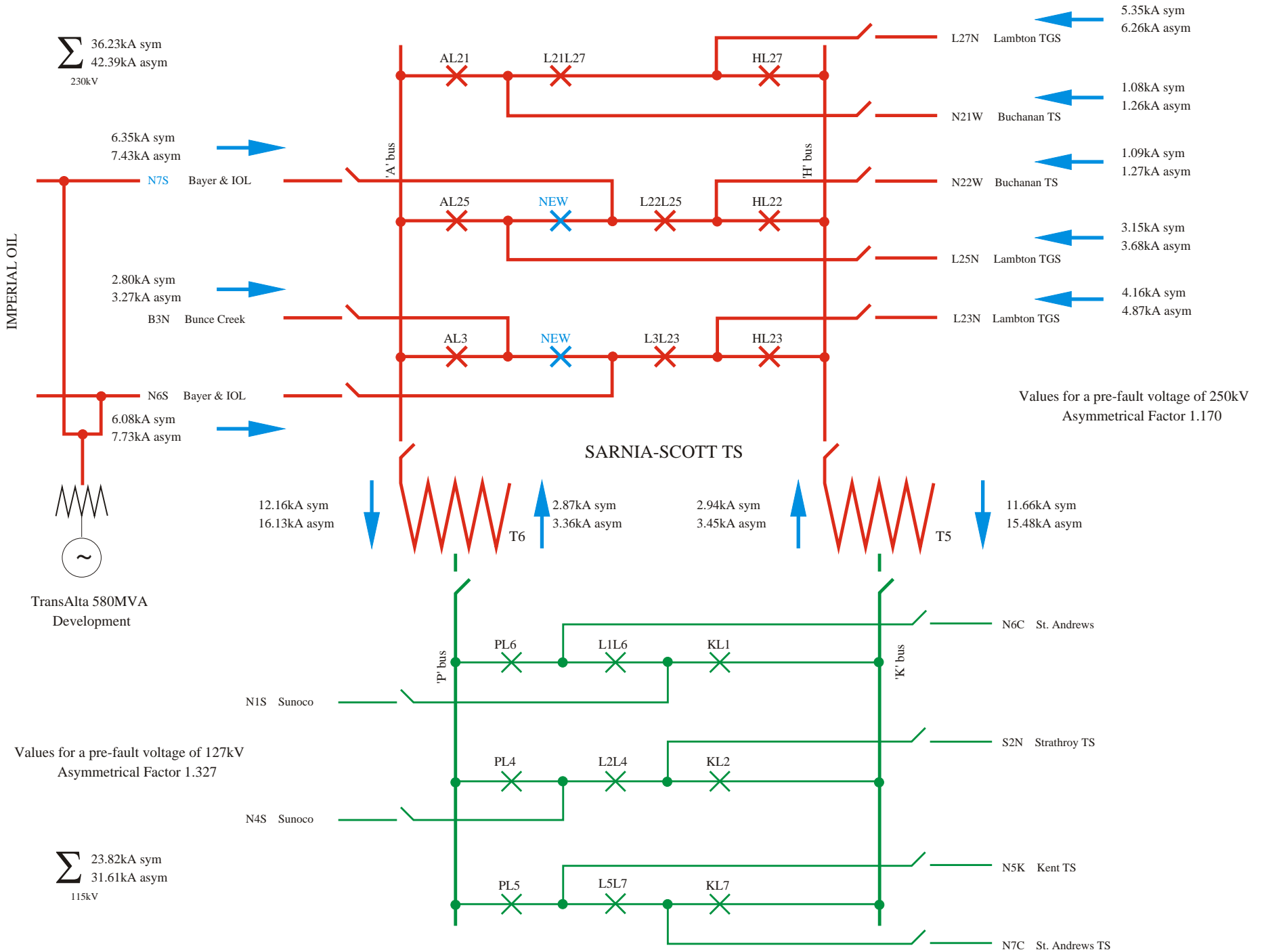
Line-to-Ground Fault Levels with the Imperial Oil [Sarnia] Project Incorporated & the Lambton Busbar 'Split'



3-phase Fault Levels with the Imperial Oil [Sarnia] Project Incorporated & the Lambton Busbar 'Split'

DIAGRAM 8

11th July 2001



Line-to-Ground Fault Levels with the Imperial Oil [Sarnia] Project Incorporated & the Lambton Busbar 'Split'

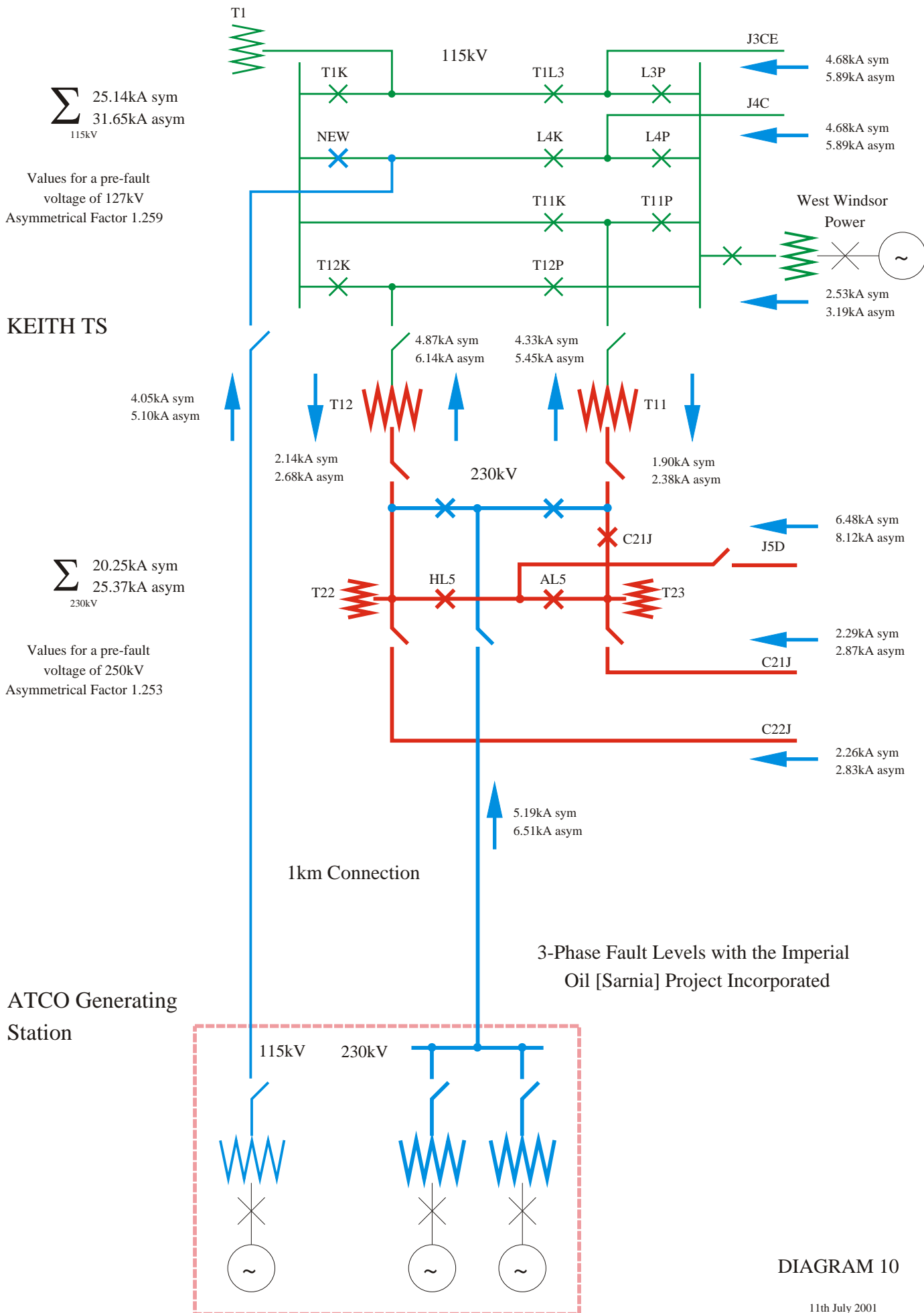
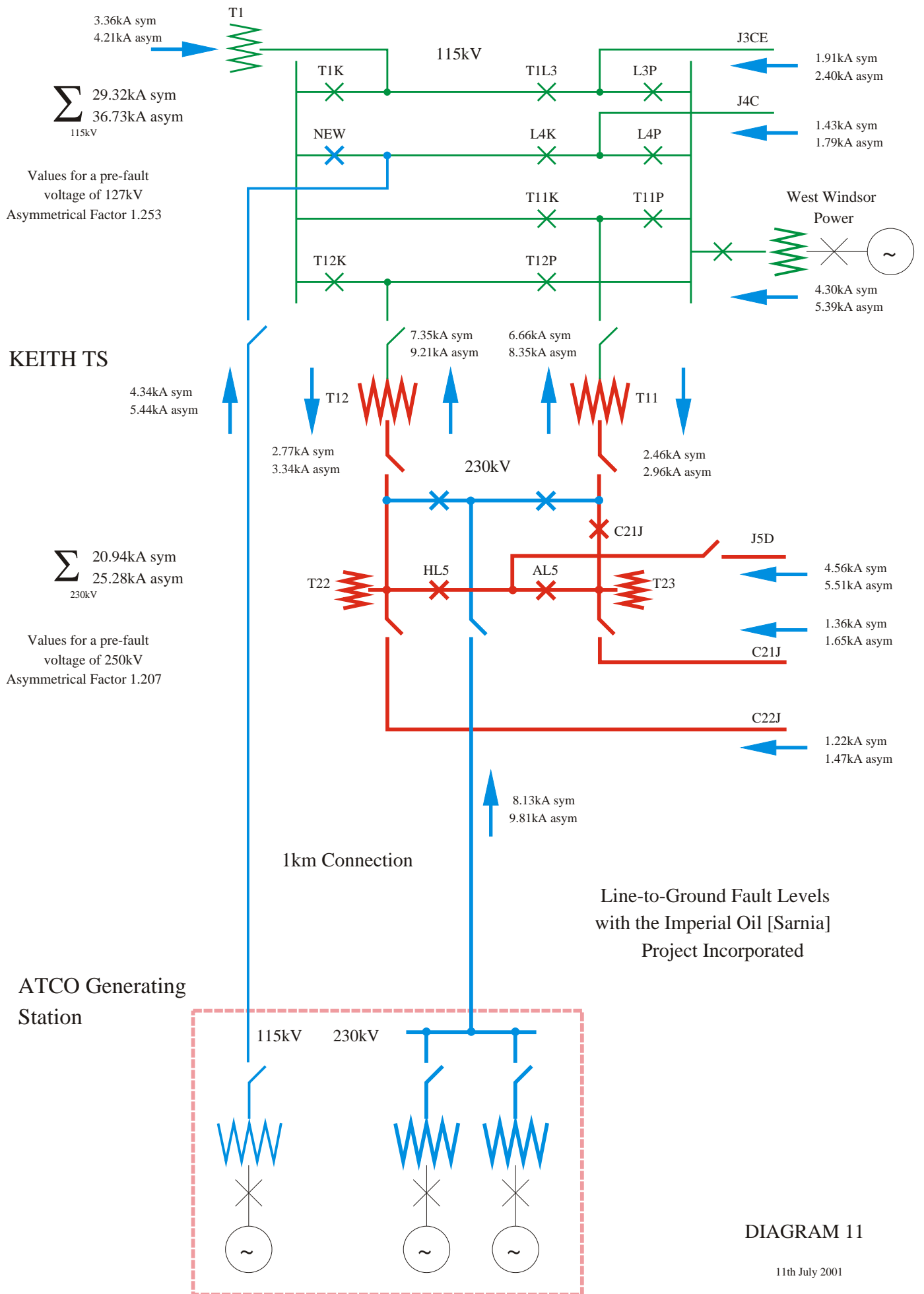


