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CONNECTION ASSESSMENT & APPROVAL PROCESS

PRELIMINARY ASSESSMENT REPORT

For the Proposed Supply to the Victor Mine Project
by De Beers Canada Exploration Inc.

CAA ID No. 2002-086

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

FINAL Version

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Preliminary Assessment Report

For the Proposed Supply to the Victor Mine Project

Acknowledgement

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

Disclaimers

IMO

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

Hydro One

Special Notes and Limitations of Study Results

The results reported in this preliminary assessment 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 ampacity ratings 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 Victor Mine Project

1. Introduction

De Beers Canada Exploration Inc. is proposing to develop the Victor Mine Project in north-eastern Ontario, located approximately 100km inland from Attawapiskat on James Bay.

Three proposals for supplying the new load are being considered:

- *The Generation Option:*

  Involving the construction of a new 115kV line, approximately 100km in length, which would be connected to the Attawapiskat terminal of the existing 270km Five Nations Energy Inc. line from Moosonee DS. Approximately 26MW of diesel generation capacity would be installed at the mine to supply the local load and these facilities would be operated in parallel with the existing 115kV transmission system via the new 115kV connection to the Five Nations Energy Inc. (FNEI) line between Moosonee DS and Attawapiskat.

  It has been assumed that a limited supply (nominally 5MW) would be available from the existing transmission facilities to supply part of the Victor Mine load.

- *The 115kV Option:*

  Involving the construction of a new 115kV line, approximately 515km in length, which would be connected to the Hydro One system at Otter Rapids GS. This line would run parallel to the existing Hydro One 115kV line C6R to Moosonee DS, and would then run parallel to the Five Nations Energy Inc. line to Attawapiskat. The final 100km to the mine site would follow a new route. Although the new line would run parallel to the existing transmission facilities for approximately 415km of its length, it would only be operated in parallel with the existing facilities under emergency conditions.

  Standby generation facilities that could be synchronised with the transmission system would be available at the mine for emergency supply.

- *The 230kV Option:*

  Involving the construction of a new 230kV line, approximately 145km in length, to extend the existing 230kV circuit R21D, between Pinard TS and Otter Rapids GS, through to Moosonee DS. A new 75MVA 230/115kV auto-transformer would be installed at Moosonee DS to interconnect the new 230kV line to the existing 115kV system. A new 115kV line, approximately 100km in length, would also be constructed from the Attawapiskat terminal of the existing 270km long Five Nations Energy Inc. line from Moosonee DS, to the mine site.

  Standby generation facilities that could be synchronised with the transmission system would be available at the mine for emergency supply.

Commissioning of the new transmission facilities is scheduled to commence in Q2-2006, with mine operations scheduled to begin in Q3-2006.

The forecast peak load at the mine is 27MW at a 0.9 power factor.

2. Existing Transmission and Generation Facilities

Diagram 1 shows the existing transmission and generation facilities in the area.

These are as follows:

Hydro One Transmission Facilities

115kV Facilities

A single-circuit 115kV line, C6R, approximately 180km in length, between Abitibi Canyon GS and Moosonee DS.

This line consists of two discrete sections:

Section 1, between Abitibi Canyon GS and Otter Rapids GS, is approximately 35km in length and is equipped with 477kcmil conductors, sagged for a maximum conductor operating temperature of 82^{o}C.

It has the following continuous thermal ratings for different ambient conditions:

Circuit C6R: Section 1		Abitibi Canyon GS to Otter Rapids GS	
Ambient Conditions		*Continuous Rating*	
30^{o}C	wind speed: 0 to 4km/hr	550A	~ 121MVA at 127kV
10^{o}C		660A	~ 145MVA at 127kV
0^{o}C		710A	~ 156MVA at 127kV

Section 2, between Otter Rapids GS and Moosonee DS, is approximately 144km in length and is equipped with 211.6kcmil conductors, sagged for a maximum conductor operating temperature of 60^{o}C.

It has the following continuous thermal ratings for different ambient conditions:

Circuit C6R: Section 2		Otter Rapids GS to Moosonee DS		
Ambient Conditions		*Continuous Rating*		
30^{o}C	wind speed: 0 to 4km/hr	260A	~ 57MVA at 127kV	~ 54MVA at 120kV
10^{o}C		320A	~ 70MVA at 127kV	~ 66MVA at 120kV
0^{o}C		360A	~ 79MVA at 127kV	~ 75MVA at 120kV

230kV Facilities

A single-circuit 230kV line, R21D, approximately 38km in length, between Pinard TS and Otter Rapids GS.

This line is equipped with 1277.5kcmil conductors and has a continuous thermal rating of 1140A (~ 474MVA at 240kV) at an ambient temperature of 30^{o}C and with a wind speed of 0 to 4km/hr.

Five Nations Energy Incorporated (FNEI) Facilities

115kV Facilities

The New Moosonee Substation is located directly adjacent to Moosonee DS and is connected to it through an extension of the original 115kV busbar. Two 115kV circuit breakers and a motorised disconnect switch, all connected in series, provide the isolation between the FNEI facilities and the Hydro One system. A 6.5MVAr shunt reactor (rated at 138kV), connected through a 115kV circuit-switcher, is terminated on to the mid-point between the two 115kV circuit breakers at the New Moosonee Substation.

A single-circuit 115kV line, M3K, approximately 270km in length, connects the New Moosonee Substation to Attawapiskat Substation via intermediate substations located at Fort Albany and Kashechewan.

This line therefore consists of three discrete sections:

Section 1, between the New Moosonee Substation and Fort Albany Substation, is approximately 159km in length.

Section 2, between Fort Albany Substation and Kashechewan Substation, is approximately 11km in length, and is switched with Section 1.

Two 3.4MVAr shunt reactors (rated at 138kV) are connected via circuit switchers directly to the 115kV busbar at Fort Albany S/S so that they are energised with Sections 1 & 2 of the FNEI line.

Section 3, between Kashechewan Substation and Attawapiskat Substation, is approximately 100km in length, and is switched separately by a circuit breaker at Kashechewan S/S.

A 2.5MVAr shunt reactor (rated at 138kV) is connected via a circuit switcher directly to the 115kV busbar at Kashechewan S/S so that it is energised with Section 3 of the FNEI line.

Circuit M3K is equipped with 211.6kcmil conductors and has a continuous thermal rating of 355A (~78MVA at 127kV) at an ambient temperature of 25^{o}C and with a wind speed of 0 to 4km/hr.

OPG Generating Facilities

Abitibi Canyon GS

OPG has five 70MVA hydroelectric generating units installed at Abitibi Canyon GS; three of which are incorporated into the 230kV system via the 230kV circuit R21D to Pinard TS, while the remaining two units are incorporated into the 115kV system via the twinned 115kV circuits C2H and C3H to Hunta SS.

Although the IMO is not aware of any current plans, a proposal to reconnect the two 115kV-connected generating units to the 230kV system was under consideration in 1995 when the G1 unit at Abitibi Canyon GS was converted from 25Hz to 60Hz operation.

Otter Rapids GS

OPG has four 52MVA hydroelectric generating units installed at Otter Rapids and all four units are normally incorporated into the 230kV system via the 230kV circuit R21D to Pinard TS.

Provisions exists to change the tap on the high voltage winding of step-up transformer T1 so that it can be transferred, together with the associated generating units G1 & G2, from the 230kV busbar to the 115kV busbar at Otter Rapids GS.

3. Details of the Development Proposals

As originally submitted, the facilities that it is proposed to install for each of the three development options, were as follows:

3.1 Generation Option

Diagram 2 shows the new facilities that it is proposed to install for this Option.

They include a new 100km 115kV line, equipped with 336.4kcmil conductors, from Attawapiskat S/S to the Victor Mine. The new line is to be terminated through a single 115kV breaker and motorised line disconnect switch on to the existing 115kV busbar at Attawapiskat S/S.

At the Victor Mine terminal, the line is to be connected through a manual 115kV line disconnect switch on to a local 115kV busbar, to which is to be connected a single 6.7MVA 115/13.8kV step-down transformer equipped with an under-load tap-changer. This transformer has been rated to accommodate a nominal 5MW supply from the existing transmission facilities.

A variable 8MVAr shunt reactor, equipped with an under-load tap-changer, is also to be connected to the 115kV busbar at the Victor Mine through a circuit-switcher.

It is proposed to connect six or seven 5.5MVA (4.4MW) diesel generating units to the 13.8kV busbar to supply most of the load at the mine, with the remainder of the mine's requirements being supplied from the existing 115kV system.

A breaker-failure condition involving the new 115kV breaker at Attawapiskat TS will be required to initiate a transfer-trip signal to open the 115kV breaker CB2 at Kashechewan S/S.

3.2 115kV Transmission Option

Diagram 3 shows the new facilities that it is proposed to install for this Option.

They include a new 515km 115kV line, equipped with 1192.5kcmil conductors, from Otter Rapids GS to the Victor Mine. The new line is to be routed along the same right-of way as the existing 115kV Hydro One line, C6R, to Moosonee DS, and along the same right-of-way as the existing 115kV FNEI line, M3K, from the New Moosonee S/S to Attawapiskat S/S.

The new 115kV line is to be terminated through a single 115kV circuit breaker and motorised line disconnect switch on to the existing 115kV busbar at Otter Rapids GS. A new 115kV breaker is also to be installed in circuit C6R at Otter Rapids GS so that contingencies involving circuit C6R can be separately isolated without affecting the new line to the Victor Mine.

At the Moosonee DS terminal, the new line is to be terminated through two, series-connected motorised disconnect switches on to the existing 115kV busbar. The new 115kV line to the Victor Mine is to be terminated through a 115kV breaker and an associated motorised line-disconnect switch on to the mid-point of these two disconnect switches.

This arrangement is intended to allow a limited supply to be provided to the Victor Mine via circuit C6R, in the event of an outage involving the section of the new 115kV line between Otter Rapids GS and Moosonee DS.

At the Victor Mine terminal, the line is to be connected through a manual 115kV line disconnect switch on to a local 115kV busbar, to which is to be connected two 30MVA 115/13.8kV step-down transformers equipped with under-load tap-changers.   A variable 24MVAr shunt reactor, equipped with an under-load tap-changer, is also to be connected to the 115kV busbar through a circuit-switcher.

Two ± 10MVAr SVCs are to be connected to the 13.8kV busbar to provide 'dynamic' reactive compensation in response to variations in the load and during contingencies. Three 5.5MVA (4.4MW) diesel generating units are to be installed at the mine to provide a back-up supply, although they will have the capability of being synchronised to the system and being operated in parallel for extended periods.

A breaker-failure condition involving either of the new 115kV breakers at Otter Rapids GS will be required to initiate a transfer-trip signal to open the two 115kV breakers associated with circuit C6R at Abitibi Canyon GS. Similarly, a breaker-failure condition involving the new 115kV breaker at Moosonee DS will be required to initiate a transfer-trip signal to open the new 115kV breaker at Otter Rapids GS in the new line to the Victor Mine.

3.3 230kV Transmission Option

Diagram 4 shows the new facilities that it is proposed to install for this Option.

They include a new 144km 230kV line, equipped with 1192.5kcmil conductors, from Otter Rapids GS to Moosonee DS, that is to be routed along the same right-of way as the existing 115kV Hydro One line, C6R.

The new 230kV line is to be terminated through a single 230kV breaker and associated motorised line disconnect switch on to the existing 230kV busbar at Otter Rapids GS. At the Moosonee DS terminal, the new line is to be connected to a 75MVA 230/115kV auto-transformer through a motorised line disconnected switch. The LV side of the auto-transformer is to be connected to the existing 115kV busbar at Moosonee DS through a 115kV circuit breaker. The auto-transformer is to be equipped with an under-load tap-changer.

A new 100km 115kV line is to be constructed between Attawapiskat S/S and the Victor Mine to extend the FNEI line, M3K, through to the mine. The new line is to be equipped with 1192.5kcmil conductors and is to be terminated through a single 115kV breaker and motorised line disconnect switch on to the existing 115kV busbar at Attawapiskat S/S.