DIAGRAM 10



CONNECTION ASSESSMENT & APPROVAL PROCESS

PRELIMINARY ASSESSMENT REPORT

*For the Proposed Development by Imperial Oil at their Complex in Sarnia.
27.6kV Incorporation Option*

CAA ID No. 2000-029:

<i>Phase I</i>	<i>112MVA</i>
<i>Phase II</i>	<i>112MVA</i>

Long Term Forecasts & Assessments Department

FINAL Version

Date: 21st August 2001

Preliminary Assessment Report

For the 27.6kV Incorporation Option for Phase I of the Proposed Development by Imperial Oil at their Complex in Sarnia.

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, on a preliminary basis, whether the connection applicant's proposed connection with the IMO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether a System Impact Assessment of the proposed connection should be conducted under Chapter 4, section 6 of the Market Rules. This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. This report has been prepared solely for use by the connection applicant, Hydro One and the IMO in accordance with Chapter 4, Section 6 of the Market Rules. The IMO assumes no responsibility to any third party for any use which it makes of this report. Any liability which the IMO may have to the connection applicant in respect of this report is governed by Chapter 1, Section 13 of the Market Rules. In the event that the IMO provides a draft of this report to the connection applicant, you must be aware that the IMO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IMO will use its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that it is using the most recent version of this report. The IMO expects the connection applicant and affected transmitter to discuss the connection project with any persons located in the vicinity of the project and to advise the IMO of any concerns they might express about the impact of the project on system reliability.

Hydro One

Special Notes and Limitations of Study Results

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

The short circuit and thermal loading levels have been computed based on the information provided by the connection proponent at the time of the study. These levels may be higher or lower if the connection information changes as a result of, but not limited to, subsequent design modifications or when more accurate test measurement data is available.

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

In this preliminary feasibility study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent upon request.

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

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

PRELIMINARY ASSESSMENT REPORT

For the 27.6kV Option for Incorporating New Generating Capacity

EXECUTIVE SUMMARY

Introduction

Imperial Oil is proposing to incorporate two new 112MVA generating units into their Complex at Sarnia.

The scheduled in-service date for the first unit is the 3rd Quarter of 2004, and
The scheduled in-service date for the second unit is the 4th Quarter of 2007.

Incorporation of the new generating units into either the existing 230kV system or the 27.6kV system is being considered. This Preliminary Assessment has examined the impact of incorporating the first of the two 112MVA generating units into the local 27.6kV system

Incorporation Arrangement

The arrangement proposed by Imperial Oil for the incorporation of the first new generating unit involves the installation of a 27.6kV 600 meter cable connection between the generating step-up transformer and the 230kV busbar at Substation 2A. Two, existing 915 metre overhead lines then connect Substation 2A to the new 230/27.6kV DESN station that Imperial Oil is planning to establish in July 2002 under their 4th Transformer Project.

Participation in the Electricity Market

Imperial Oil has indicated that the new generating unit may be utilised solely for load displacement at their Complex in Sarnia, and that at no time would any excess capacity be offered to the Market.

Should the situation change then the Imperial Oil facility would only be permitted to participate in the Electricity Market if the following conditions are met:

Impedance of the Generator Step-up Transformer

This must be restricted to a maximum of approximately 11% so that the combined impedance of the transformer; the cable connection to Substation 2A; and the two over-head line circuits between Substation 2A and the 27.6kV busbar at the new 230/27.6kV DESN station; does not exceed the 13% limit that will have to be respected to comply with the Market Rules (Appendix 4.2 - Reference 2).

Installation of a Generation Rejection Scheme

Due to the limited thermal ratings for the two 230kV circuits N6S & N7S (formally L23N), restrictions would need to be imposed on the amount of output that could be accommodated from the Imperial Oil facilities whenever the TransAlta Project is operating at, or close to, its maximum output.

Furthermore, under contingency conditions involving either of the 230kV circuits, N6S or N7S, the entire pre-contingency flow on the two circuits would appear on the remaining circuit. In order to ensure that the transfer on the remaining circuit is reduced to within the continuous rating of the circuit, automatic generation rejection would need to be initiated at both the TransAlta Project and the Imperial Oil Project.

Imperial Oil would therefore be required to install a generation rejection scheme to respond to contingencies involving the 230kV circuits N6S or N7S.

In addition it may be necessary to make provision for the future incorporation of generating capacity at the Imperial Oil Complex into the existing Lambton Generation Rejection Scheme.
(This is to be examined in the System Impact Assessment.)

Impact on Fault Levels

Since fault level analysis had previously been performed for the 230kV-connection option with two generating units in-service, and as the fault contribution to the 230kV system with only a single unit incorporated at 27.6kV would be substantially lower, it was decided not to repeat the studies.

Should Imperial Oil decide to proceed with the 27.6kV-connection option then together with the other Projects in the cluster, a comprehensive review of the fault levels in the area will be performed as part of the System Impact Assessment.

Impact on Transfer Capabilities

While the new generating facilities would increase congestion within the area as a result of displacing load at the Imperial Oil Complex, they will not, *in isolation*, result in any reduction in the existing operating limits or transfer capabilities.

Transient Stability

The transient stability studies that were performed for a number of normally-cleared and delayed-clearance fault conditions showed that, subject to the breaker failure scheme on the 27.6kV facilities at the Imperial Oil Complex having a maximum delay limited to 150 milliseconds, the generating unit would be expected to remain stable. For a delay of 300 milliseconds, the unit was shown to lose synchronism.

Preliminary Assessment Report for the Imperial Oil Project in Sarnia: 27.6kV Incorporation Option

1. Introduction

The Imperial Oil Complex in Sarnia is currently supplied via St. Andrews 115/27.6kV TS as well as by the single DESN station at the Complex that consists of the two 230/27.6kV step-down transformer T3 & T4. Imperial Oil is currently in the process of establishing a second DESN station, and this is to consist of the existing 'switchable-spare' step-down transformer, T2, and a new 230/27.6kV step-down transformer, T1. The scheduled in-service date for the new DESN is July 2002.

Imperial Oil has submitted a proposal to install a single 112MVA gas-turbine generating unit which would be incorporated at 27.6kV into Substation 2A that is to be supplied from their new DESN station. The proposed in-service date for this new generating unit is 3rd Quarter of 2004.

Imperial Oil has also indicated that they may consider installing a second generating unit, and that this would be incorporated into Substation 2B that is supplied from their existing DESN station. Should Imperial Oil decide to proceed with the installation of the second generating unit, then its expected in-service date would be during the 4th Quarter of 2007.

This Connection Assessment addresses only the incorporation of the first generating unit.

Note: This Report should be read in conjunction with the Preliminary Assessment Report for the 230kV Incorporation Option.

2. Connection Arrangement

Diagram 1 shows the proposed arrangement of both the existing and the planned DESN stations at the Imperial Oil Complex, as well as the proposed incorporation arrangement for the first new generating unit.

The existing DESN station is located close to the termination of the 230kV circuits N6S & N7S (formally circuit L23N) at the Imperial Oil complex. Two 27.6kV overhead lines currently connect Substation 2A to the 27.6kV busbar at the existing DESN station. These two lines, which are approximately 3000 feet in length and are equipped with twin 795kcmil conductors, are to be reterminated on to the 27.6kV busbar at the new DESN station so that it will become the supply point for Substation 2A.

The connection from Substation 2A to the 27.6/13.8kV step-up transformer for the new generator is to be via a single 27.6kV underground circuit consisting of twin 1500kcmil cables per phase. The approximate length of the underground circuit will be 600 metres.

Synchronising of the new generating unit is to be via a 13.8kV circuit breaker. The step-up transformer is to be connected directly to the cable connection to Substation 2A where it is to be terminated on to a new switched-position rated at 3000amp and 1500MVA.

The incorporation circuit from the new generating unit is to be terminated on to both sides of the 27.6kV busbar at Substation 2A through separate 27.6kV circuit breakers. Although the 27.6kV busbar at Substation 2A is to be operated normally-closed, this arrangement is intended to allow the new generating unit to be connected to either half of the 27.6kV busbar, whenever this busbar needs to be operated 'split'.

3. Comments on the Connection Arrangement

Faults associated with the new generating unit, which are not cleared by the 13.8kV synchronising breaker, are to be cleared via a breaker-failure scheme. This will trip the two breakers associated with the 27.6kV incorporation circuit at Substation 2A. These breakers will also be utilised for isolating faults on either the generator step-up transformer or the cabled circuit. Should either of these breakers malfunction, then the breaker-failure scheme will initiate clearance of the fault by tripping the breakers associated with the particular half of the 27.6kV busbar at Substation 2A that is associated with the breaker that has malfunctioned.

Isolation of any faults associated with the generator; its step-up transformer; or its incorporation circuit will therefore be confined to the 27.6kV switching facilities at the Imperial Oil Complex. The absence of any 230kV circuit breakers as part of this proposal is therefore considered to be acceptable.

However, should Imperial Oil require to be able to isolate from the main system and operate as an island, then a 230kV breaker would need to be installed in circuits N6S & N7S at the terminal point of each circuit to the Imperial Oil Complex.

Loads at the Imperial Oil Complex

Once the new DESN station has been placed in-service at the Imperial Oil Complex there would be sufficient capacity to allow those loads that are currently supplied from the 115/27.6kV St. Andrews TS to be transferred to the new facilities. With all of the load at the Imperial Oil Complex supplied via the two DESN stations, the respective peak loadings are expected to be 74MVA on the existing T1/T2 transformer combination, and 65MVA on the new T3/T4 combination.

Consequently, when the new generating unit is operating at its rated output of 85.4MW and with the load on the T1/T2 DESN station at its forecast peak value, there would be a net transfer of approximately 19MW through the two step-down transformers. Even for the most extreme condition, with zero load at the T1/T2 DESN and with one of the step-down transformers out-of-service, the transfer through the remaining transformer, with the generator operating at full output, would remain within the rating of the transformer.

27.6kV Connection Facilities

For the extreme operating condition with *no load* on Substation 2A, both of the 27.6kV feeders M1 & M2 would need to be in-service to carry the peak output of the new generating unit. For this condition the maximum current, corresponding to the peak output of 112MVA from the generating unit, which would flow through the 27.6kV connections would be approximately 2340 amps. This would exceed the continuous summertime rating of one of the twin-conductored 27.6kV feeders (at an ambient temperature of 30°C the continuous rating corresponding to a maximum conductor operating temperature of 93°C would be 1740 amps).

Alternatively, for the new generating unit to be able to operate at full output while one of the 27.6kV feeders is out-of-service, a minimum load of approximately 29MVA would need to be maintained at Substation 2A.

Step-up Transformer Impedance

The Market Rules (Appendix 4.2 - Reference 2) require that each generating facility should be capable of operating continuously at its full rated output within $\pm 5\%$ of the generating facility's terminal voltage.

This means that for a specific, selected voltage (a 'reference' system voltage) on the IMO-controlled grid, it must be possible to vary the output of the generator (at its terminals) between 90% lagging and 95% leading power factor, while operating at full rated power, solely by adjusting the terminal voltage of the generator from 105% to 95%.

While the intent was for the 'reference' system voltage to be on the IMO-controlled grid at the 230kV or the 115kV terminals of the step-up transformer (as appropriate), this is currently not explicitly stated in the Market Rules.

If Imperial Oil were to be classified as a transmitter then the IMO-controlled grid would extend to the 27.6kV feeder breakers at the Imperial Oil DESN stations. However, since Imperial Oil is currently classified as a Connected Wholesale Customer, the IMO-controlled grid only extends to the terminations of the 230kV circuits N6S & N7S at the Imperial Oil Complex.

In order to comply with the requirements of Market Rule (Appendix 4.2 - Reference 2) the total impedance between the generator terminals and the IMO-controlled grid should not exceed approximately 13% (on 100MVA_{base}). However this would be impossible to achieve with the 21.5% impedance (on 80MVA) of the two step-down transformers at the DESN station.

For the purpose of applying Market Rule (Appendix 4.2 - Reference 2) it is therefore proposed to treat the Imperial Oil connection in the same manner as though Imperial Oil were a transmitter and to assume that the IMO-controlled grid extends to the 27.6kV breakers at the Imperial Oil DESN station.

From the impedance values provided by Imperial Oil, the total impedance to the 27.6kV busbar at the Imperial Oil DESN station would be approximately 13.9% (12% for the transformer; 0.5% for the cabled circuit to Substation 2A; & 1.4% for the two overhead circuits connected in parallel between Substation 2A and the new DESN Station). Therefore, in order to comply with the Market Rules, the impedance of the step-up transformer would need to be limited to a maximum value of approximately 11.0% on 100MVA_{base}.

4. Ability of the Transmission System to Accommodate Excess Output from the Imperial Oil Facility

Once the remedial work has been completed at the Bayer Junction tap, the two 230kV circuits, N6S & N7S, will only be capable of accommodating excess output from the Imperial Oil facility during periods when the TransAlta Project is not fully dispatched and/or when ambient conditions result in improved thermal ratings.

This aspect has been dealt with in the Preliminary Assessment Report for the 230kV Incorporation Option.

However, if there are ever going to be occasions when the Imperial Oil Project is expected to transfer surplus output to the IMO-controlled grid, then it will be an IMO requirement for the connection of this Project that a generation rejection scheme be installed to initiate rejection of generating capacity at the Imperial Oil facility for contingencies involving either circuit N6S or N7S.

In addition, in order to be able to maintain the transfer capability of the Ontario-Michigan Interface once it has been reconfigured to allow it to be operated 'split', it may become a requirement for connection for capacity at the Imperial Oil Complex to be incorporated into the Lambton Generation Rejection Scheme.

It is proposed to examine these related issues in the System Impact Assessment.

5. Voltage Response under Contingency Conditions

While it is not of direct concern to the IMO, since there will be no other customers other than Imperial Oil that will be supplied from the 27.6kV busbars at the two DESN stations, a limited number of studies were performed to determine the maximum voltage variation that could be experienced at that busbar.

The most onerous condition, with respect to the maximum voltage variation that was recorded, involved a contingency on one of the 230kV circuits, N6S or N7S, with the Imperial Oil generator assumed to be exporting to the system.

This contingency condition would result in the loss of the associated transformer at each of the two DESN stations and, on the assumption that the post-contingency output from the TransAlta Project would result in the companion 230kV circuit being fully loaded, would require that the generating unit at the Imperial Oil Complex be rejected. In addition it was assumed that the TransAlta facility would be operating at maximum output, pre-contingency, and that two generating units at that facility would therefore have to be rejected.

For this situation, with assumed loads of 40MVA at Substation 2A and 20MVA at Substation 2B, the voltage decline that was recorded was approximately 4.6%, which is within the IMO's criterion of 10%.

6. Data Supplied

Diagrams 2 & 3, together with the Table below, show the data that were provided/assumed for the transient stability analysis.

Imperial Oil will be responsible for ensuring that the equipment that is eventually installed meets or exceeds the values that have been assumed in the analysis.

Generator Parameters			
X_d	2.241	T'_{do}	5.375
X_q	2.2	T''_{do}	0.022
X'_d	0.320	T'_{qo}	0.459
X'_q	0.6	T''_{qo}	0.045
X''_d	0.165	S (1.0)	0.13
X_1	0.15	S (1.2)	0.43
X_2	0.158	H	5.588 kWsec/kVA
X_0	0.128	D	0.0

Note: The shaded cells show the data that were assumed.

7. Fault Level Analysis

Fault level analysis had previously been performed for the 230kV Incorporation Option, with two new generating units assumed to be in-service at the Imperial Oil Complex. The results of this analysis are contained in the Preliminary Assessment Report for the 230kV Option.

This analysis also assumed that the four generating projects in the initial Sarnia-Windsor cluster were in-service, together with additional generating capacity on the Detroit Edison Company System in the St. Clair area, and that the proposed reconfiguration of the 230kV busbar at Lambton TGS had been completed to allow it to be operated permanently 'split'.

This earlier fault level analysis had shown that the additional generation capacity proposed under the 230kV Incorporation Option, *in isolation*, would not increase the fault levels sufficiently to cause the fault interrupting capability of any of the existing circuit breakers to be exceeded. Since a single generating unit, incorporated at 27.6kV would have even less impact, it was decided not to undertake additional fault level studies for this option.

Once a decision has been taken by Imperial Oil to proceed with either the 230kV or the 27.6kV Incorporation Option, then a comprehensive review of the fault levels in the area will be undertaken as part of the System Impact Assessment.

While incorporating new generation via the 27.6kV system at the Imperial Oil Complex would have less of an impact on the fault levels on the 230kV and the 115kV busbars in the area than the option involving incorporation at 230kV, it would be a major contributor to the fault levels on the Imperial Oil 27.6kV system. Should Imperial Oil decide to proceed with the 27.6kV option then the impact of incorporating new generating capacity on the existing switchgear at Substation 2A would need to be examined.

8. Transient Stability Analysis

Transient stability analysis was performed for faults at various locations on the system, for both the normal loading condition and with light loads at the Imperial Oil Complex.

Both three-phase faults, with clearance occurring within normal time intervals, and line-to-line-to-ground faults with delayed clearance were examined.

Diagrams 4 to 10 show the results for a selected number of representative studies, as detailed below:

<i>Diagram No.</i>	<i>Fault Type</i>	<i>Location</i>	<i>Clearance Times</i>
<i>Summer Peak Load Condition</i>			
4	Three-Phase	Termination of 230kV circuit N7S at Scott TS	Normal
5	Three-Phase	The 27.6kV busbar at Imperial Oil: associated with circuit N7S	Normal
6	Line-Line-Ground	230kV circuit N7S at Scott TS: with failure of 27.6kV breaker at Imperial Oil	Delayed: 150 milliseconds
10			Delayed: 300 milliseconds
<i>Light-Load Condition</i>			
7	Three-Phase	Termination of 230kV circuit N7S at Scott TS	Normal
8	Three-Phase	The 27.6kV busbar at Imperial Oil: associated with circuit N7S	Normal
9	Line-Line-Ground	230kV circuit N7S at Scott TS: with failure of 27.6kV breaker at Imperial Oil	Delayed: 150 milliseconds

Diagrams 4 & 7; 5 & 8; and 6 & 9 are directly comparable, with the first Diagram of each pair representing the peak-load condition, while the second Diagram shows the results for the light-load condition.

Diagrams 4 & 7; and 5 & 8 are for three-phase faults, cleared in normal time, and the results show that stability was maintained with a positively damped response. The principal differences between the peak and light load conditions for these cases are the increased swing in the rotor angle ($\approx 5^\circ$) and the increase in magnitude of the transient over-voltage ($\approx 2\%$).

Diagrams 6 & 9 are for line-to-line-to-ground faults, with delayed clearance due to a breaker failure condition. The fault condition assumed considered a fault at Scott TS on the terminal of circuit N7S, and normally this would be cleared at the remote end via the 27.6kV breakers associated with transformers T2 & T4. However, the 27.6kV breaker associated with transformer T2 was assumed to malfunction, resulting in the fault being cleared, after a time delay, by the 27.6kV bus-section breaker and the M2 feeder breaker. The normal time delay for the breaker failure protection at DESN stations is 300 milliseconds. However, as shown in Diagram 10, this condition resulted in instability of the generating unit. With an assumed time delay of 150 milliseconds, the results show that stability would be maintained with a positively damped response. Again, the principal differences between the peak load and the light load conditions are the increased swing in the rotor angle and the increased transient over-voltage.

As mentioned previously, Diagram 10 shows that instability of the Imperial Oil unit would result from a 300-millisecond time delay in the breaker-failure protection. All the other generating units that were monitored remain stable. Furthermore, the situation would be expected to be worse for the light-load condition.

The results indicate that the generating unit would be expected to remain stable for all of the fault conditions examined as long as the delay in the 27.6kV breaker failure scheme is kept to a maximum of 150 milliseconds.

Restricting this time delay to 150 milliseconds (maximum) would be a requirement for connection to the IMO-controlled grid should the 27.6kV Incorporation Option be adopted.

9. Impact on System Transfers

The effect of incorporating *two* new generating units at the Imperial Oil Complex has been dealt with in the Preliminary Assessment Report for the 230kV Incorporation Option. The conclusions were that these two units would increase congestion within the area as a result of displacing load at the Imperial Oil Complex, but that they would not, *in isolation*, result in any reduction in the existing operating limits or transfer capabilities.