At the Victor Mine terminal, the line is to be connected through a manual 115kV line disconnect switch on to a local 115kV busbar, to which is to be connected two 30MVA 115/13.8kV step-down transformers equipped with under-load tap-changers. A variable 8MVAr shunt reactor, equipped with an under-load tap-changer, is also to be connected to the 115kV busbar through a circuit-switcher.

Two ± 10MVAr SVCs are to be connected to the 13.8kV busbar to provide 'dynamic' reactive compensation in response to variations in the load and during contingencies. Three 5.5MVA (4.4MW) diesel generating units are to be installed at the mine to provide a back-up supply, although they will have the capability of being synchronised to the system and being operated in parallel for extended periods.

A breaker-failure condition involving the new 115kV breaker at Attawapiskat TS will be required to initiate a transfer-trip signal to open the 115kV breaker CB2 at Kashechewan S/S.

4. Load Forecast

The following estimates for the future load at Moosonee DS and at the Five Nations communities were extracted from the SNC-Lavalin Inc. Report, dated September 1997. These estimated loads were used in the analysis:

Forecast Loads						
Location		*2006*	*2010*	*2015*	*2020*	*2030*
Moosonee	*Power Factor: 0.975*	14.4MW 3.3MVAr	15.0MW 3.4MVAr	15.8MW 3.6MVAr	16.6MW 3.8MVAr	18.3M 4.2MVAr
Fort Albany		1.9MW 0.4MVAr	2.3MW 0.5MVAr	2.8MW 0.6MVAr	3.5MW 0.8MVAr	5.5MW 1.3MVAr
Kashechewan		2.2MW 0.5MVAr	2.8MW 0.6MVAr	3.5MW 0.8MVAr	4.4MW 1.0MVAr	6.8MW 1.5MVAr
Attawapiskat		2.6MW 0.6MVAR	3.2MW 0.7MVAr	4.1MW 0.9MVAr	5.2MW 1.2MVAr	8.4MW 1.9MVAr
Total		*21.1MW 4.8MVAr*	*23.3MW 5.3MVAr*	*26.2MW 6.0MVAr*	*29.7MW 6.8MVAr*	*39.1MW 8.9MVAr*

5. Power System Analysis

The three Options, as *originally proposed* are fundamentally different in their approach to supplying the load at the Victor Mine.

The Generation Option

The Generation Option relies on the local generation at the mine to supply the majority of the mine load, with the existing 115kV system providing a synchronous connection, together with whatever limited supplies would be available within its existing capability after supplying the local loads.

The 115kV Transmission Option

The 115kV Transmission Option provides a dedicated supply to the mine from Otter Rapids GS, and therefore, with the existing generation at Abitibi Canyon GS, is essentially independent of the loads and performance of the 115kV system to Moosonee DS and the FNEI system. The only common element would be the section of the 115kV circuit, C6R, between Abitibi Canyon GS and Otter Rapids GS. As shown in Section 2 of this Report the thermal rating of this section of circuit C6R would be more than adequate to supply all of the mine load, together with the forecast loads at Moosonee and the Five Nations communities, through to at least 2020.

The 230kV Transmission Option

The 230kV Transmission Option is the only one that relies on the FNEI circuit, M3K, to supply the total mine load of 27MW. Consequently, for this Option to be a viable alternative, it needs to have the capability of supplying not only the mine load, but also the future load growth at Moosonee and at the Five Nations communities, or of being enhanced to increase its capability to be able to meet these expanding loads.

Consequently the analysis focused on this Option, and since the projected life of the mine is approximately 14 years, the forecast loads at Moosonee and the Five Nations communities for 2020 were used in the base-case model.

5.1 Changes to the 230kV Transmission Option

In the preliminary studies that were performed for the 230kV Transmission Option, considerable difficulty was experienced when attempting to optimise the reactive output of the variable 8MVAr shunt reactor at the Victor mine, so as to ensure that sufficient reactive capability remained available within the two SVCs to address contingencies under various load levels at the Mine.

The contingencies that were considered in this analysis included -

- i. The loss of one of the 230/13.8kV step-down transformers at the mine.
- ii. The loss of an SVC at the mine.
- iii. A 115kV line contingency involving circuit C6R, and
- iii. A 230kV line contingency involving the new line, together with load rejection at the Victor Mine .

Since it was considered that this difficulty could translate into a serious control issue if this arrangement were to be implemented, it was therefore recommended that the variable 8MVAr 115kV shunt reactor be omitted from the design and replaced with three +12MVAr/-15MVAr SVCs.

The proposed changes to the 230kV Transmission Option are shown in Diagram 5.

FNEI Shunt Reactors

In the initial series of studies, all the shunt reactors associated with the FNEI 115kV line were modelled to switch automatically with changing voltage. This meant that under peak load conditions, when supplying a mine load of 27MW, all of the FNEI shunt reactors were out-of-service.

For a contingency involving the new 230kV line to Moosonee DS, even with load rejection initiated, excessive voltage declines were recorded at Moosonee DS.

Similarly, for a contingency involving the 115kV line to the Victor Mine, excessive voltage increases were recorded at Attawapiskat S/S.

Studies showed that the respective voltage changes could be minimised by adopting the following measures:

- Maintain the 6.5MVAr shunt reactor at the New Moosonee S/S in-service at all times, and use the under-load tap-changer on the new 230/115kV auto-transformer to control the voltage. For this analysis the voltage was controlled within the range of 129kV & 131kV.

  In the event of a contingency involving the new 230kV line, initiate immediate cross-tripping of the shunt reactor.

- In response to a contingency involving the 115kV line between Attawapiskat S/S and the Victor Mine, initiate automatic insertion of the 2.5MVAr shunt reactor if it has been switched out-of-service to control the pre-contingency voltage.

The studies for the 230kV Transmission Option were therefore repeated with three SVCs at the Victor Mine, having enhanced ratings that would allow the 115kV-connected shunt reactor in the original proposal to be removed. In addition, the FNEI shunt reactors were modelled so that automatic post-contingency switching could be initiated in response to the problematic 230kV and 115kV line contingencies.

5.2 Changes to the 115kV Transmission Option

Initial studies showed that if the 24MVAr variable shunt reactor that it is proposed to install at the Victor Mine terminal, were unavailable, then energisation of the entire 115kV line would result in excessively high voltages. These voltages - 183kV at the Victor Mine terminal and 170kV at the mid-point of the line - would be well beyond the 138kV design standard for the line.

Furthermore, to reduce the exposure of the mine to possible supply interruptions due to permanent line faults, it was agreed that the design of the 115kV Transmission Option should be modified to introduce a new sectioning point at Attawapiskat S/S. This would then allow the section of the new 115kV line between Moosonee DS and Attawapiskat S/S to be isolated should it be subject to a permanent line fault.

The proposed arrangement, which is shown in Diagram 6, would allow a synchronous connection, together with a limited supply to the mine, to be provided via the FNEI line whenever the section of the new 115kV line between Moosonee DS and Attawapiskat S/S is out-of -service, or is unable to be energised due to the shunt reactor being unavailable. Diagram 7 shows the required status of the various disconnect switches for the different operating conditions.

With an additional breaker installed in the new 115kV line at Attawapiskat S/S, the location and rating of the 115kV-connected shunt reactor would also change, as shown in Diagram 6.

Furthermore, with a separate line section between Attawapiskat S/S and the Victor Mine (although it will not normally be interconnected with circuit M3K at Attawapiskat S/S), the reactive compensation requirements for this section would be the same as those for the 230kV Transmission Option, namely three +12MVAr/-15MVAr SVCs.

5.3 Line Energisation Studies

Studies were performed to examine the effect of line energisation with the shunt reactors that had originally been proposed; with the revised SVC ratings; and also to determine the appropriate size of the shunt reactors that would need to be installed to correspond with the changes that have been recommended to the original arrangements.

5.3.1 Line Energisation for the Generation Option

The following Table shows the results for the energisation of the 100km line from Attawapiskat S/S to the Victor Mine.

Energisation of the 100km line section from Attawapiskat S/S to the Victor Mine as shown in Diagram 2			
i. With the 8MVAr reactor at the mine out-of-service		Pre-Energisation	Post-Energisation
Voltages	Abitibi Canyon GS (115kV)	130.8kV	131.3kV
	Otter Rapids GS (115kV)	131.5kV	132.0kV
	Attawapiskat S/S	127.0kV	139.8kV
	At the Victor Mine	-	140.9kV
Reactive Power Output	Abitibi Canyon GS (115kV)	+9.0MVAr	+5.4MVAr
ii. With the 8MVAr reactor at the mine in-service		Pre-Energisation	Post-Energisation
Voltages	Abitibi Canyon GS (115kV)	130.8kV	130.7kV
	Otter Rapids GS (115kV)	131.5kV	131.0kV
	Attawapiskat S/S	127.0kV	121.7kV
	At the Victor Mine	-	119.4kV
Reactive Power Output	Abitibi Canyon GS (115kV)	+9.0MVAr	+9.7MVAr

These results show that switching the 115kV circuit without the 115kV shunt reactor at the Mine in-service would result in unacceptably high voltages at the Victor Mine, as well as at Attawapiskat S/S.

With the reactor set to its maximum value of 8MVAr, the voltage at Attawapiskat S/S would experience a modest 4% voltage decline, in response to the line being energised.

5.3.2 Line Energisation for the 115kV Transmission Option

For the original arrangement as shown in Diagram 3 ***Energisation of the entire 115kV line from Otter Rapids GS to the Victor Mine (~ 515km)***			
i. With the 24MVAr reactor at the mine out-of-service		Pre-Energisation	Post-Energisation
Voltages	Otter Rapids GS (115kV)	129.8kV	137.7kV
	Mid-point	-	170.2kV
	At the Victor Mine	-	182.9kV
Reactive Power Output	Abitibi Canyon GS (115kV)	+13.9MVAr	-7.2MVAr
ii. With the 24MVAr reactor at the mine in-service		Pre-Energisation	Post-Energisation
Voltages	Otter Rapids GS (115kV)	129.8kV	130.6kV
	Mid-point	-	130.9kV
	At the Victor Mine	-	115.0kV
Reactive Power Output	Abitibi Canyon GS (115kV)	+13.9MVAr	+11.9MVAr

These results show that switching the entire 115kV circuit from Otter Rapids GS to the Victor Mine without the 24MVAr shunt reactor at the Mine would result in unacceptably high voltages at the Victor Mine.

<table>
<tr><td colspan="4">For the revised arrangement as shown in Diagram 6
Energisation of the Otter Rapids GS to Attawapiskat S/S section (~ 415km)</td></tr>
<tr><td colspan="2">i. With the 15MVAr reactor at Attawapiskat out-of-service</td><td>Pre-Energisation</td><td>Post-Energisation</td></tr>
<tr><td rowspan="3">Voltages</td><td>Otter Rapids GS (115kV)</td><td>128.1kV</td><td>135.2kV</td></tr>
<tr><td>Mid-point</td><td>-</td><td>156.4kV</td></tr>
<tr><td>At the Attawapiskat terminal</td><td>-</td><td>160.0kV</td></tr>
<tr><td>Reactive Power Output</td><td>Abitibi Canyon GS (115kV)</td><td>+0.5MVAr</td><td>-18.7MVAr</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2">ii. With the 15MVAr reactor at Attawapiskat in-service</td><td>Pre-Energisation</td><td>Post-Energisation</td></tr>
<tr><td rowspan="3">Voltages</td><td>Otter Rapids GS (115kV)</td><td>128.1kV</td><td>130.6kV</td></tr>
<tr><td>Mid-point</td><td>-</td><td>132.7kV</td></tr>
<tr><td>At the Attawapiskat terminal</td><td>-</td><td>126.0kV</td></tr>
<tr><td>Reactive Power Output</td><td>Abitibi Canyon GS (115kV)</td><td>+0.5MVAr</td><td>-6.2MVAr</td></tr>
</table>

Similarly, these results show that switching the reduced section of the new 115kV line from Otter Rapids GS to the Attawapiskat S/S without the proposed 15MVAr shunt reactor at the Attawapiskat terminal would result in unacceptably high voltages. However, it should be noted that since there would be no connection between the new 115kV line and Attawapiskat S/S, these voltages would not have a direct impact on the voltages at Attawapiskat S/S.