Incorporating only a single new generating unit would reduce the extent of the congestion that would be expected to occur.

10. Conclusions

The Preliminary Assessment has examined the effect on the IMO-controlled grid of incorporating a single generating unit via one of the 27.6kV busbars at the Imperial Oil Complex in Sarnia, and the following conclusions have been reached:

- The proposed connection arrangement will have no adverse impact on reliability, as long as there are no net transfers to the system.
- If net transfers to the system are expected to occur, then the IMO will require a generation rejection scheme to be installed, to allow rejection of the generating unit to be initiated for contingencies involving either of the 230kV circuits N6S and N7S.

If circuits N6S & N7S were to be reconductored to increase their continuous ratings, then there could be a relaxation in the generation rejection requirements. In addition, this work could allow any restrictions on the amount of generating capacity that could be dispatched at the Imperial Oil Complex during light-load periods, to be relaxed.

- On the assumption that the Lambton 230kV busbar will be reconfigured and operated 'split', the new generating unit, *in isolation*, will not increase the fault levels at Sarnia-Scott TS sufficiently to require remedial action to be taken. However, Imperial Oil will need to consider the impact that the new generator will have on its own facilities.
- Transient stability analysis was performed for a number of normally-cleared and delayed-clearance fault conditions. This analysis showed that, subject to the breaker failure scheme on the 27.6kV facilities at the Imperial Oil Complex having a maximum delay limited to 150 milliseconds, the generating unit would be expected to remain stable. For a delay of 300 milliseconds, the unit was shown to lose synchronism.

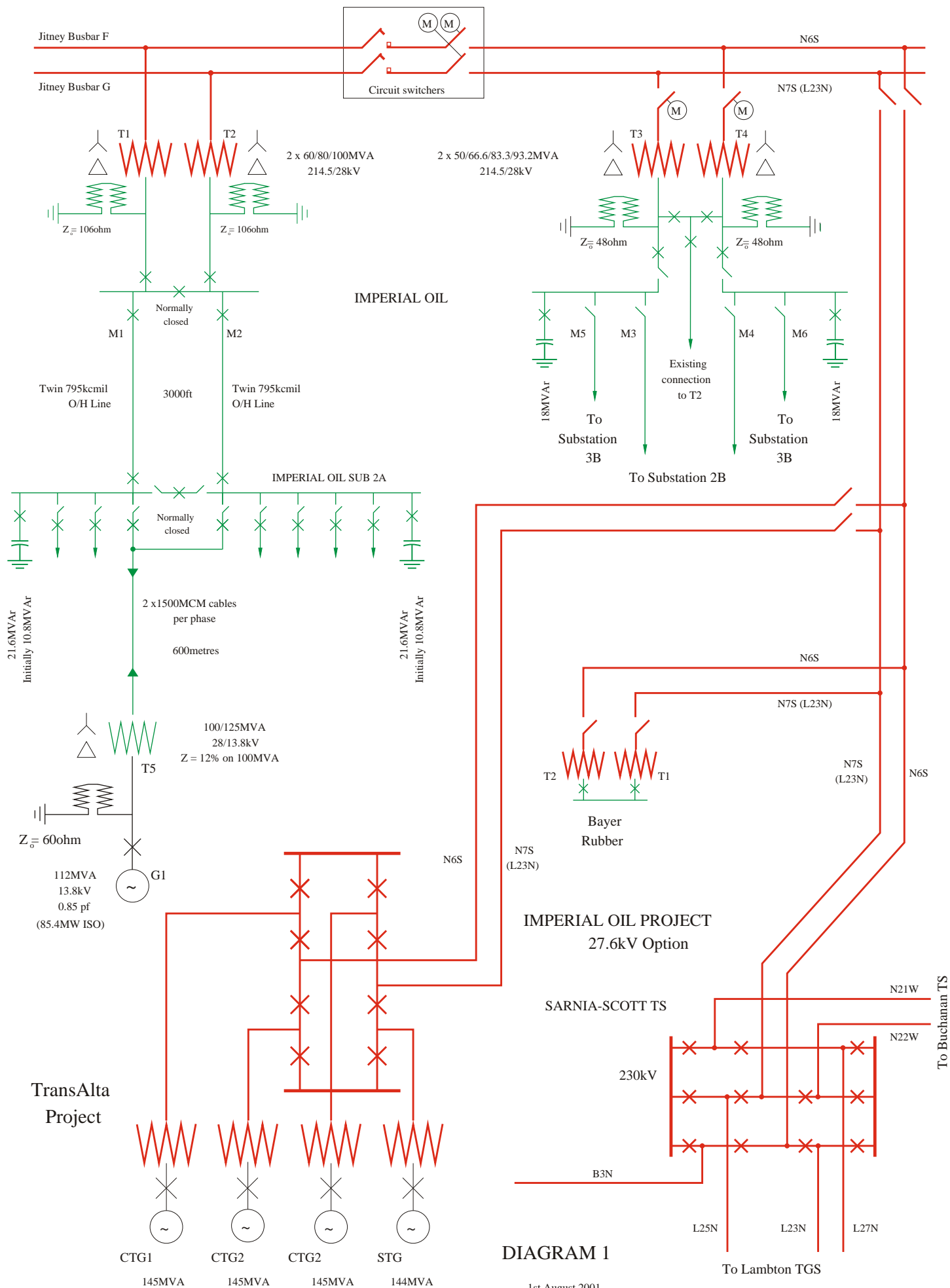
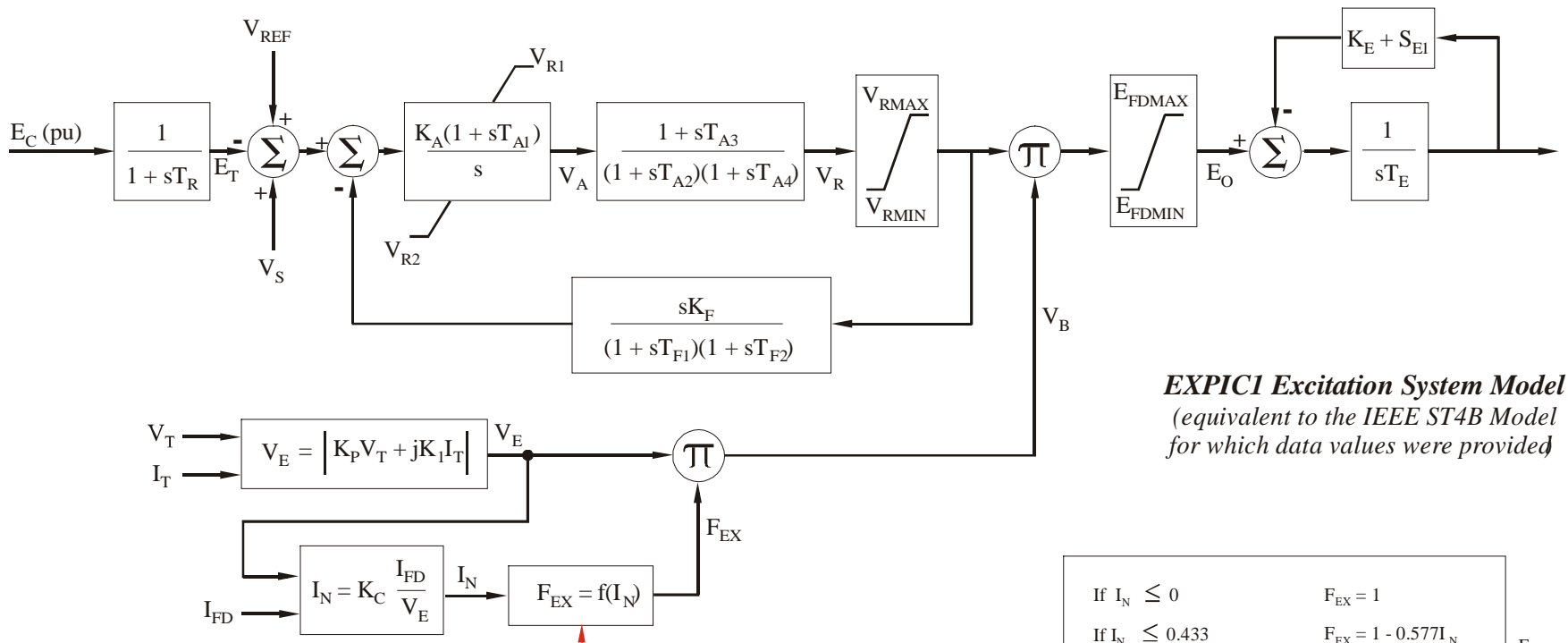


DIAGRAM 1

1st August 2001



EXPIC1 Excitation System Model
 (equivalent to the IEEE ST4B Model
 for which data values were provided)

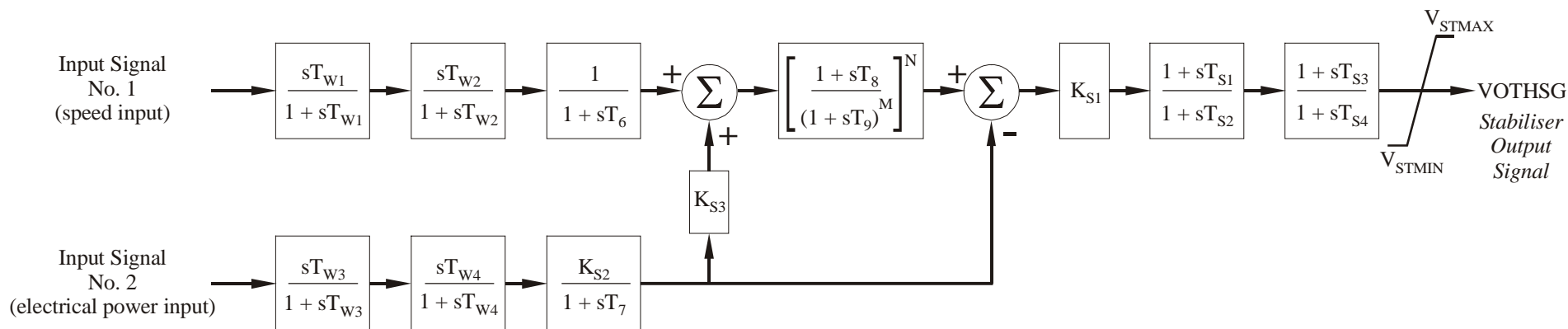
$I_N \leq 0$	$F_{EX} = 1$
$I_N \leq 0.433$	$F_{EX} = 1 - 0.577I_N$
$0.433 < I_N < 0.75$	$F_{EX} = \sqrt{(0.75 - I_N)^2}$
$I_N \geq 0.75$	$F_{EX} = 1.732(1 - I_N)$
$I_N \geq 1$	$F_{EX} = 0$

Values used in Transient Stability Analysis

E_1	0.0	T_{A1}	1.00 sec
E_2	0.0	T_{A2}	0.01 sec
K_1	0.0 (Potential Source)	T_{A3}	0.00 sec
K_A	20.0	T_{A4}	0.00 sec
K_C	0.81	$T_{F1} (> 0)$	1.00 sec
K_E	1.0	T_{F2}	0.00 sec
K_F	0.0	T_R	0.00 sec
K_P	4.67	V_{R1}	7.73
S_{E1}	0.0	V_{R2}	-7.73
S_{E2}	0.0	V_{RMAX}	7.73
T_E	0.0	V_{RMIN}	-7.73
		E_{FDMAX}	7.73
		E_{FDMIN}	-7.73

DIAGRAM 2

7th July 2001



**IEEE Dual-Input Stabiliser Model
(Typical EX2000 Power System Stabiliser)**

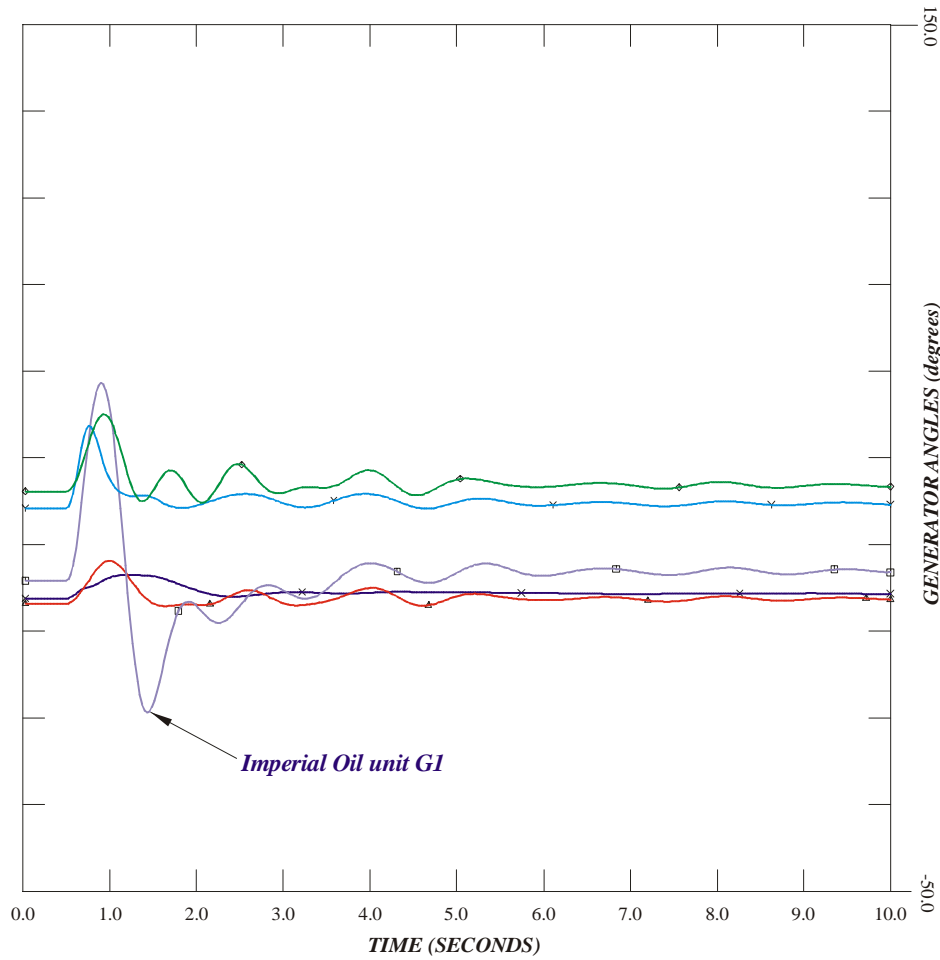
Values used in Transient Stability Analysis

ICS1	1 (rotor speed deviation pu)	T_1	0.15 sec
ICS2	3 (generator electrical power pu)	T_2	0.03 sec
REMBUS1	0	T_3	0.15 sec
REMBUS2	0	T_4	0.03 sec
M	5	T_6	0.00 sec
N	1	T_7	2.00 sec
K_{S1}	8	T_8	0.50 sec
K_{S2}	0.179	T_9	0.10 sec
K_{S3}	1.0	T_{W1}	2.00 sec
V_{STMAX}	0.1	T_{W2}	2.00 sec
V_{STMIN}	-0.1	T_{W3}	2.00 sec
		T_{W4}	0.00 sec

DIAGRAM 3

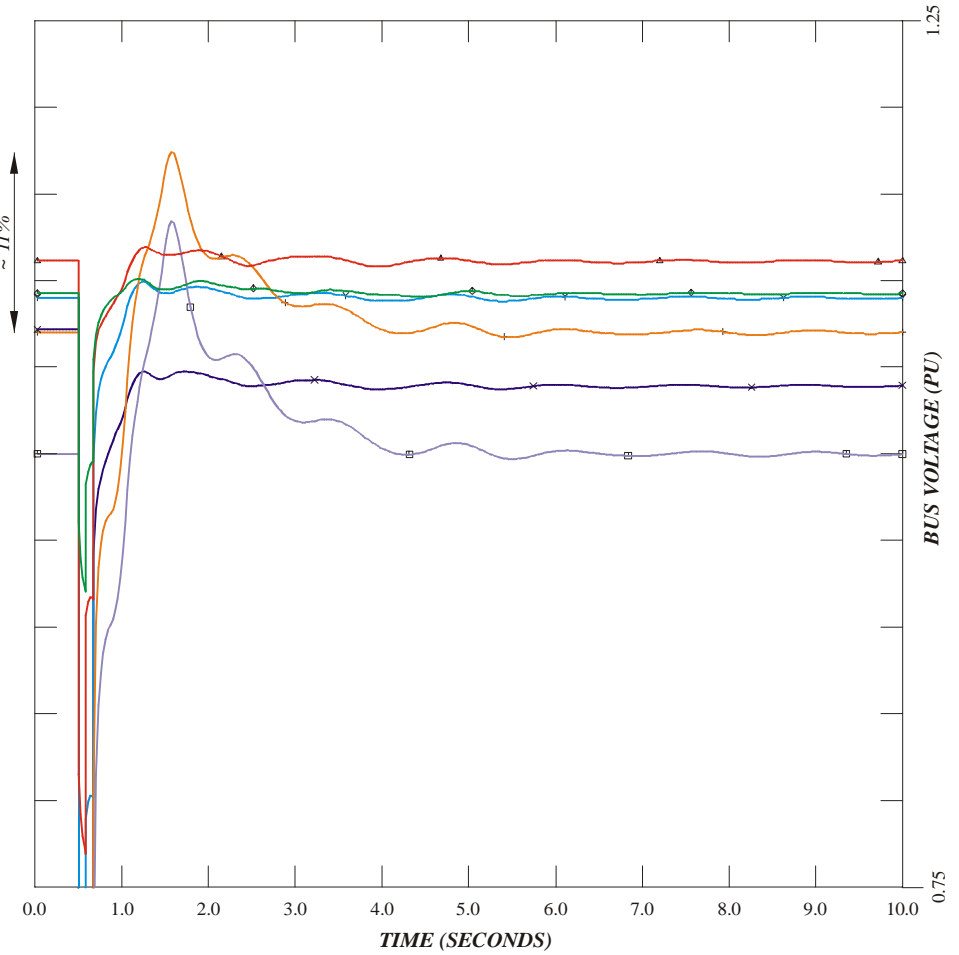
7th July 2001

THREE-PHASE FAULT on 230kV Circuit N7S at Scott TS: Tripped in normal time
Peak Summer Loads at Imperial Oil



GENERATOR ANGLES - degrees

- LAMBTON G2 >—>
- NANTICOKE G2 x—x
- AES G2 ◆—◆
- ATCO G2 <—<
- IMPERIAL-G1 □—□



BUS VOLTAGE - p.u

- LAMBTON 220kV >—>
- BAYER 13.8kV x—x
- IMPERIAL 27.6kV +—+
- KEITH 220kV ◆—◆
- CHATHAM 220kV <—<
- IMPERIAL-G1 □—□
- Generator Terminal Voltage

DIAGRAM 4

28th June 2001

THREE-PHASE FAULT on the 27.6kV busbar at Imperial Oil, associated 230kV Circuit N7S: Tripped in normal time
 Peak Summer Loads at Imperial Oil