Energisation of the 115kV line section from Attawapiskat to the Victor Mine

With an additional breaker installed in the new 115kV line at Attawapiskat S/S, the final section between Attawapiskat S/S and the Victor Mine would be energised separately.

The results would be similar to those tabulated in the second half of the following section.

5.3.3 Line Energisation for the 230kV Transmission Option

1. *Energisation of the 230kV line & the associated 230/115kV Auto-transformer at Moosonee DS:*

<table>
<tr><td colspan="5">i. With the 115kV breaker at Moosonee DS Open</td></tr>
<tr><td colspan="3"></td><td>Pre-Energisation</td><td>Post-Energisation</td></tr>
<tr><td rowspan="4">Voltages</td><td colspan="2">Otter Rapids GS (230kV)</td><td>242.0kV</td><td>242.0kV</td></tr>
<tr><td rowspan="2">Moosonee DS</td><td>230kV</td><td>-</td><td>246.3kV</td></tr>
<tr><td>115kV</td><td>125.8kV</td><td>132.0kV</td></tr>
<tr><td colspan="2">Attawapiskat S/S</td><td>123.5kV</td><td>123.5kV</td></tr>
<tr><td rowspan="2">Reactive Power Output</td><td colspan="2">Otter Rapids GS (230kV)</td><td>-5.6MVAr</td><td>-33.2MVAr</td></tr>
<tr><td colspan="2">Abitibi Canyon GS (115kV)</td><td>+9.4MVAr</td><td>+9.4MVAr</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">ii. With the 115kV breaker at Moosonee DS Closed</td></tr>
<tr><td rowspan="4">Voltages: Pre- ULTC</td><td colspan="2">Otter Rapids GS (230kV)</td><td colspan="2">242.0kV</td></tr>
<tr><td rowspan="2">Moosonee DS</td><td>230kV</td><td colspan="2">246.5kV</td></tr>
<tr><td>115kV</td><td colspan="2">132.7kV</td></tr>
<tr><td colspan="2">Attawapiskat S/S</td><td colspan="2">131.0kV</td></tr>
<tr><td rowspan="2">Reactive Power Output</td><td colspan="2">Otter Rapids GS (230kV)</td><td colspan="2">-35.6MVAr</td></tr>
<tr><td colspan="2">Abitibi Canyon GS (115kV)</td><td colspan="2">+8.0MVAr</td></tr>
</table>

These results show that with no shunt reactors installed on the new 230kV line, the voltages on both the 230kV and 115kV busbars at Moosonee DS can be kept within acceptable limits by relying on the reactive absorption capability of the generators at Otter Rapids GS and at Abitibi Canyon GS (115kV).

Furthermore, a detailed examination of the reactive power flows show that they are close to zero at the Moosonee DS end of the new 230kV line. Consequently, for any reactors to be effective in reducing the amount of reactive power absorbed by the generating units at Otter Rapids GS, they would need to be installed at the Otter Rapids GS terminal.

Since the reactive power absorption requirements for energisation of the new 230kV line would be well within the capability of the existing generating units, it is not considered necessary to install separate shunt reactors. However, since the situation could change, it is recommended that provisions be included in the design of the Project for the future installation of shunt reactors, either at Pinard TS/Otter Rapids GS or at Moosonee DS. At Pinard TS, further reactors could be accommodated on the tertiary windings of the two 500/230kV auto-transformers, while at Moosonee DS a similar arrangement could be adopted if the tertiary winding on the new auto-transformer were to be 'brought-out'.

2. Energisation of the 115kV line section from Attawapiskat S/S to the Victor Mine:

The effect of energising the 115kV line between Attawapiskat S/S and the Victor Mine with various numbers of SVCs in-service at the Victor Mine was examined, and the results are recorded in the following Tables:

i. With no SVCs at the Victor Mine				
			Pre-Energisation	Post-Energisation
Voltages	Abitibi Canyon GS	(115kV)	128.8kV	128.9kV
	Otter Rapids GS	115kV	129.0kV	129.5kV
		230kV	242.0kV	242.0kV
	Attawapiskat S/S		129.6kV	139.0kV
	At the Victor Mine	115kV	-	140.0kV
		13.8kV	-	16.2kV
Reactive Power Output	Otter Rapids GS	(230kV)	-39.2MVAr	-44.4MVAr
	Abitibi Canyon GS	(115kV)	-1.4MVAr	-2.3MVAr

ii. With one +12MVAr/-15MVAr SVC at the Victor Mine (effective output from the SVC: -3.7MVAr)				
			Pre-Energisation	Post-Energisation
Voltages	Abitibi Canyon GS	(115kV)	128.8kV	128.8kV
	Otter Rapids GS	115kV	129.0kV	129.2kV
		230kV	242.0kV	242.0kV
	Attawapiskat S/S		129.6kV	133.4kV
	At the Victor Mine	115kV	-	133.3kV
		13.8kV	-	15.3kV
Reactive Power Output	Otter Rapids GS	(230kV)	-39.2MVAr	-41.2MVAr
	Abitibi Canyon GS	(115kV)	-1.4MVAr	-1.4MVAr

iii. With two +12MVAr/-15MVAr SVCs at the Victor Mine (effective output from the SVCs: -6.6MVAr)				
			Pre-Energisation	Post-Energisation
Voltages	Abitibi Canyon GS (115kV)		128.8kV	128.7kV
	Otter Rapids GS	115kV	129.0kV	129.0kV
		230kV	242.0kV	242.0kV
	Attawapiskat S/S		129.6kV	128.4kV
	At the Victor Mine	115kV	-	127.0kV
		13.8kV	-	14.5kV
Reactive Power Output	Otter Rapids GS (230kV)		-39.2MVAr	-38.4MVAr
	Abitibi Canyon GS (115kV)		-1.4MVAr	-1.2MVAr

iv. With three +12MVAr/-15MVAr SVCs at the Victor Mine (effective output from the SVCs: -9.0MVAr)				
			Pre-Energisation	Post-Energisation
Voltages	Abitibi Canyon GS (115kV)		128.8kV	128.7kV
	Otter Rapids GS	115kV	129.0kV	128.9kV
		230kV	242.0kV	242.0kV
	Attawapiskat S/S		129.6kV	123.7kV
	At the Victor Mine	115kV	-	121.3kV
		13.8kV	-	13.8kV
Reactive Power Output	Otter Rapids GS (230kV)		-39.2MVAr	-36.0MVAr
	Abitibi Canyon GS (115kV)		-1.4MVAr	-0.8MVAr

These results show that with no SVCs in-service, the voltages at Attawapiskat S/S (139.0kV) and the Victor Mine (140.0kV) would be unacceptably high following energisation of the 115kV line to the Mine.

With a single SVC in-service, the voltages at Attawapiskat S/S (133.4kV) and the Victor Mine (133.3kV), although high, would be within the operating range of the equipment.

With two or three SVCs in-service, the voltages at Attawapiskat S/S (128.4kV & 123.7kV, respectively) and the Victor Mine (127.0kV & 121.3kV, respectively) would be close to ideal.

This shows that energisation of the new 115kV line to the Mine could be safely accomplished with only a single SVC in-service, although it would be preferable to have a minimum of two SVCs in-service.

5.3.4 Conclusions from the Line Energisation Analysis.

1. Generation Option

Energising the 115kV line from Attawapiskat S/S to the Victor Mine would require the 8MVAr shunt reactor to be in-service to avoid high voltages on the FNEI line and at the Victor Mine. If the reactor were unavailable, then it would be very difficult to energise the line and would likely entail having to artificially suppress the voltage at Abitibi Canyon GS until the Mine load could be increased.

Replacing the 8MVAr shunt reactor with at least two SVCs, as shown in Diagram 10, would allow energisation of the line to the Victor Mine to be performed if only a single SVC were to be available.

2. 115kV Transmission Option

Energising the 115kV line would similarly require the 24MVAr reactor at the Victor Mine to be available to avoid excessively high voltages at the Victor Mine.

With the revised arrangement, with an additional breaker installed in the new 115kV line at Attawapiskat S/S as shown in Diagram 6, a 15MVAr reactor would need to be connected to the line at the Attawapiskat terminal. However, in this case, if the reactor were unavailable, the section between Attawapiskat and the Victor Mine could be connected to the 115kV busbar at Attawapiskat S/S and the line to the mine energised using the SVCs at the mine.

3. 230kV Transmission Option

Since this option would require no shunt reactors for the 230kV line portion of this development, there would be no similar constraints on its energisation.

For the 115kV line portion of this development, since it is proposed to install a total of three SVCs at the Victor Mine, and since the line could safely be energised with only a single SVC in-service, the absence of an SVC (or even two SVCs), would not hinder the safe energisation of this line.

5.4 Supply Capability of the Existing 115kV System: Generation Option

Although it is intended to install sufficient generating capacity under the Generation Option to be able to supply all of the load at Victor Mine, it is also intended to take advantage of whatever capacity is available from the existing transmission facilities to limit the extent of the on-site generation activities. The original proposal for the Generation Option assumed that a nominal 5MW of capacity would be available from the existing facilities and the single step-down transformer was rated accordingly.

Preliminary studies had indicated that the declining voltages at the FNEI substations would limit the amount of power that could be supplied before the thermal rating of circuit C6R would be exceeded. Consequently, a series of studies was performed to determine the extent of the voltage support that would be required to allow the full thermal capability of circuit C6R to be utilised.

SVCs were therefore assumed to be installed at Moosonee DS and the FNEI substations. A maximum rating of +10MVAr/-13MVAr was assumed for these SVCs so that they would be compatible with the 10MVA step-down transformers installed at each FNEI substation. It was further assumed that part of the output from the SVCs would be used to supply the reactive power requirements of the local load so that the resulting flows through the transformers would remain within their rating. Furthermore with a net value of -3MVAr, the maximum voltage change that would occur upon switching these devices, after allowing for the increase in fault level resulting from the new generating capacity at the Victor Mine, would be within the 4% limit.

This analysis was also intended to provide an indication of what facilities would need to be installed to allow the maximum supply to be provided to the mine in the event of a protracted outage of the proposed 230kV line.

The results of the analysis are summarised in the following Tables (Tables 1.1, 1.2 & 1.3):

TABLE 1.1	With the Forecast Loads at Moosonee & the Five Nations Communities for 2006			
Supply Capability of the Existing Transmission Facilities with Additional SVCs Installed				
Load at the Victor Mine	*14MW*	*16MW*	*18MW*	*20MW*
Voltages				
Moosonee DS	122.2kV **	119.9kV **	123.8kV	120.9kV
Fort Albany S/S	126.9kV	125.1kV	126.5kV	124.3kV
Attawapiskat S/S	127.7kV	126.4kV	126.7kV	125.2kV
Victor Mine	129.7kV	129.1kV	129.2kV	128.4kV
Losses				
Circuit C6R	6.0MW	9.8MW	11.5MW	14.0MW
Circuit M3K	5.2MW	6.8MW	7.2MW	8.7MW
Victor Mine Circuit	0.1MW	0.2MW	0.2MW	0.3MW
Total	*11.3MW*	*16.8MW*	*18.9MW*	*23.0MW*
Flow on Circuit C6R at Otter Rapids GS	50MVA	54MVA	60MVA	65MVA
Output of the SVCs				
Moosonee DS	0.0MVAr	0.0MVAr	+ 9.5MVAr	+ 9.6MVAr
Fort Albany S/S	+ 3.6MVAr	+ 4.6MVAr	+ 3.8MVAr	+ 5.0MVAr
Kashechewan S/S	+ 3.6MVAr	+ 4.5MVAr	+ 3.8MVAr	+ 5.0MVAr
Attawapiskat S/S	+ 0.2MVAr	+ 0.9MVAr	+ 0.7MVAr	+ 1.6MVAr
Victor Mine	+ 13.2MVAr	+ 16.7MVAr	+17.5MVAr	+ 21.5MVAr

Notes: ** No SVC at Moosonee DS

(shaded) Exceeds summer rating of 57MVA (30°C): Within winter rating of 79MVA (0°C)

Comments on the Studies for the 2006 loading condition

These studies show that with SVCs installed at the locations identified below, the existing 115kV transmission system would have the capability to supply the following loads at the Victor Mine:

- Approximately 20MW during the winter months -
  Constrained by the voltage at Moosonee DS.
- Approximately 16MW during the summer months (when the ambient temperatures are above 30°C) -
  Constrained by the thermal rating of the Otter Rapids GS to Moosonee DS section of circuit C6R

With SVCs installed at:

Moosonee DS one +10/-13MVAr unit
Fort Albany S/S one +10/-13MVAr unit
(to meet the combined SVC requirements of Fort Albany S/S & Kashechewan S/S)
Victor Mine two +12/-15MVAr units

It should also be noted that for a combined load of 21MW at Moosonee and the Five Nations communities, the total losses, when supplying a load of 20MW at the Victor Mine, would be approximately 23MW.
(i.e. the losses would be approximately 56% of the total load)

TABLE 1.2	**With the Forecast Loads at Moosonee & the Five Nations Communities for 2010**		
Supply Capability of the Existing Transmission Facilities with Additional SVCs Installed			
Load at the Victor Mine	*16MW*	*18MW*	*20MW*
Voltages			
Moosonee DS	123.6kV	120.8kV	***112.3kV***
Fort Albany S/S	126.4kV	124.4kV	118.7kV
Attawapiskat S/S	126.8kV	125.5kV	122.0kV
Victor Mine	129.3kV	128.7kV	127.1kV
Losses			
Circuit C6R	11.7MW	14.0MW	20.1MW
Circuit M3K	7.1MW	8.1MW	12.5MW
Victor Mine Circuit	0.2MW	0.2MW	0.2MW
Total	*19.0MW*	*22.3MW*	*32.8MW*
Flow on Circuit C6R at Otter Rapids GS	60MVA	65MVA	75MVA
Output of the SVCs			
Moosonee DS	+ 10.0MVAr	+ 9.5MVAr #	+ 8.2MVAr #
Fort Albany S/S	+ 4.0MVAr	+ 5.1MVAr	+ 8.4MVAr
Kashechewan S/S	+ 4.1MVAr	+ 5.1MVAr	+ 8.2MVAr
Attawapiskat S/S	+ 0.9MVAr	+ 1.7MVAr	+ 3.7MVAr
Victor Mine	+ 15.9MVAr	+ 19.6MVAr	+ 26.8MVAr

Notes: # Reduced SVC Output is due to declining voltage at Moosonee DS

[shaded box] Exceeds summer rating of 57MVA: Within winter rating of 79MVA (0^oC)

112.3kV Less than the minimum voltage of 113kV that is specified in the Market Rules

Comments on the Studies for the 2010 loading condition

These studies show that for loads of approximately 16MW at the Victor Mine, the single SVC at Moosonee DS would become limiting and would therefore be unable to maintain the 27.6kV voltage at Moosonee DS. This is evident from the reduced output of the 10MVAr capacitor portion of the SVC (9.5MVAr for a load of 18MW and 8.2MVAr for a load of 20MW) and the declining voltage on the 115kV system (120.8kV for a load of 18MW and 112.3kV for a load of 20MW).

While the installation of an additional SVC at Moosonee DS would allow the LV & HV voltages to be maintained at acceptable values, the thermal rating of the 115kV circuit C6R would then become the limiting factor. As shown in the Table, the flows on circuit C6R would exceed its summer rating (for an ambient temperature of 30^oC) for supplies to the mine that are 16MW or higher. Furthermore, for a supply to the mine of 20MW or higher, the thermal rating of circuit C6R, corresponding to a 10^oC ambient temperature, would be exceeded.

It should also be noted that for a combined load of 23MW at Moosonee and the Five Nations communities, the total losses, when supplying a load of 18MW at the Victor Mine, would be approximately 22MW.
(i.e. the losses would be approximately 54% of the total load)

Furthermore, for a supply of 20MW to the mine, in addition to requiring a second SVC to be installed at Moosonee DS, an SVC would also need to be installed at Kashechewan S/S.

TABLE 1.3	*With the Forecast Loads at Moosonee & the Five Nations Communities for 2020*	
Supply Capability of the Existing Transmission Facilities with Additional SVCs Installed		
Load at Victor Mine	*12MW*	*14MW*
Voltages		
Moosonee DS	122.2kV	121.2kV
Fort Albany S/S	123.4kV	122.0kV
Attawapiskat S/S	125.0kV	123.9kV
Victor Mine	127.8kV	127.3kV
Losses		
Circuit C6R	13.3MW	15.7MW
Circuit M3K	7.1MW	7.9MW
Victor Mine Circuit	0.1MW	0.2MW
Total	*20.5MW*	*23.8MW*
Flow on Circuit C6R at Otter Rapids GS	64MVA	69MVA
Output of the SVCs		
Moosonee DS	+ 14.4MVAr	+ 17.3MVAr #
Fort Albany S/S	+ 6.1MVAr	+ 6.9MVAr
Kashechewan S/S	-	-
Attawapiskat S/S	+ 2.6MVAr	+ 3.3MVAr
Victor Mine	+ 13.9MVAr	+ 17.1MVAr

Notes: # Reduced SVC Output is due to declining voltage at Moosonee DS

[shaded box] Exceeds summer rating of 57MVA (30^{o}C): Within winter rating of 70MVA (10^{o}C)

Comments on the Studies for the 2020 loading condition

These studies show that the installation of a second SVC at Moosonee DS would only allow a load of approximately 14MW to be supplied at the Victor Mine. At this supply level, the SVCs at Moosonee DS would start to become limiting and would therefore be unable to maintain the 27.6kV voltage at Moosonee DS. This is shown to result in a declining voltage on the 115kV system at Moosonee DS.

Furthermore, at this supply level, the flows on circuit C6R would exceed its summer rating of 57MVA (for an ambient temperature of 30^{o}C) and would also be within 1MVA of its winter rating of 70MVA (for an ambient temperature of 10^{o}C).

For the combined forecast load of 30MW at Moosonee and the Five Nations communities, the total losses, when supplying a load of 14MW at the Victor Mine, would be approximately 24MW.
(i.e. the losses would be approximately 55% of the total load)

5.4.1 Summary of the Studies on the Existing System

The series of studies that was performed on the existing system show that while SVCs could be installed at Moosonee DS and at the Five Nations Substations to support the voltage, the supply capability to the Victor Mine, after supplying the local loads, would be limited by the thermal rating of the section of the existing 115kV circuit, C6R, between Otter Rapids GS and Moosonee DS.

Furthermore, with increases in the loads at Moosonee and the Five Nations communities the supply capability to the mine will gradually diminish, as shown in Table 1.4:

TABLE 1.4 ***Supply Capability to the Victor Mine of the Existing 115kV System***

	2006	***2010***		***2020***
Approximate Supply Capability to the Victor Mine	*20MW*	*18MW*	*20MW*	*14MW*
Maximum Flow on Circuit C6R	65MVA	65MVA	***75MVA***	69MVA
SVC Requirements (+10/-13MVAr units):				
Moosonee DS	1	1	2	2
Fort Albany S/S	1	1	1	1
Kashechewan S/S	-	-	1	-
Attawapiskat S/S	½ (5MVAr unit)	½ (5MVAr unit)		½ (5MVAr unit)
Victor Mine	Three +12/-15MVAr SVCs			
Losses:	23.0MW	22.3MW	32.8MW	23.8MW

(shaded)	Flow on circuit C6R exceeds summer rating of 57MVA (30^{o}C), but is within winter rating of 70MVA (10^{o}C)
xxx	Flow on circuit C6R is within winter rating of 79MVA (0^{o}C)

Notes: 1. Whenever possible, the reactive support requirements for Fort Albany S/S and Kashechewan S/S have been combined into a single unit at Fort Albany S/S.

2. Although an SVC with a rating approximately half that of the other units would be sufficient to meet the reactive support requirements at Attawapiskat S/S, a 'full sized' unit is recommended at this location to provide additional voltage control in the event of a contingency involving the 115kV line to the Victor Mine from Attawapiskat S/S. It would also provide support under outage conditions involving the other SVCs.

Revised arrangement for the Generation Option

Diagram 10 shows the changes that would need to be made to the original arrangement proposed for the Generation Option in order to maximise the amount of power that could be derived from the existing transmission facilities, while respecting the thermal rating of circuit C6R.

These changes include the installation of a second step-down transformer at the Victor Mine site and an increase in their maximum rating to 20MVA, together with the installation of an SVC at Moosonee DS, Fort Albany S/S & Attawapiskat S/S.

5.5 Study Results for the 230kV Transmission Option

The projected life of the Victor Mine is expected to be approximately 14 years, from 2006 to 2020. Studies were therefore performed to determine whether the facilities as originally proposed would be capable of supplying the full 27MW requirement of the mine under the peak load conditions at Moosonee and at the Five Nations communities that have been forecast for 2020.

These studies indicated that although the voltages at Moosonee DS (supported by the tap-changer on the 230/115kV auto-transformer) and at the Victor Mine (supported via the local SVCs) were acceptable, the declining voltages at the intermediate substations along the FNEI line, limited the transfers and hence the load that could be supplied at the mine.

Installing shunt capacitors at the intermediate substations was considered, but because of the amount of reactive support that would be required, and the maximum size of each capacitor bank that could be switched while respecting the 4% voltage change limit, it was concluded that SVCs would be the appropriate devices.

Furthermore, since the existing transformers at Attawapiskat S/S, Kashechewan S/S and Fort Albany S/S are rated at 10MVA the SVCs that were assumed in the analytical model were rated +10MVAr & -13MVAr. The additional inductive capability (-3MVAr) was selected because it would allow some of the existing shunt reactors at the FNEI substations to be switched out-of-service in normal operation. This would simplify control of the SVCs and avoid possible conflicts between the switching of the shunt reactors in response to variations in the local voltage and the operation of the SVCs.

The studies showed that with a +10/-13MVAr SVC installed at Fort Albany S/S and with a lower-rated unit installed at Attawapiskat S/S, the 230kV Transmission Option would permit the 27MW load at the mine to be supplied together with the forecast loads for 2020 at Moosonee and at the Five Nations communities.

The proposed system arrangement with the additional SVCs is shown in Diagram 8 and the results of the study are summarised in Table 2:

TABLE 2	***230kV Transmission Option with a 230kV new line installed between Otter Rapids GS & Moosonee DS: Operating at 230kV***	***2020 Loads***
Supply Capability to the Victor Mine		
Load at the Victor Mine	*27MW*	
Voltages		
Abitibi Canyon GS	129.4kV	
Otter Rapids GS	130.4kV	242.0kV
Moosonee DS	128.8kV	243.6kV
Fort Albany S/S	122.5kV	
Kashechewan S/S	122.4kV	
Attawapiskat S/S	121.5kV	
Victor Mine	13.8kV	126.1kV
Losses		
Circuit C6R from Abitibi Canyon GS to Moosonee DS	1.4MW	
New 230kV line from Otter Rapids GS to Moosonee DS	0.9MW	
Circuit M3K	17.2MW	
Victor Mine Circuit	0.5MW	
Total	*20.0MW*	
Flows		
Circuit C6R at Abitibi Canyon GS	24MVA	
New 230kV line at Otter rapids GS	63MVA	
Output of the SVCs		
Moosonee DS	-3MVAr	
Fort Albany S/S	+6.6MVAr	
Kashechewan S/S	+6.9MVAr	
Attawapiskat S/S	+4.7MVAr	
Victor Mine	+31.1MVAr	

[Although the studies have shown that an SVC rated at around 5MVAr would be sufficient at Attawapiskat S/S, it would be prudent to install the same size of SVC as at Fort Albany S/S since the additional capacity would:

- help off-set some of the impact of an outage involving the SVC at Fort Albany S/S, and
- help limit any voltage rise at Attawapiskat S/S following a contingency involving the 115kV line from Attawapiskat S/S to the Victor Mine.]

5.5.1 Effect of installing a new 115kV line between Moosonee DS & Fort Albany S/S

The results in Table 2 show that while the 230kV auto-transformer at Moosonee DS would be able to optimise the 115kV voltage at that location, the increased transfers on the 115kV circuit M3K due to the growth in the local load, results in a declining voltage profile. For the period beyond 2020 (or for load growth higher than that which has been forecast) the increased losses on circuit M3K would further aggravate the situation.