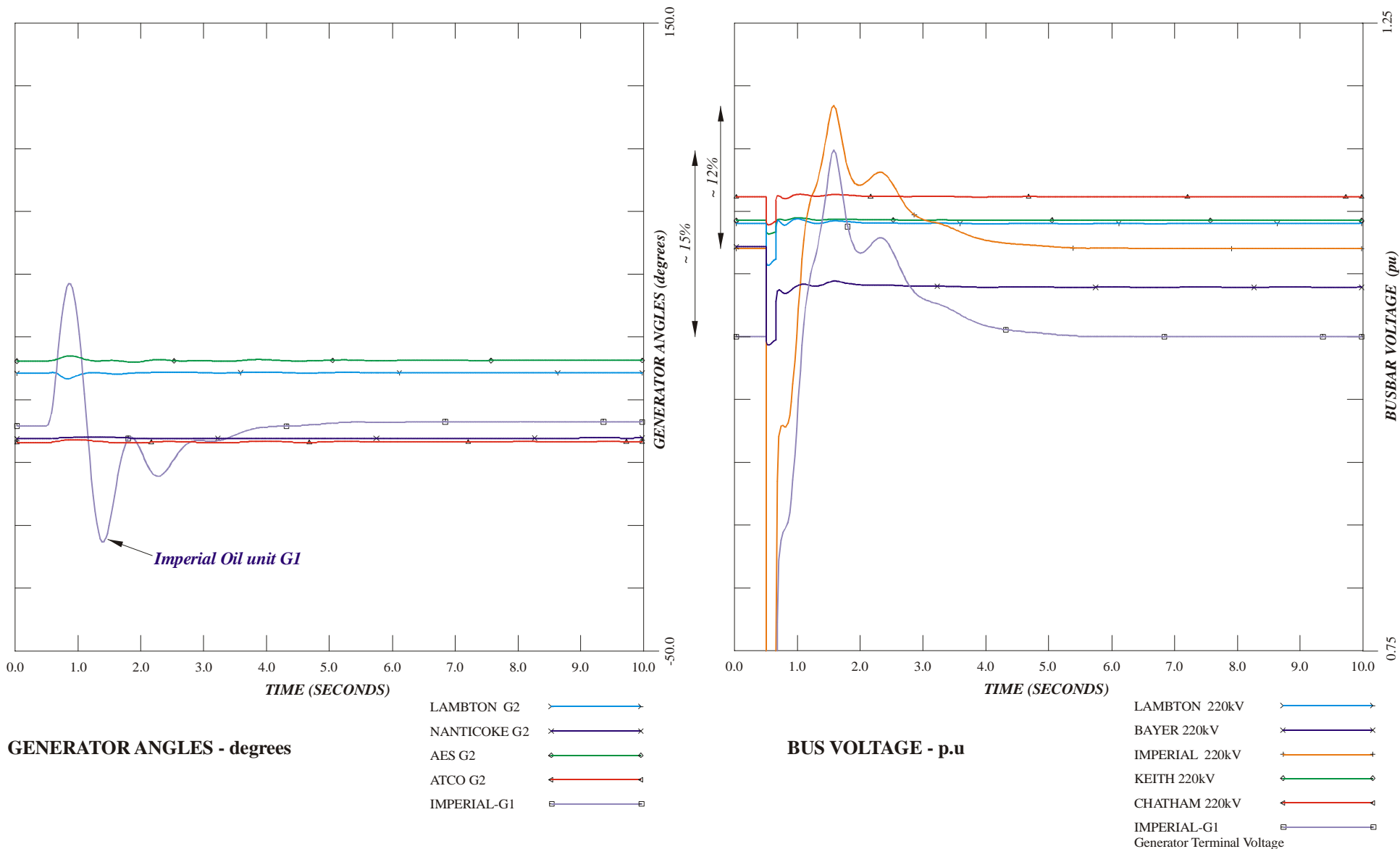
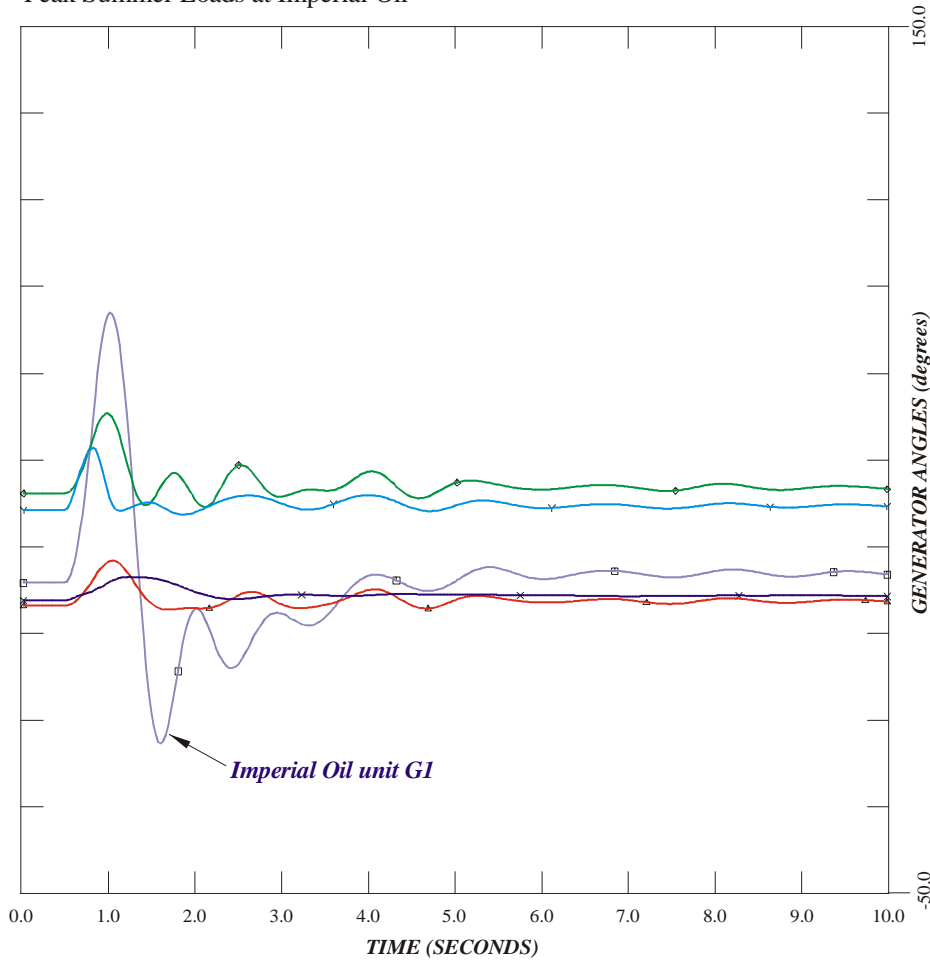


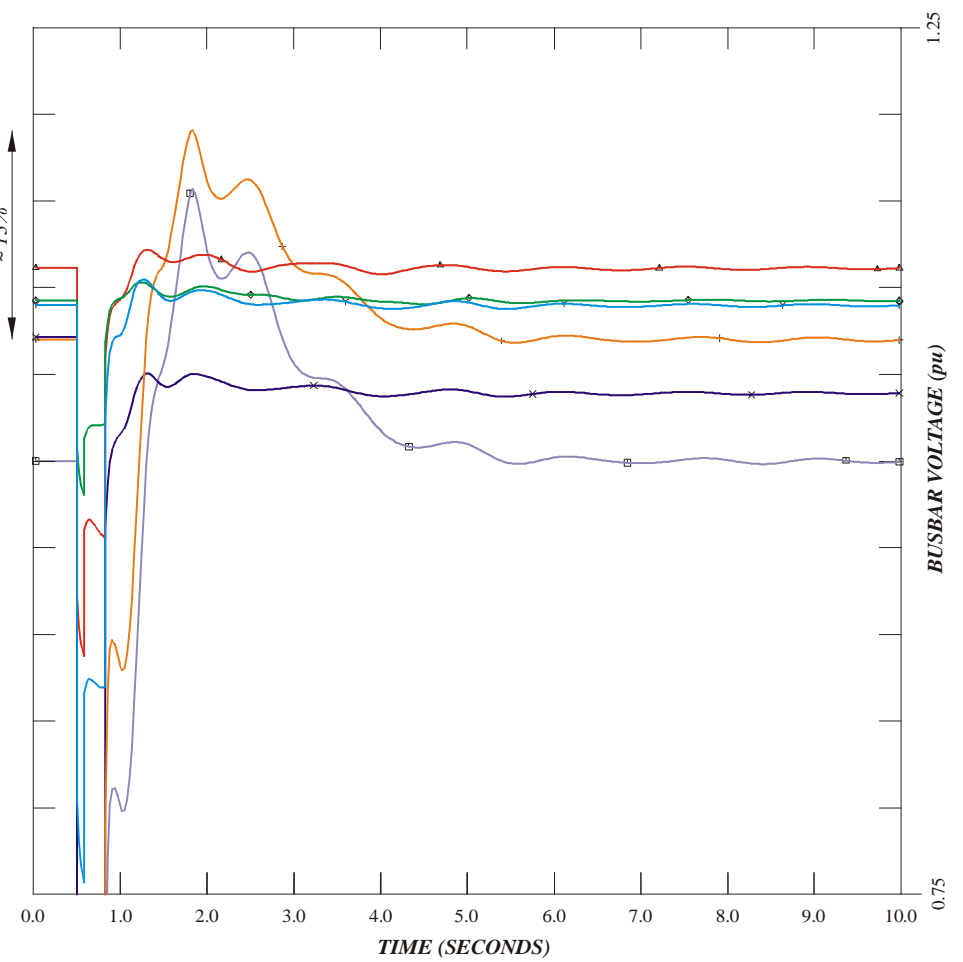
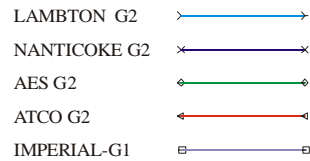
DIAGRAM 5

LINE-TO-LINE-GROUND FAULT on 230kV Circuit N7S at Scott TS: With breaker failure at Imperial Oil. Fault cleared with 150msec delay

Peak Summer Loads at Imperial Oil



GENERATOR ANGLES - degrees



BUS VOLTAGE - p.u

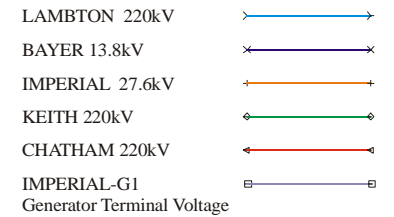
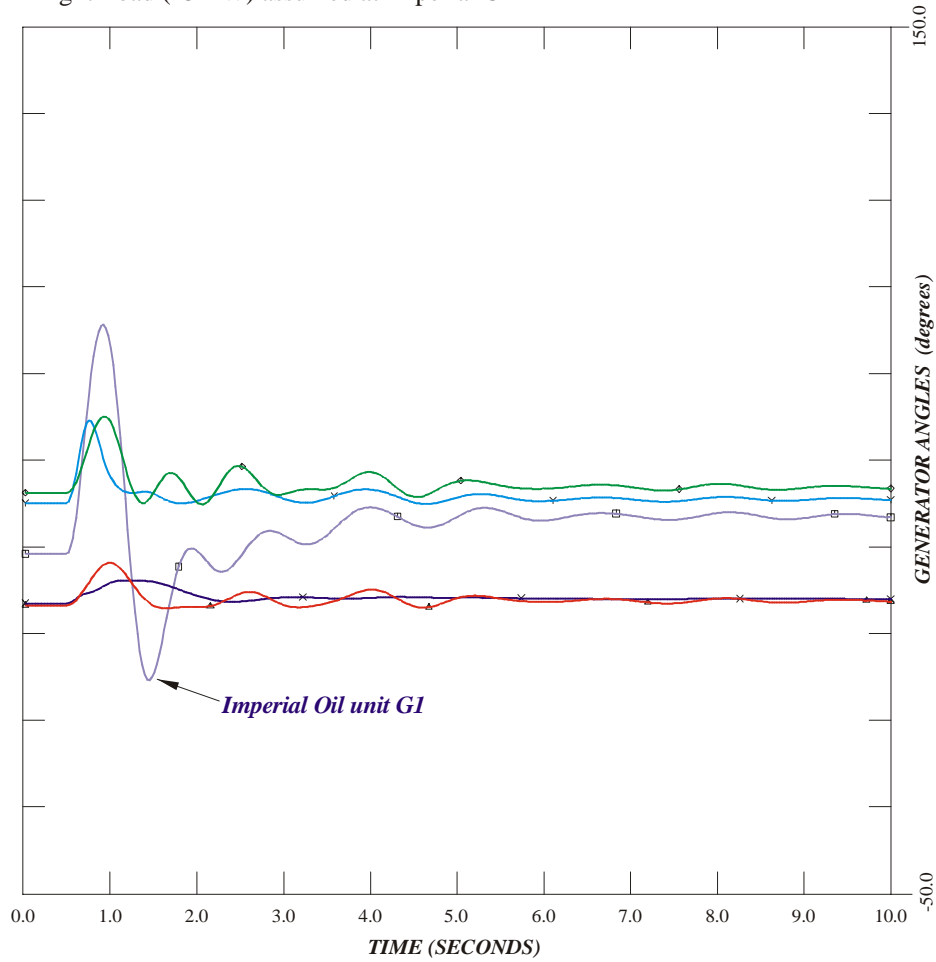