Since the losses on circuit M3K have been shown to have a major influence on the performance of the local system, additional studies were performed to examine the impact of a new 115kV line, equipped with 795kcmil conductors, connected in parallel with circuit M3K, between Moosonee DS and Fort Albany S/S.

The proposed arrangement is shown in Diagram 9 and the results have been summarised in Table 3:

TABLE 3	***230kV line between Otter Rapids GS & Moosonee DS operating at 230kV AND with a new 115kV line between Moosonee DS & Fort Albany S/S***	***2020 Loads***
Supply Capability to the Victor Mine	***2020 Load Forecast:***	
Load at the Victor Mine	*27MW*	
Voltages		
Abitibi Canyon GS	129.4kV	
Otter Rapids GS	130.6kV	242.0kV
Moosonee DS	130.2kV	245.5kV
Fort Albany S/S	131.7kV	
Kashechewan S/S	131.1kV	
Attawapiskat S/S	126.6kV	
Victor Mine	13.8kV : 128.3kV	
Losses		
Circuit C6R from Abitibi Canyon GS to Moosonee DS	1.0MW	
New 230kV line from Otter Rapids GS to Moosonee DS	0.5MW	
Circuit M3K from Moosonee DS to Fort Albany S/S	1.4MW	
New 115kV circuit from Moosonee DS to Fort Albany S/S	0.7MW	
Circuit M3K from Fort Albany to Attawapiskat S/S	3.3MW	
Victor Mine Circuit	0.4MW	
Total	*7.3MW*	
Flows		
Circuit C6R at Abitibi Canyon GS	21MVA	
New 230kV circuit at Otter rapids GS	58MVA	
Circuit M3K at Moosonee DS	23MVA	
New 115kV circuit at Moosonee DS	31MVA	
Output of the SVCs		
Moosonee DS	-7MVAr	
Fort Albany S/S	+1.3MVAr	
Kashechewan S/S	+1.9MVAr	
Attawapiskat S/S	+1.6MVAr	
Victor Mine	+22.4MVAr	

Comments on the studies with the 230kV line operating at 230kV and a new 115kV line connected in parallel with circuit M3K

The results show a marked improvement in the voltage profile and a substantially reduced reactive support requirement. In addition, the losses are approximately a third of those for the comparable case (Table 2) without the new 115kV line.

It should also be noted that the SVC that had been assumed at Moosonee DS is actually absorbing reactive power, indicating that presence of the 230/115kV auto-transformer at Moosonee DS is less critical for controlling the 115kV voltage at Moosonee DS.

5.6 Staged Development of the 230kV Transmission Option

The results summarised in the preceding section show that in the initial years, with reduced loads at Moosonee and the Five Nations communities, the supply capability to the Victor Mine would be limited more by the thermal rating of the 115kV circuit C6R than by the voltages at the FNEI substations, which could be supported through the installation of SVCs.

Increasing the rating of circuit C6R by raising the maximum temperature at which its conductors can be operated is not considered a viable option, primarily because of the length involved. Furthermore, unless the existing 211.6kcmil conductors were to be replaced with ones with a larger cross-sectional area, the very high losses would not be addressed. Reducing the losses on circuit C6R is considered to be crucial to the supply situation because they have a disproportionate effect on the voltage declines experienced at Moosonee DS.

Installing a parallel 115kV circuit between Otter Rapids GS and Moosonee DS would reduce the combined losses on the 115kV facilities between Abitibi Canyon GS and Moosonee DS by approximately half. (There would only be a marginal reduction in the losses on the common section between Abitibi Canyon GS and Otter Rapids GS as a result of installing the new 115kV line between Otter Rapids GS and Moosonee DS.)

Furthermore, if this new line were to be insulated for eventual operation at 230kV, then it could form the basis for the 230kV Transmission Option.

Studies were therefore performed with a new 230kV line, operating at 115kV, installed between Otter Rapids GS and Moosonee DS for the 2020 peak loading condition.

The proposed arrangement is shown in Diagram 11, and the results are summarised in Table 4:

TABLE 4	*230kV line between Otter Rapids GS & Moosonee DS: Operating at 115kV 2020 Loads*		
Supply Capability to the Victor Mine			
Load at the Victor Mine	*24MW*	*26MW*	*27MW*
Voltages			
Abitibi Canyon GS	129.0kV	128.7kV	128.8kV
Otter Rapids GS	128.7kV	128.0kV	128.3kV
Moosonee DS	126.7kV	125.3kV	126.3kV
Fort Albany S/S	121.1kV	116.3kV	122.5kV
Kashechewan S/S	120.9kV	115.9kV	122.7kV
Attawapiskat S/S	122.1kV	115.8kV	123.0kV
Victor Mine	13.8kV : 127.7kV	***12.7kV : 120.3kV***	***13.7kV : 128.9kV***
Losses			
Circuit C6R: AC GS to OR GS	1.7MW	1.9MW	2.1MW
Circuit C6R: OR GS to Moosonee DS	3.1MW	3.6MW	3.9MW
New 230kV line: OR GS to Moosonee DS	1.4MW	1.6MW	1.8MW
Circuit M3K	15.1MW	17.9MW	19.5MW
Victor Mine Circuit	0.5MW	0.5MW	0.6MW
Total	*21.8MW*	*25.5MW*	*27.9MW*
Flows			
Circuit C6R at Abitibi Canyon GS	77MVA	83MVA	86MVA
Circuit C6R at Otter Rapids GS	33MVA	35MVA	35MVA
New 230kV line at Otter rapids GS	45MVA	48MVA	50MVA
Output of the SVCs			
Moosonee DS	+ 2.4MVAr	+ 6.4MVAr	+ 3.5MVAr
Fort Albany S/S	+ 7.4MVAr	+ 10.0MVAr	+ 7.6MVAr
Kashechewan S/S	-	-	+ 10.0MVAr
Attawapiskat S/S	+ 4.3MVAr	+ 8.1MVAr	+ 3.8MVAr
Victor Mine	+ 32.2MVAr	***+ 30.6MVAr***	***+ 35.4MVAr***

XXX Output limit of SVCs has been reached, resulting in declining voltages & reduced SVC output

Comments on the Studies for the 2020 loading condition with a new 230kV line, operating at 115kV

Comparing the results in Table 4 with those in Table 2 for the condition with the 230kV line operating at 230kV, shows the effect of not having the capability to optimise the 115kV voltage at Moosonee DS through the tap-changer on the 230/115kV auto-transformer.

The lower voltage profile on the FNEI circuit M3K results in increased losses, both MW and MVAr, which effectively restricts the supply capability to the mine. As shown in the final column of the Table, it would only be possible to supply 27MW at the Victor Mine with the loads forecast for 2020 by installing an additional SVC at Kashechewan S/S, to support the voltage at that location.

Furthermore, for the 26MW supply case (without the additional SVC at Kashechewan S/S) & the 27MW case, the three SVCs at the Victor Mine are shown to be limiting and are therefore unable to maintain the LV voltage at the mine at 13.8kV.

The results therefore show that, without an additional SVC at Kashechewan S/S, the arrangement with the 230kV line operating at 115kV would only be able to supply approximately 24MW at the Victor Mine. However, since the projected load growth at Moosonee and the Five Nations communities between 2015 & 2020 is approximately 3.5MW (distributed between the various communities), then in order to be able to supply the full 27MW requirement at the Mine and avoid having to install an additional SVC at Kashechewan S/S, the 230kV line would need to be operated at 230kV starting around 2015.

Furthermore, if the additional SVC were to be installed at Kashechewan S/S, and if the mine continued to operate beyond 2020, then it would be necessary to uprate the line to 230kV operation and install the auto-transformer at Moosonee DS around 2020.

Terminal Facilities at Otter Rapids GS

If the new line between Otter Rapids GS and Moosonee DS were to be insulated for eventual operation at 230kV, but operated initially at 115kV, then it is recommended that the arrangement shown in Diagram 12 be implemented at the Otter Rapids GS terminal.

The new breaker and its associated motorised line disconnect switch would need to be rated for 230kV operation. In addition two interlocked disconnect switches would need to be installed to allow the line to be connected to either the 230kV busbar or the 115kV busbar at Otter Rapids GS.

When the line is eventually uprated to 230kV operation and the 75MVA 230/115kV auto-transformer is installed at Moosonee DS, a by-pass connection with a disconnect switch would also need to be installed at Moosonee DS. This by-pass disconnect switch would need to be interlocked with the 230kV disconnect switch for the auto-transformer, as shown in the Diagram.

This arrangement, once the appropriate disconnect switches have been operated, would allow the line to revert to 115kV operation in the event of an extended outage of the 230/115kV auto-transformer.

5.7 Integrated 115kV Transmission Option

From the preceding results, it is evident that the losses on the existing 115kV circuits, C6R & M3K, have a major impact on the overall supply capability to the Victor Mine and to Moosonee and the Five Nations communities. Reinforcing the existing system with new transmission facilities designed to reduce these losses has been shown to have a major impact on the supply capability.

The installation (and operation at 230kV) of a new 230kV line between Otter Rapids GS and Moosonee DS has been shown to provide an improvement in the supply capability, primarily because of its ability to maintain an optimum voltage on the 115kV busbar at Moosonee DS. However, the relatively high transfers over circuit M3K, which are further aggravated by the substantial transmission losses, require a substantial investment in SVCs to provide the voltage support necessary to achieve the required supply capability.

Installing a parallel 115kV connection, equipped with 795kcmil conductors, between Moosonee DS and Fort Albany S/S has been shown to significantly reduce the losses on circuit M3K while also providing voltage support, as demonstrated by the reduced output of the SVCs. In particular, the SVC that was assumed at Moosonee DS is shown to be operating in the inductive mode, absorbing reactive power. This indicates that the need for a 230kV line, together with an associated auto-transformer at Moosonee DS, to maintain an optimum 115kV voltage at that location would be diminished with the installation of a new 115kV line connected in parallel to circuit M3K.

Studies were therefore performed with the new 230kV line between Otter Rapids GS and Moosonee DS operating at 115kV, together with a new 115kV line between Moosonee DS and Fort Albany S/S.

The proposed arrangement is shown in Diagram 13 and the results are summarised in Table 5:

TABLE 5	230kV line between Otter Rapids GS & Moosonee DS operating at 115kV AND with a new 115kV line between Moosonee DS & Fort Albany S/S	2020 Loads

Supply Capability to the Victor Mine 2020 Load Forecast:	
Load at the Victor Mine	*27MW*
Voltages	
Abitibi Canyon GS	129.5kV
Otter Rapids GS	130.3kV
Moosonee DS	130.3kV
Fort Albany S/S	131.7kV
Kashechewan S/S	131.1kV
Attawapiskat S/S	126.6kV
Victor Mine	13.8kV : 128.3kV
Losses	
Circuit C6R from Abitibi Canyon GS to Otter Rapids GS	1.4MW
Circuit C6R from Otter Rapids GS to Moosonee DS	2.5MW
New 230kV line from Otter Rapids GS to Moosonee DS (Op. at 115kV)	1.1MW
Circuit M3K from Moosonee DS to Fort Albany S/S	1.4MW
New 115kV circuit from Moosonee DS to Fort Albany S/S	0.7MW
Circuit M3K from Fort Albany to Attawapiskat S/S	3.3MW
Victor Mine Circuit	0.4MW
Total	*10.8MW*
Flows	
Circuit C6R at Abitibi Canyon GS	71MVA
Circuit C6R at Otter Rapids GS	31MVA
New 230kV circuit at Otter Rapids GS (Operating at 115kV)	42MVA
Circuit M3K at Moosonee DS	23MVA
New 115kV circuit at Moosonee DS	31MVA
Output of the SVCs	
Moosonee DS	-2.7MVAr
Fort Albany S/S	+1.3MVAr
Kashechewan S/S	+1.9MVAr
Attawapiskat S/S	+1.6MVAr
Victor Mine	+22.4MVAr

Comments on the studies with the 230kV line operating at 115kV and a new 115kV line connected in parallel with circuit M3K

The results in Table 5 are remarkably similar to those in Table 3, showing a similar voltage profile and the same level of reactive support from the SVCs at the FNEI substations.