DIAGRAM 6

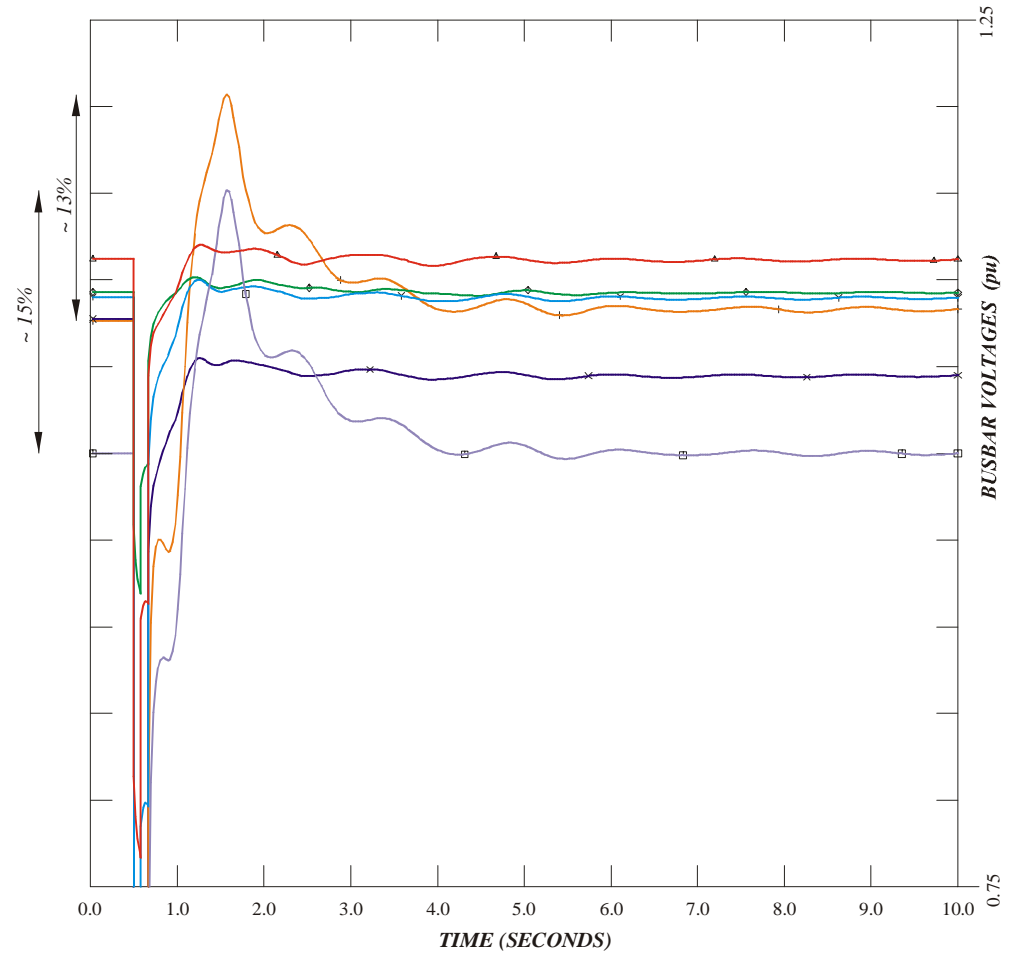
28th June 2001

THREE-PHASE FAULT on 230kV Circuit N7S at Scott TS: Tripped in normal time
 Light Load (15MW) assumed at Imperial Oil



GENERATOR ANGLES - degrees

- LAMBTON G2 >—>
- NANTICOKE G2 x—x
- AES G2 ◆—◆
- ATCO G2 ◀—▶
- IMPERIAL-G1 ◻—◻



BUS VOLTAGE - p.u

- LAMBTON 220kV >—>
- BAYER 13.8kV x—x
- IMPERIAL 27.6kV +—+
- KEITH 220kV ◆—◆
- CHATHAM 220kV ◀—▶
- IMPERIAL-G1 Generator Terminal Voltage ◻—◻

DIAGRAM 7

28th June 2001

THREE-PHASE FAULT on the 27.6kV busbar at Imperial Oil, associated 230kV Circuit N7S: Tripped in normal time

Light Load (15MW) assumed at Imperial Oil

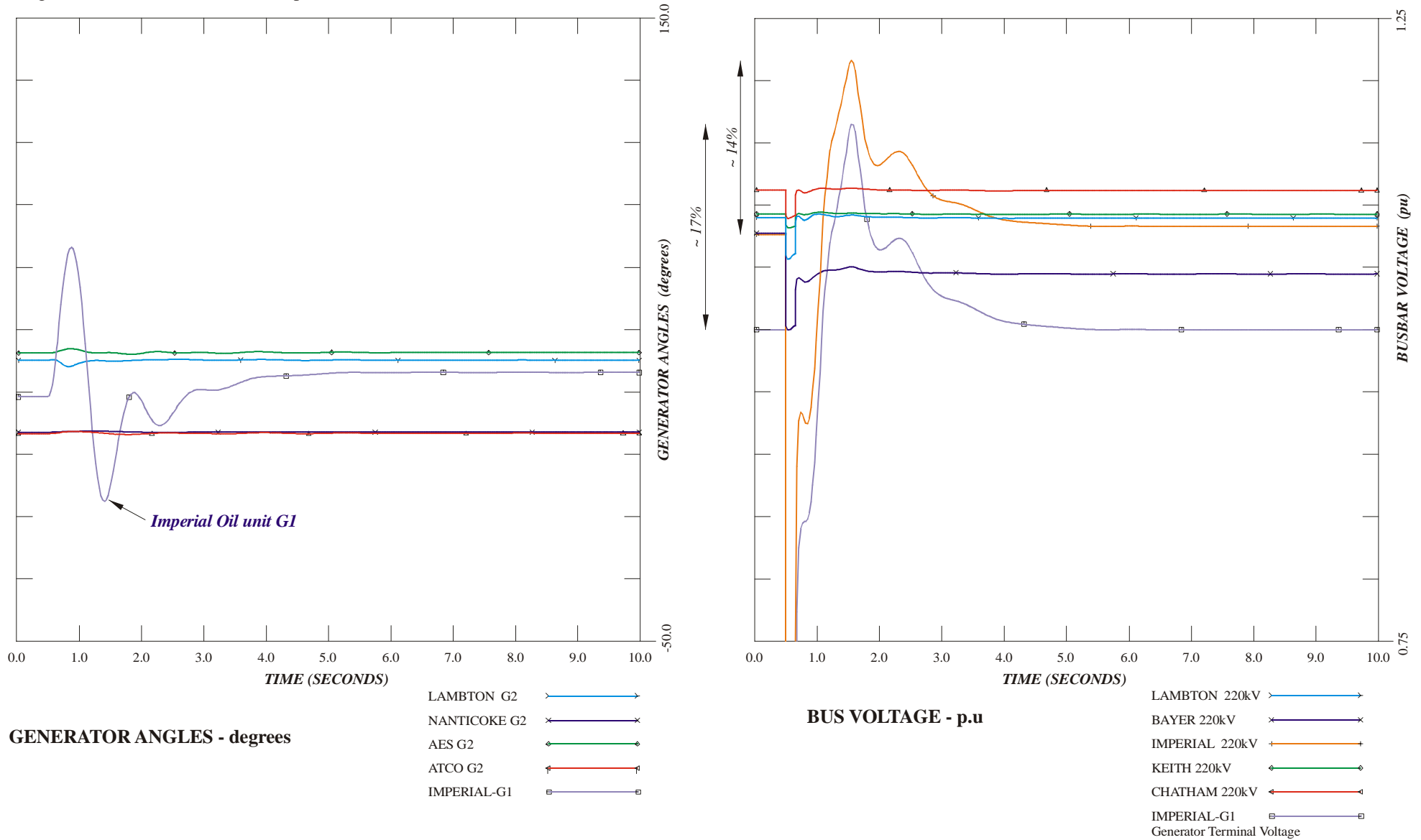
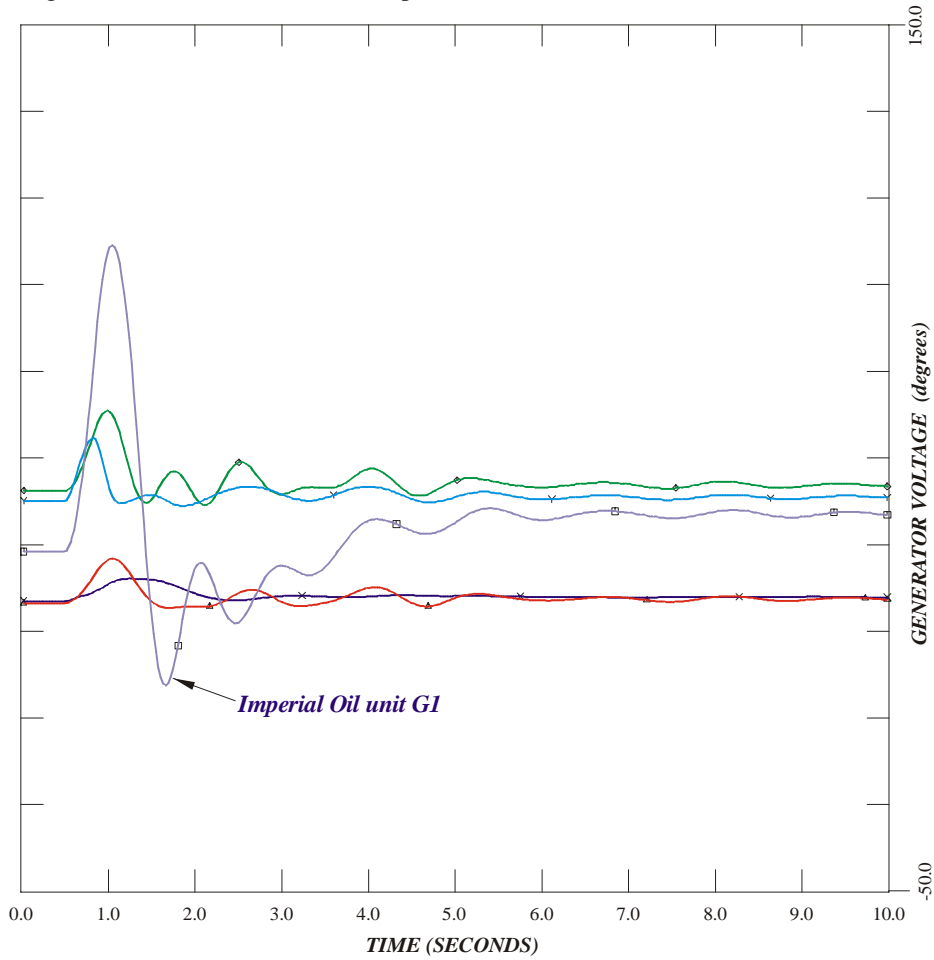