The only difference between the two sets of results is the increased losses (3.5MW) on circuit C6R and the parallel 115kV connection between Otter Rapids GS and Moosonee DS.

Since the performance of the 'Integrated' 115kV Transmission Option has been shown to be so satisfactory, additional studies were performed to examine its performance at the higher load levels that have been forecast for 2030. This would represent the situation should the mine life extend beyond 2020 or if the loads at Moosonee and the Five Nations communities were to grow at a higher rate than has been forecast.

The results are summarised in the following Table:

TABLE 6 ***230kV line between Otter Rapids GS & Moosonee DS operating at 115kV AND with a new 115kV line between Moosonee DS & Fort Albany S/S***	***2030 Loads***
Supply Capability to the Victor Mine 2030 Load Forecast:	
Load at the Victor Mine	*27MW*
Voltages	
Abitibi Canyon GS	129.1kV
Otter Rapids GS	129.1kV
Moosonee DS	127.9kV
Fort Albany S/S	129.3kV
Kashechewan S/S	128.6kV
Attawapiskat S/S	124.5kV
Victor Mine	13.8kV : 127.4kV
Losses	
Circuit C6R from Abitibi Canyon GS to Otter Rapids GS	2.0MW
Circuit C6R from Otter Rapids GS to Moosonee DS	2.6MW
New 230kV line from Otter Rapids GS to Moosonee DS (Op. at 115kV)	1.6MW
Circuit M3K from Moosonee DS to Fort Albany S/S	2.1MW
New 115kV circuit from Moosonee DS to Fort Albany S/S	0.9MW
Circuit M3K from Fort Albany to Attawapiskat S/S	4.5MW
Victor Mine Circuit	0.5MW
Total	*14.2MW*
Flows	
Circuit C6R at Abitibi Canyon GS	84MVA
Circuit C6R at Otter Rapids GS	36MVA
New 230kV circuit at Otter Rapids GS (Operating at 115kV)	49MVA
Circuit M3K at Moosonee DS	27MVA
New 115kV circuit at Moosonee DS	37MVA
Output of the SVCs	
Moosonee DS	-0.2MVAr
Fort Albany S/S	+3.3MVAr
Kashechewan S/S	+4.1MVAr
Attawapiskat S/S	+3.9MVAr
Victor Mine	+26.1MVAr

Comments on the studies with the 230kV line operating at 115kV and a new 115kV line connected in parallel with circuit M3K - for the 2030 loading condition

While the voltages have declined slightly from those for the 2020 loading condition they remain satisfactory. The losses have increased by approximately 3.4MW for a corresponding increase in load of 9.4MW. Furthermore, although additional voltage support is shown to be required, the installation of a single +10/-13MVAr SVC at Fort Albany S/S or Kashechewan S/S should be adequate.

5.8 Conclusions from the studies on the 230kV and Integrated 115kV Transmission Options

Table 2 shows that

The 230kV Transmission Option (with the new 230kV line operating at **230kV**) has been shown to be capable of supplying the entire 27MW requirement of the Victor Mine together with projected load growth at Moosonee and the Five Nations communities through to 2020 if sufficient reactive support is installed at the FNEI substations:

- One SVC at Fort Albany S/S
- One SVC at Attawapiskat S/S, and
- Three SVCs at the Victor Mine

For this arrangement, the losses during the peak load periods for 2020 would be approximately 20MW.

Table 3 shows that

With the new 230kV line between Otter Rapids GS and Moosonee DS operating at **230kV** AND with a new 115kV line connected in parallel with the existing FNEI circuit M3K between Moosonee DS and Fort Albany S/S, the full 27MW requirement of the Victor Mine together with the forecast loads for 2020 could be supplied with no voltage support installed at the FNEI substations.

Furthermore, for this arrangement, the losses during the peak load periods for 2020 would be approximately 7MW.

This arrangement would also have the capability of supplying the mine load together with future load growth at Moosonee and the Five Nations communities well beyond 2020.

Table 4 shows that

The new 230kV line could be operated initially at **115kV**. With the following SVCs installed at the FNEI substations it is expected to be capable of supplying the full 27MW requirement of the Victor Mine through to approximately 2015:

- One SVC at Fort Albany S/S
- One SVC at Attawapiskat S/S, and
- Three SVCs at the Victor Mine

It is estimated that the losses for this arrangement during peak load periods in 2015 would be approximately 22MW.

The new line would then need to be uprated to **230kV** operation and the 230/115kV auto-transformer installed at Moosonee DS around 2015 for the facilities to be able to supply the full 27MW requirement of the Victor Mine in succeeding years.

Table 5 shows that

With the new 230kV line between Otter Rapids GS and Moosonee DS operating at **115kV** (or with a new 115kV line installed instead) AND with a new 115kV line connected in parallel with the existing FNEI circuit M3K between Moosonee DS and Fort Albany S/S, the full 27MW requirement of the Victor Mine together with the forecast loads for 2020 could be supplied with no voltage support installed at the FNEI substations.

For this arrangement, the losses during the peak load periods for 2020 would be approximately 11MW.

Table 6 shows that

With the same arrangement as above (with a new 115kV connection between Otter Rapids GS and Fort Albany S/S, via Moosonee DS), the full 27MW requirement of the Victor Mine together with the forecast loads for ***2030*** could be supplied with a single SVC installed at Kashechewan S/S or Fort Albany S/S.

For this arrangement, the losses during the peak load periods for 2030 would be approximately 14MW.

These results show that if a new 115kV line were to be constructed between Moosonee DS and Fort Albany S/S, and connected in parallel with the existing FNEI circuit M3K, then a new 115kV line between Otter Rapids GS and Moosonee DS would be adequate to supply the full 27MW requirement of the Victor Mine as well as the forecast loads at Moosonee and the Five Nations communities to at least 2030.

5.9 Comparison of System Losses for the Various Supply Options

For a supply of 27MW to the Victor Mine, with the Forecast Loads for 2020			
			Approximate Transmission Losses
1.	***115kV Transmission Option:***		
	1.1	With a dedicated 115kV line from Otter Rapids GS to the Victor Mine *Separate losses on the existing 115kV system (From SNC-Lavalin Report)*	***1.4MW*** *4.2MW*
2.	***230kV Transmission Option:***		
	2.1	With a new 230kV line from Otter Rapids GS to Moosonee DS	***20.0MW***
	2.2	With a new 230kV line from Otter Rapids GS to Moosonee DS + a 115kV line from Moosonee DS to Fort Albany S/S	***7.3MW***
3.	***Integrated 115kV Transmission Option:***		
	3.1	With a new 230kV line from Otter Rapids GS to Moosonee DS, operating at 115kV	***27.9MW***
	3.2	With a new 115kV line from Otter Rapids GS to Moosonee DS + a 115kV line from Moosonee DS to Fort Albany S/S	***10.8MW***

5.10 Termination & Energisation of the Proposed 115kV Line at Fort Albany S/S

Diagram 13 shows the proposed arrangement for incorporating the new 115kV line from Moosonee DS on to the 115kV busbar at Fort Albany S/S. This arrangement would require three new 115kV breakers to be installed to allow each of the circuits that terminate at that location to be separately switched.

In addition, although not shown on the Diagram, the two shunt reactors would have had to be reterminated so that they would be directly associated with the 159km L2 section of circuit M3K. This would ensure that the two reactors would be energised at the same time as the line section, and the terminal voltage would therefore maintained at an acceptable value.

A further reactor, which has not been included on the Diagram, would also be required for the energisation of the new 115kV line from Moosonee DS.

Further consideration has indicated that it would be better to extend the new 115kV a further 11km to Kashechewan S/S and terminate on to that 115kV busbar as shown in Diagram 14.

This would reduce the number of additional 115kV breakers that would be required to two, and also avoid having to reterminate the existing shunt reactors. It would also have the added benefit of concentrating all the 115kV circuit breakers at Kashechewan S/S.

Energisation of the 115kV line to Kashechewan S/S

The selection of the 3.4MVAr reactors (at 138kV) at Fort Albany S/S was based on an assumed fault level at that location of 85MVA (at 138kV) and the requirement to maintain the voltage change upon switching at 4%, or less. The corresponding fault level at Kashechewan S/S was quoted as 81MVA. *[From the SNC-Lavalin Report dated September 1997.]*

The installation of a second 115kV line between Otter Rapids GS and Kashechewan S/S would be expected to increase the fault level at Kashechewan S/S to approximately 145MVA (at 138kV). Consequently, with all the new line sections in-service, this would therefore allow a 5.8MVAr shunt reactor to be switched while respecting the 4% voltage change criterion.

Studies were performed with a nominal 5.5MVAr reactor (rated at 138kV) connected to the Kashechewan terminal of the proposed 115kV line from Moosonee DS. The results are summarised below:

For the revised arrangement as shown in Diagram 14 Energisation of the 115kV line between Moosonee DS to Kashechewan S/S (~ 170km)			
i. With the 5.5MVAr reactor at Kashechewan S/S out-of-service		Pre-Energisation	Post-Energisation
Voltages	Otter Rapids GS (115kV)	130.0kV	133.0kV
	Moosonee DS	132.3kV	136.2kV
	At the Kashechewan terminal	-	139.5kV
Reactive Power Output	Abitibi Canyon GS (115kV)	-4.7MVAr	-12.7MVAr
ii. With the 5.5MVAr reactor at Kashechewan S/S in-service		Pre-Energisation	Post-Energisation
Voltages	Otter Rapids GS (115kV)	130.0kV	130.6kV
	Moosonee DS	-	133.3kV
	At the Kashechewan terminal	-	133.6kV
Reactive Power Output	Abitibi Canyon GS (115kV)	-4.7MVAr	-9.5MVAr

These show that connecting a 5.5MVAr reactor directly to the proposed 115kV line between Moosonee DS and Kashechewan S/S would maintain an acceptable voltage at the line terminal upon energisation.

5.11 Contingency Analysis

Generation Option

Line Contingencies

For the Generation Option as originally proposed (Diagram 2), or as modified to enhance the supply capability that could be provided from the existing transmission facilities (Diagram 10), a contingency involving any part of the 115kV system (circuits C6R, L1, L2 or L3) would separate the Victor Mine, together with a portion of the FNEI system, from the remainder of the system.

For those generating units that were operational pre-contingency to be able to continue to supply the load at the Victor Mine following a line contingency, facilities would need to be installed to detect separation from the Hydro One system and to initiate isolation of the Victor Mine by tripping the line between Attawapiskat S/S and the Victor Mine. Automatic re-insertion of the 2.5MVAr shunt reactor at Attawapiskat S/S would also be required to limit the voltage rise at Attawapiskat S/S.

Similarly for a contingency involving the 115kV line between Attawapiskat S/S and the Victor Mine, automatic insertion of the 2.5MVAr shunt reactor at Attawapiskat S/S would be required.

Furthermore, whenever the Victor Mine is isolated from the system in response to a contingency, and depending on the pre-loading on the individual generating units and the extent of any supply that was being provided from the Hydro One/FNEI systems, load rejection at the Victor Mine could also be required.

Local Facilities

For the original arrangement, with only a single step-down transformer installed at the Victor Mine, a contingency involving this transformer would isolate the Victor Mine from the Hydro One/FNEI systems.

As before, depending on the pre-loading on the individual generating units and the extent of any supply that was being provided from the Hydro One/FNEI systems, load rejection at the Victor Mine would need to be initiated for this contingency.

For the enhanced arrangement, with two 20MVA step-down transformers installed at the Victor Mine, the post-contingency flow would remain within the rating of the remaining transformer, even with a maximum supply of 20MW being taken from the Hydro One/FNEI systems. In addition, the two SVCs at the Victor Mine would be capable of supporting the voltage at the Victor Mine, even if none of the local generating units was operating.

At high import levels, with no generating units operating at the Victor Mine, the loss of one of the SVCs would result in low voltages on the 13.8kV busbar. If load rejection were to be avoided for this contingency, then a minimum number of generating units would have to be maintained in-service. Alternatively a third SVC would need to be installed.

[Table 1.1 shows that for a 20MW supply to the Victor Mine, 21.5MVAr of reactive support (equivalent to two SVCs) would be required at the Victor Mine.]