DIAGRAM 8

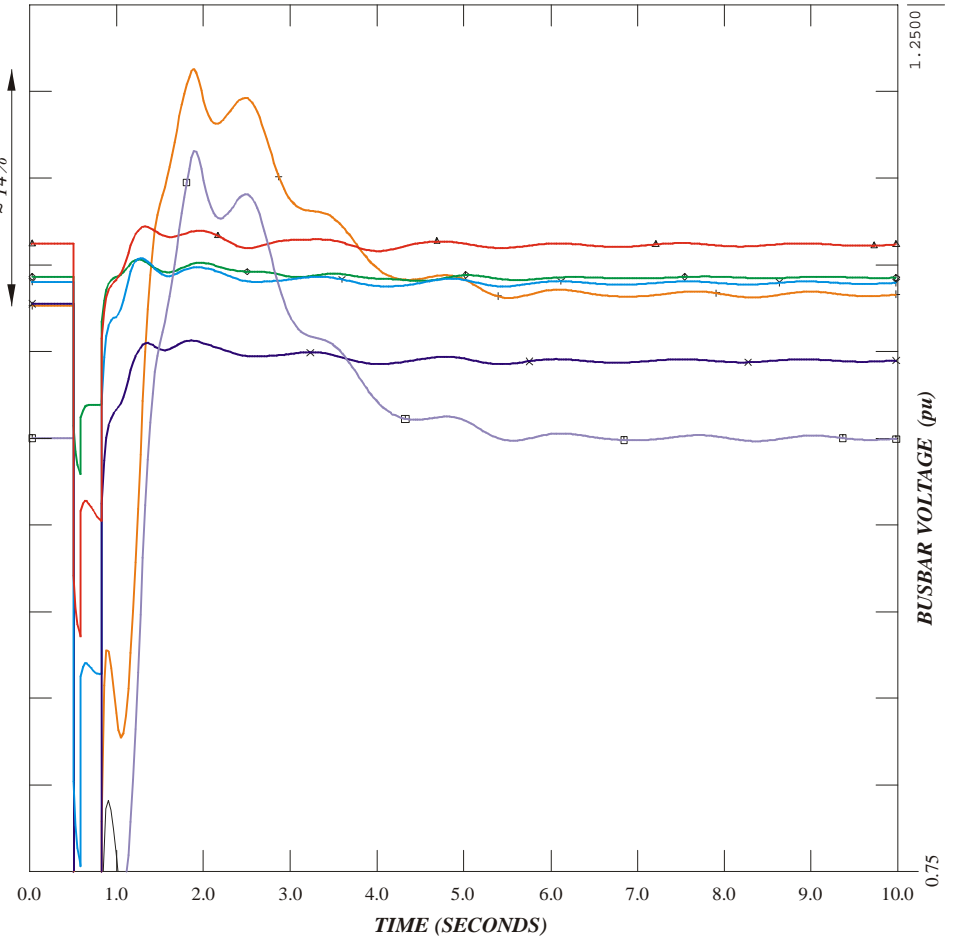
LINE-TO-LINE-GROUND FAULT on 230kV Circuit N7S at Scott TS: With breaker failure at Imperial Oil. Fault cleared with 150msec delay

Light Load (15MW) assumed at Imperial Oil



GENERATOR ANGLES - degrees

- LAMBTON G2 —>
- NANTICOKE G2 x
- AES G2 ◇
- ATCO G2 ◀
- IMPERIAL-G1 □



BUS VOLTAGE - p.u

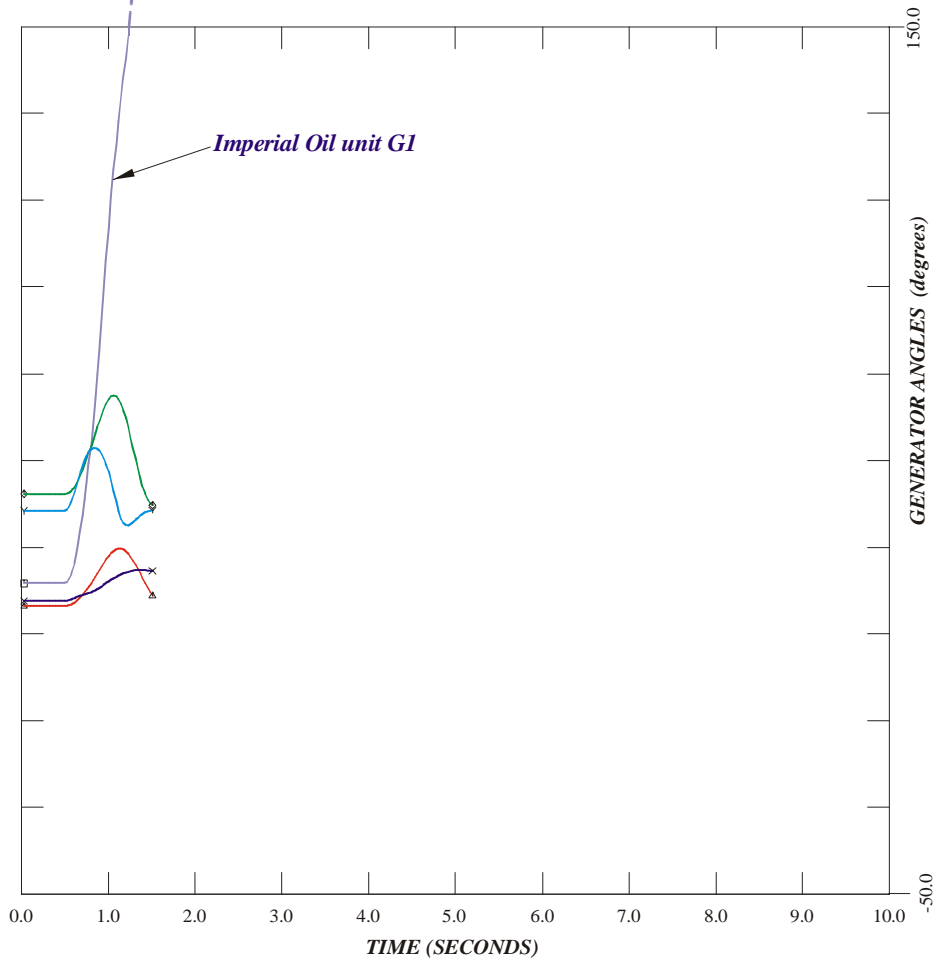
- LAMBTON 220kV —>
- BAYER 13.8kV x
- IMPERIAL 27.6kV +
- KEITH 220kV ◇
- CHATHAM 220kV ◀
- IMPERIAL-G1 □
- Generator Terminal Voltage

DIAGRAM 9

28th June 2001

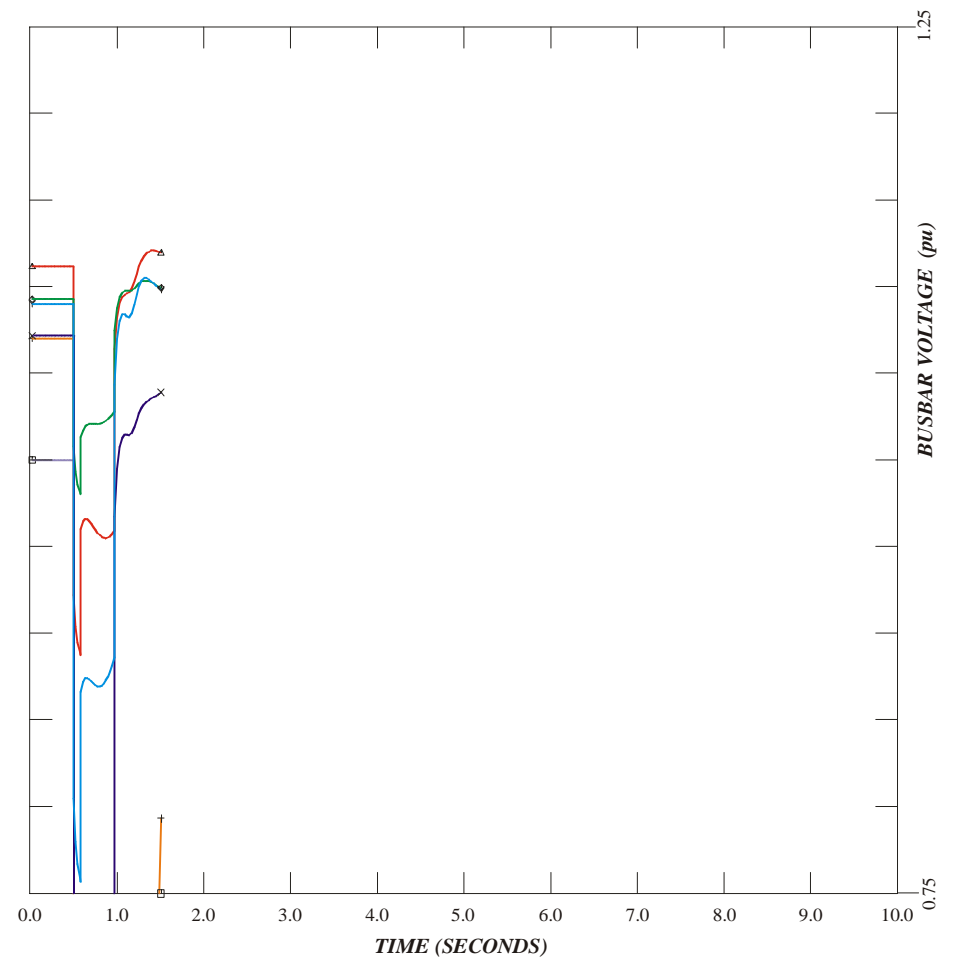
LINE-TO-LINE-GROUND FAULT on 230kV Circuit N7S at Scott TS: With breaker failure at Imperial Oil. Fault cleared with 300msec delay

Peak Summer Loads at Imperial Oil



GENERATOR ANGLES - degrees

- LAMBTON G2 —>
- NANTICOKE G2 —x
- AES G2 —>
- ATCO G2 —>
- IMPERIAL-G1 —□



BUS VOLTAGE - p.u

- LAMBTON 220kV —>
- BAYER 13.8kV —x
- IMPERIAL 27.6kV —+
- KEITH 220kV —>
- CHATHAM 220kV —>
- IMPERIAL-G1 Generator Terminal Voltage —□