Dedicated 115kV Transmission Option

Line Contingencies

For either the original arrangement (Diagram 3) or the modified arrangement (Diagram 6), a contingency involving the initial line sections (Otter Rapids to Moosonee DS in Diagrams 3 & 6 *OR* Moosonee DS to Attawapiskat S/S in Diagram 6) would separate the Victor Mine from the Hydro One system.

If any of the generating units were to be operating at the Victor Mine, then facilities would need to be available to initiate tripping of the transformers at the Victor Mine. A load rejection scheme would also be required so that sufficient load could be tripped to ensure that the remaining load at the mine remained within the capacity of those generating units that were operational.

Local Facilities

With two transformers at the Victor Mine, each rated at 30MVA, there would be sufficient capacity to supply the entire mine load with only a single unit in-service.

With three SVCs installed, a contingency involving a single SVC would leave sufficient reactive support available to maintain an acceptable voltage on the LV busbar.

[Table 3 shows that for a load of 27MW at the Victor Mine, and with a voltage of approximately 127kV maintained at Attawapiskat S/S, 22.4MVAr of reactive support (equivalent to two SVCs) would be required.]

Parallel Operation of the 115kV Facilities

As shown in Diagrams 6 & 7, facilities have been proposed to allow a limited supply to be provided to the Victor Mine when either the section of the new line between Otter Rapids GS and Moosonee DS, or the section between Moosonee DS and Attawapiskat S/S is out-of-service.

Under these circumstances, the extent of the supply capability to the mine would depend on the loads at Moosonee DS and the Five Nations communities, as well as on any decision to install SVCs at Moosonee DS and the FNEI substations.

If a subsequent line contingency involving circuit C6R were to occur, and if any of the generating units were to be operating at the Victor Mine, then facilities would need to be available to initiate tripping of the transformers at the Victor Mine to ensure its isolation from the system.

230kV Transmission Option

Line Contingencies

For the proposed arrangement (as shown in Diagram 5), a contingency involving the new 230kV line from Otter Rapids GS to Moosonee DS would require automatic load rejection at the Victor Mine. In addition, automatic tripping of the 6.5MVAr shunt reactor at the New Moosonee substation would be required to maintain an acceptable voltage at Moosonee DS.

If the SVCs that are shown in Diagram 8 were to have been installed, then this would limit the extent of the load rejection that would be required, particularly during periods of light load at Moosonee DS and the Five Nations communities.

The results of the studies in Section 5.4 of this Report for the Existing 115kV System, provide an indication of the supply capability that would be available with the proposed 230kV line out-of-service.

With the new 230kV line in-service, a contingency involving the existing 115kV circuit, C6R, would have no adverse impact on the voltages at Moosonee DS or the FNEI substations.

A contingency involving any section of the FNEI circuit, M3K, or the 115kV line from Attawapiskat S/S to the mine would require isolation of the mine together with automatic re-insertion of the 2.5MVAr shunt reactor at Attawapiskat S/S. In addition, if any generating units were operational at the mine, then automatic rejection of sufficient load would need to be initiated to ensure that the remaining load at the mine remained within the capacity of those generating units.

Local Contingencies

With three SVCs installed at the mine there would be sufficient reactive support available to respond to either the loss of one of the step-down transformers or one of the SVCs.

Staged 230kV Transmission Option

With the new 230kV line between Otter Rapids GS & Moosonee DS operating at 115kV

For this arrangement, with additional SVCs installed as shown in Diagram 11, a contingency involving either circuit C6R or the new line would require load rejection to be initiated at the Victor Mine, particularly during peak load periods at Moosonee and the Five Nations communities.

Furthermore, for a contingency involving the new line, a greater amount of load rejection would need to be initiated than for one involving circuit C6R, because of the more restrictive thermal rating of circuit C6R.

Integrated 115kV Transmission Option

With additional 115kV transmission facilities connected in parallel with the FNEI circuit M3K, as shown in Diagrams 13 & 14, the impact of a contingency involving circuit C6R or the new line between Otter Rapids GS and Moosonee DS would be reduced. However, the limited thermal rating of circuit C6R would remain an issue for contingencies involving the new line.

Furthermore, the new 115kV line between Moosonee DS and Fort Albany S/S (or Kashechewan S/S) would eliminate the need to initiate load rejection at the Victor Mine for contingencies involving the parallel section(s) of the FNEI circuit M3K.

5.12 Transfer of the 115kV-connected generating units at Abitibi Canyon GS

In all the analysis for the 115kV-related Options, the voltage at Abitibi Canyon GS was assumed to be maintained at approximately 130kV.

Should the two generating units that are presently connected to the 115kV busbar at Abitibi Canyon GS be transferred to the 230kV system, then the voltage on the 115kV system would then be controlled by the tap-changers on the 230/115kV auto-transformers at Spruce Falls TS (in Kapuskasing) and Ansonville TS (in Iroquois Falls). This would be expected to result in a reduction of the voltage at Abitibi Canyon GS to approximately 127kV.

A reduction in the voltage at Abitibi Canyon GS would have an adverse impact on the performance of the 115kV-related Options, and to ensure that the supply capability to the Victor mine would not be compromised, it might be necessary to implement one of the following measures:

- Install sufficient SVC capacity at Moosonee DS to be able to maintain an optimum voltage of approximately 130kV at that location

OR

- If the new transmission line between Otter Rapids GS and Moosonee DS has been insulated for eventual operation at 230kV, reconnect it to the 230kV busbar at Otter Rapids GS and install the auto-transformer at Moosonee DS, to coincide with the transfer of the two units to the 230kV busbar at Abitibi Canyon GS.

Alternatively, consideration could be given to the permanent connection of the step-up transformer, T1, at Otter Rapids GS together with the associated generating units G1 & G2, to the 115kV system so that they could be used to maintain the voltage at Otter Rapids GS to approximately 130kV.

5.13 Transient Stability Analysis

The following data were provided for the diesel generating units that it is proposed to install at the Victor Mine. These units are to be suitable for synchronisation and parallel operation with the system.

For the Generation Option they will normally be operated in parallel with the existing facilities, with a portion of the mine load being supplied from the system.

For the two Transmission Options, they are expected to be operate in parallel only when transmission elements are out-of-service, or, for the Hybrid Transmission/Generation Option, during those periods when the supply capability of the system is inadequate to supply all of the mine load.

Modelling Data

The following data were provided for the diesel generating units, but no modelling data were provided for the governors, the exciters or the power system stabilisers. Wherever data were unavailable, appropriate values were assumed.

Generator Parameters				
5.5MVA: 13.8kV units				
Excitation: PMG				
X_d	Unsaturated	1.208		
X_q		0.704	T'_{do}	4.436
X'_d		0.241	T''_{do}	0.044
X'_q		0.704	T'_{qo}	1.000
X''_d		0.159	T''_{qo}	0.022
X''_q		0.218	S (1.0)	0.30
X_l		0.010	S (1.2)	0.40
X_2		0.202	H	2.0kWsec/kVA
X_0		0.029	D	0.0

Assumed values (shaded cells)

Where data have had to be assumed, the Proponent will be responsible for ensuring that the equipment that is eventually installed meets or exceeds the values that are shown in Diagrams 15 to 18, inclusive, so that the performance will be equal to, or superior to that shown in the stability plots.

Diagrams 15, 16, 17 & 18 show the respective models that were used in the analysis for the generator, its governor, its exciter and its power system stabiliser, respectively.

Results of the Transient Stability Studies

A selection of the Plot Diagrams for the most severe transient stability cases as detailed in the following Table, have been included.

These studies were performed for the system configuration corresponding to the Generation Option, with no additional transmission facilities installed. The loads that were assumed at Moosonee DS and the Five Nations communities correspond to the peak load period for 2006.

Plot Diagrams for a Selection of the Transient Stability Studies	
Diagram No.	*Fault Condition*
Diagram 19	3-Phase fault on the LV Busbar at the Victor Mine
Diagram 20	3-Phase fault on Unit G2 at the Victor Mine
Diagram 21	3-Phase fault on the LV Busbar at Attawapiskat S/S
Diagram 22	3-Phase fault on 115kV Circuit C3H at Abitibi canyon GS
Diagram 23	
Diagram 24	3-Phase fault on the 115kV Circuit to the Victor mine

Discussion of the Transient Stability Studies

In all of the studies a fault clearance time of 82 milliseconds was assumed at the fault location, with clearance at the remote terminal, where appropriate, occurring after a further 33 milliseconds (for a total clearance time of 115 milliseconds).

Diagram 19 is for a normally-cleared 3-phase fault on the 13.8kV busbar at the Victor Mine that does not result in the loss of any of the generating units.

Five generating units were assumed to be in-service supplying approximately 16MW to the mine. The remaining requirements at the mine were supplied from the system.

The results show that all of the units remain stable, with acceptable machine damping.

Diagram 20 is for a similar LV 3-phase fault that results in the loss of one of the five generating units.

As before, all of the remaining generating units remain stable, with acceptable machine damping.

Diagram 21 is for a normally-cleared 3-phase fault on the LV busbar at Attawapiskat S/S.

The response of the generating units to this fault is much less severe (with a change in the rotor angle of less than 10^{o} compared to approximately 40^{o} for the disturbance shown in Diagram 19), which reflects the relative remoteness of the fault location.

As before, all of the generating units remain stable, with acceptable machine damping.

Diagrams 22 & 23 are for a normally-cleared 3-phase fault on the 115kV circuit C3H at Abitibi canyon GS.

This fault results in the greatest disturbance of the generating units at the Victor Mine, resulting in a change in the rotor angle of approximately 45^{o}.

However, as shown in Diagram 22, all the generating units at the Victor Mine remain stable, with acceptable machine damping. Diagram 23 shows the effect of the fault on other generating units at selected locations. The greatest impact, after that on the generating units at the Victor Mine, occurs on the 115kV-connected units at Abitibi Canyon GS, followed by the generating units at the Mattagami River plants (represented by Kipling GS). However, the impact at Abitibi Canyon GS and at Kipling GS is negligible.

Diagram 24 is for a normally-cleared 3-phase fault at the Victor Mine terminal of the 115kV circuit between Attawapiskat S/S and the mine.

This fault isolates the mine from the system, resulting in islanded operation of the generating units at the mine.

The results show the generating units increasing their aggregated output from approximately 16MW to the 22MW that was assumed for the study.

The results also show the effect of the power system stabiliser that is tending to prolong the oscillations unnecessarily. Automatic tripping of the power system stabiliser should islanding of the Victor Mine occur is therefore recommended. However, since the continued operation of the power system stabiliser under these conditions would have no adverse impact on the IMO-controlled grid, it is not an IMO-requirement.

Separation of the Victor Mine for External Contingencies.

If any of the generating units at the Victor Mine are to be operated in parallel with the Hydro One/FNEI transmission systems for any of the arrangements that have been examined, then it is recommended that facilities be installed to detect separation of all, or a portion of the FNEI system, and initiate isolation of the Victor Mine, by tripping the line between Attawapiskat S/S and the Victor Mine.

e.g.

The following contingencies would isolate the Victor Mine with all or part of the load at Moosonee & the Five Nations communities:

i. *For the Generation Option, shown in Diagrams 2 & 10*

Contingencies involving circuits C6R, L1, L2 or L3

ii. *For the 230/115kV Transmission Option, shown in Diagrams 4 & 11*

Contingencies involving circuits L1, L2 or L3

OR

Contingencies involving either C6R or the parallel 230kV or 115kV line, when the companion circuit is out-of-service.

iii. *etc.*

Unless this response is initiated, the generators at the Victor Mine could end up trying to supply additional load to that at the Victor Mine.

5.14 Reactive Compensation following Generation Rejection in response to a 500kV contingency

The existing Hydro One transmission system in north-eastern Ontario consists of a single-circuit 500kV connection between Hanmer TS (in Sudbury) and Pinard TS (in Fraserdale), via Porcupine TS (in Timmins). A 115kV connection is operated in parallel with the 500kV line between Hanmer TS and Porcupine TS.

In the event of a contingency involving the 500kV line, sufficient generating capacity has to be rejected to ensure that the post-contingency flow on the parallel 115kV connection is maintained within very tight limits so that the remaining generation capacity does not become unstable.

With reduced post-contingency transfers on the 500kV circuit between Porcupine TS and Pinard TS, very high voltages can be experienced at Pinard TS. To ensure that the post-contingency voltages remain within the rating of the existing equipment, minimum reactive power requirements (absorption) that must be maintained on the system, post-contingency, have been specified. These include the two 60MVAr shunt reactors that are connected to the tertiary windings of the two 500/230kV auto-transformers at Pinard TS.

Installing a new 144km 230kV line between Otter Rapids and Moosonee DS would add approximately 20MVAr to 30MVAr reactive power output, depending on the voltage at which it is operated and the transfers on it. It was expected that the additional reactive power output from the new line would require additional post-contingency compensation to be available to ensure that acceptable voltages could be maintained.

Preliminary studies indicated that the effect of the new line would be off-set by the post-contingency reactive power flows to the 115kV system via the 230/115kV auto-transformer that would be installed at Moosonee DS as part of this development. Consequently only a minor increase in the voltage at Pinard TS was detected for the conditions with, and without, the new 230kV line to Moosonee DS.

However, since more rigorous studies of the post-contingency performance of the system following a contingency involving the 500kV circuit between Hanmer TS and Porcupine TS could still determine a need for additional reactive compensation, the installation of shunt reactors on the tertiary windings of the 500/230kV auto-transformers at Pinard TS could become a requirement for implementation of the 230kV Transmission Option.

6. IMO Requirements for connection to the IMO-controlled grid

Each of the proposed connection arrangements would be acceptable to the IMO, subject to meeting the following requirements:

6.1 Generation Option

The generation option, as originally proposed, would allow a limited supply (between 5MW and 8MW) to be taken from the existing system, with the remainder of the requirements of the mine being supplied via the local generation facilities.

However, as indicated in this Report, installing additional SVCs at the FNEI substations would allow the amount of power supplied to the mine from the existing transmission facilities to be increased as shown in the following Table.

If it is intended to make use of this increased supply capability then it is recommended that the new 115kV line between Attawapiskat S/S and the Victor Mine be equipped with **795kcmil** conductors.

With the existing transmission facilities	***2006***	***2010***		***2020***
Approximate Supply Capability to the Victor Mine Restricted by the thermal rating of circuit C6R	*20MW*	*18MW*	*20MW*	*14MW*
SVC Requirements (+10/-13MVAr units):				
Moosonee DS	1	1	2	2
Fort Albany S/S	1	1	1	1
Kashechewan S/S	-	-	1	-
Attawapiskat S/S	½ (5MVAr unit)	½ (5MVAr unit)		½ (5MVAr unit)
Victor Mine	Two +12/-15MVAr SVCs			

Proposed Arrangement for the Generation Option

The proposed arrangement for the Generation Option is shown in Diagram 10.

The particular SVCs that have been included in the Diagram correspond to the peak loading conditions for 2006 and 2010 (which would be expected to provide a supply capability to the mine during peak load periods of approximately 18MW).

Two SVCs have been shown in the Diagram at the Victor Mine, which would provide adequate support for a supply of approximately 20MW to the mine from the system. However, it is recommended that consideration be given to installing a third unit to cater for the situation when one SVC is out-of-service, while also providing support for higher transfers to the mine during light load periods as long as the flows on circuit C6R remain within its thermal rating.

In addition, facilities are required to be available that would allow the shunt reactor at Attawapiskat S/S to be automatically re-inserted following a contingency that results in isolation of the Victor Mine from the system.

6.2 115kV Transmission Option

While the dedicated 115kV connection to the mine would be able to supply the full 27MW required by the mine, it would be susceptible to contingencies involving the 515km line, or to outages involving the 24MVAr variable reactor at its remote terminal.

To provide added security, it has been recommended that an additional 115kV circuit breakers be installed at Attawapiskat S/S. This would then allow a synchronous connection to be provided from Attawapiskat S/S via the final 100km line section to the mine.

With an additional 115kV breaker installed at Attawapiskat S/S, a 15MVAr variable shunt reactor will need to be installed at Attawapiskat S/S, connected directly at the end of the 115kV line section from Moosonee DS.

Three +12/-15MVAr SVCs would need to be installed at the Victor Mine site to provide adequate compensation for energising the line from Attawapiskat S/S and to cater for local contingencies. In addition, whenever the mine is supplied from the FNEI circuit, facilities are required to be available that would allow the shunt reactor at Attawapiskat S/S to be automatically re-inserted following a contingency involving the connection to the mine.

The proposed arrangement is shown in Diagram 6.

Should it also be required to maximise the supply capability to the mine whenever the section of the new line between Moosonee DS and Attawapiskat TS is out-of-service, then additional SVCs would need to be installed at Fort Albany S/S and Attawapiskat S/S.

6.3 230kV Transmission Option

As discussed in this Report, this alternative has many variations, all of which would be acceptable to the IMO:

i. With a 230kV line between Otter Rapids GS and Moosonee DS, together with an SVC located at Fort Albany S/S and Attawapiskat S/S.

   The proposed arrangement is shown in Diagram 8.

   For this arrangement the shunt reactor at the New Moosonee S/S is required to be in-service pre-contingency. Facilities will be required to automatically cross-trip this reactor following a contingency involving the new 230kV line. In addition, facilities to auto-insert the shunt reactor at Attawapiskat S/S following a contingency involving the 115kV circuit to the mine will also be required.

   With SVCs installed at Fort Albany S/S and Attawapiskat S/S, there would be an opportunity to operate the new line at 115kV until approximately 2015. It would then be necessary to uprate it to 230kV operation and install the 230/115kV auto-transformer at Moosonee DS.

ii. Installing a 115kV line between Moosonee DS and Kashechewan S/S (or Fort Albany S/S) would reduce the very high losses on the FNEI circuit M3K, and also avoid the requirement for SVCs at the FNEI substations.

   The new 115kV line would require a 5.5MVAr shunt reactor to be installed at its remote terminal for line energisation.

   The proposed arrangement is shown in Diagram 14.

iii. If a new 115kV line is to be constructed between Moosonee DS and Kashechewan S/S (or Fort Albany S/S), then the new line between Otter Rapids GS and Moosonee DS could be constructed for operation only at 115kV.

   This arrangement, with no SVCs installed at any of the FNEI substations would be adequate for the entire 27MW requirement of the mine together with the projected local loads through to 2030.

6.4 General (Common) Requirements

Generator, Exciter, Governor & Power System Stabiliser Data

Appropriate data are to be provided where they were missing or unavailable.

Power System Stabilisers will need to be installed to ensure stable post-contingency performance of the generating units at the Victor Mine.

Facilities are required to automatically disable the Power System Stabilisers should the Victor Mine facilities become islanded.

Load Rejection

Load Rejection Schemes will be required for the Transmission Options as well as for the Generation Option if a supply is to be taken from the system that exceeds the capability of the operational generating units at the Victor Mine to automatically 'pick-up'.

These schemes need to be 'connectivity based'. This means that the signal that initiates the required load rejection is to be derived from a change in status of the circuit breakers associated with a particular transmission element.

The schemes are also required to be fully duplicated.

Communications

Suitable communications will need to be provided for the following:

- To initiate load rejection
- For remote control and monitoring of circuit breakers, disconnect switches and circuit switchers
- For protective relaying and transfer trip signals
- For disabling of the Power System Stabilisers should the Victor Mine become islanded
- For the control and the automatic post-contingency switching of the shunt reactors
- etc.

It is therefore strongly recommended that wherever new transmission lines are to be built, consideration be given to the use of optical fibre skywires to provide reliable and secure communication paths.

Breakers

In view of the harsh environment, the IMO recommends that all breakers be equipped with heater blankets.

Static VAr Compensators

These devices must be capable of delivering their full inductive capability upon energisation, so that, for the suggested rating of +12MVAr capacitive and -15MVAr inductive, the device would appear to have a net value of -3MVAr inductive. Only when the SVC has been energised can the thyristors then start to adjust the current to vary the inductive portion of the SVC.

Variable Shunt Reactors

The reactance of these devices should change by increments of approximately 1MVAr, with a minimum reactance no greater than 2MVAr or 3MVAr. At this minimum value, it would be possible to respect the 4% 'abrupt voltage change limit' whenever it is necessary to switch the reactors out-of-service.

Auto-reclosure

Appendix 4.4 - Transmitter Requirements of the Market Rules, states:

> Transmission circuits shall be equipped with timed, single-shot automatic re-closing facilities.

Following a contingency either the 115kV or the 13.8kV breakers associated with the step-down transformers would trip to isolate the Victor Mine from the system. The mine load would then be supplied from the local generation capacity at the mine.

However, in order to be able to attempt to restore the system supply without interrupting the operation of the mine, the layout of LV busbar should be designed to allow the generating units and the load to be automatically disassociated from the step-down transformers and the SVCs. This would then allow the transformers and the SVCs (which should have reverted to their full inductive mode) to be reconnected to the 115kV line from Attawapiskat S/S in preparation for re-energisation of the line.

This arrangement would also ensure that the generators are isolated from the system before auto-reclosure is attempted.

Facilities will also be required for synchronising the operational portion of the mine to the system, following separation. The synchronising breakers should also be capable of withstanding a voltage of at least two per unit across their open terminals.

7. Approximate Cost Estimates

An attempt has been made to provide approximate cost estimates for the work that would need to be done for the various options under consideration.

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

It should also be noted that, for those situations that involve modifications to existing facilities the extent of any associated upgrades to station buswork is unlikely to be known until a detailed review of the existing station facilities has been undertaken.

7.1 A 144km 115kV line between Otter Rapids GS & Moosonee DS, equipped with 795kcmil conductors

Estimated Cost ≈ \$23 to \$25 million

7.2 A 170km 115kV line between Moosonee DS & Kashechewan S/S, equipped with 795kcmil conductors

Estimated Cost ≈ \$27 to \$29 million

7.3 A 270km 115kV line between Moosonee DS & Attawapiskat S/S, equipped with 1192.5kcmil conductors

Estimated Cost ≈ \$48 to \$51 million

7.4 A 100km 115kV line between Attawapiskat S/S & the Victor Mine, equipped with 795kcmil conductors

Estimated Cost ≈ \$16 to \$18 million

7.5 A 144km 230kV line between Otter Rapids GS & Moosonee DS, equipped with 795kcmil conductors

Estimated Cost ≈ \$30 to \$36 million

7.6 A 75MVA 230/115kV auto-transformer

Estimated Cost ≈ $5 to $7 million

7.7 Each 115kV breaker

Estimated Cost ≈ $1.5 to $2 million

7.8 Each SVC

Estimated Cost ≈ $2 to $3 million

7.9 Each 115kV shunt Reactor, including a circuit switcher

Estimated Cost ≈ $2 to $3 million

8. Identification of 'Sole Beneficiary'

Section 9.1.3 of the Transmission System Code states:

> *The cost of modifications and upgrades on specific network facilities that are triggered by and are for the sole benefit of the generator shall be borne by the generator.*

The IMO considers the following system modifications to be for the 'sole benefit' of the Victor Mine Project Project:

i. The 115kV line between Attawapiskat S/S and the Victor Mine, including the termination at Attawapiskat S/S. (For the Generation Option and the 230kV Transmission Option.)

ii. The scheme for the auto-insertion of the shunt reactor at Attawapiskat S/S following a contingency involving the 115kV line to the mine.

iii. The dedicated 115kV line from Moosonee DS to the Victor Mine. (For the 115kV Transmission Option.)

9. Customer Impact Assessment

Hydro One Networks Inc. and Five Nations Energy Inc. have informed the IMO that a Customer Impact Assessment will be required to determine whether the proposed facilities could have an adverse impact on the existing supply facilities to Moosonee and the Five Nations communities.

De Beers Canada Exploration Inc. has elected to postpone this phase of the process. This Report has therefore been finalised but should any issues be raised when the Customer Impact Assessment is subsequently undertaken, then they will be addressed through an Addendum to the PA Report.

10. Notification of Approval of the Connection Proposal

Subject to the completion of the Customer Impact Assessments by Hydro One Networks Inc. and Five Nations Energy Inc., and the satisfactory resolution of any issues that may raised, it is proposed to issue a Notification of Approval to Connect for this Project