



TRANSMISSION PLANNING & DESIGN DIVISION

SYSTEM PLANNING
DEPARTMENT

REPORT ON

MINIMUM TRANSMISSION REQUIREMENTS FOR
HVDC BULK SYSTEM RELIABILITY
SPD 01/7



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EXECUTIVE SUMMARY

Safe and reliable operation of the Manitoba Hydro HVdc system is important to all customers of the utility. As load grows within the province, dependency on the HVdc system assumes increasing importance.

Recent concerns have centered around catastrophic type outages to HVdc facilities. The potential loss of Dorsey station for a one to three year period and the potential loss of the HVdc lines for up to two months are key considerations. Manitoba Hydro suffered a catastrophic outage to its HVdc facilities on September 5th, 1996 when nineteen towers in total on both HVdc lines blew down during a strong wind event. The combination of low Manitoba load, location, and extent of damage made this event less problematic than it might otherwise have been.

At various times in the past, Manitoba Hydro was contemplating a third bipole and possibly a fourth, due to either fast developing load growth or to a major sale commitment as to Ontario in the early 1990's. Additional bipole(s) with a separated corridor location and separated converter locations would have lessened the dependence on any single HVdc corridor or station.

In assessing the risk to our HVdc facilities, Manitoba Hydro has contracted Teshmont Consultants Inc. to provide a more thorough analytical approach. Teshmont and its sub-contractors have shown significant risk to our HVdc facilities. The major risks are wind, ice, fire, and terrorism/ sabotage.

To address the loss of the two HVdc lines in the common corridor, which may also involve the loss of significant parallel ac transmission, it is recommended to construct a +/- 500 kV HVdc transmission line on the east side of Lake Winnipeg from a point near Radisson station to Riel station. Additionally a paralleling line is recommended to be constructed between Riel and Dorsey. The line essentially pays for itself by assigning a value to the reduction of losses on the HVdc system. The availability of this line also provides very significant benefits to the reliability of the electric power supply in Manitoba, especially as it will likely be built to a higher standard than the Bipole I and II lines.

A second recommendation is to establish sectionalization of the major 500 kV ac line D602F at the Riel site. This work will also involve sectionalization of certain 230 kV lines that are in close proximity to the Riel site. Riel sectionalization provides an alternative import location for D602F power after the catastrophic loss of Dorsey station. It also provides a convenient location for spare 230/500 kV autotransformer capacity.

The construction of the Bipole III line and/or sectionalization neither commits Manitoba Hydro to, nor counts on, any specific

generation expansion sequence. However, it does enhance generation alternatives for which HVdc is required.

Recommendation of the Bipole III line is firm and is based on loss reductions and on reliability benefits. Planning studies for Riel sectionalization with Bipole III are still being conducted. Some operational situations will necessitate opening of the Riel sectionalization. If such situations are extensive and credible technical fixes are not available, then judgments will be required as to the desirability of alternate solutions. Such solutions are more costly and more complex.

Riel sectionalization and the Bipole III line are recommended independently of each other and independently of any future generating station. Riel sectionalization costs \$73M (2001) without interest and escalation and has an in service date of September 2008. Building of the Bipole III line with the paralleling line costs \$247M (2001) without interest and escalation and has an in service date of October 2010.

The sectionalization of the 500 kV line is being proposed at this time before detailed studies are complete in order to place this item in the capital budget.

SECTIONALIZATION OF DORSEY-FORBES 500 kV LINE D602F AT RIEL

CAPITAL PROJECT JUSTIFICATION

Project Description

Riel 230 kV and 500 kV buses are developed including the necessary transformation to accommodate the sectionalization of the Dorsey to Forbes 500 kV ac line, and the sectionalization of three existing 230 kV transmission lines.

Recommendation

Sectionalize Dorsey to Forbes 500 kV line D602F at Riel, including 230 kV to 500 kV transformation, and sectionalize the 3 existing 230 kV lines R32V, R33V, and R49R at Riel.

Project Scope

Includes the establishment of Riel Station, the installation of a 230 kV bus with 3 bays, the installation of a 500 kV ring bus, the installation of a 230 kV to 500 kV transformer bank, and installation of 500 kV line reactors with salvaging of the reactors at Dorsey.

Background

This project is being recommended based on its significant reliability benefits as presented in the report, Manitoba Hydro Transmission System Reliability and Enhancement Options, which will be released in the fall of 2001.

Justification (BCA and Link to Corporate/Business Unit Goals)

The sectionalization of the 500kV line allows power to be imported on the 500 kV line during a catastrophic Dorsey outage. The sectionalization also provides an alternative path for power export on the 500 kV line during the outage of a Dorsey 230-500 kV transformer. The critical importance of the 500 kV line for import capability is discussed in the report referenced in the Background section.

Risk Analysis

Provides critical import capability from the 500 kV line at Riel for a catastrophic Dorsey outage, to avoid or minimize provincial rotating blackouts.

Risk Analysis is documented in System Planning and Resource Planning and Market Analysis joint report on Manitoba Hydro Transmission System Reliability and Enhancement Options, to be released in the fall of 2001.

Related Projects And Reference Documents

RADISSON to RIEL ± 500 kV HVDC LINE, other projects may be recommended in the Reference Document which is to be released in the fall of 2001.

This project is recommended in the report, Minimum Transmission Requirements for HVDC Bulk System Reliability, which also recommends the Radisson to Riel ± 500 KV HVdc transmission line.

These two projects are the first recommendations to which come out of the work associated with the report, Manitoba Hydro Transmission System Reliability and Enhancement Options, which will be released in the fall of 2001.

RADISSON to RIEL \pm 500 KV HVDC LINE

CAPITAL PROJECT JUSTIFICATION

Project Description

An 800 km, \pm 500 kV dc transmission line is constructed between the proposed Bipole I and II emergency paralleling site near Radisson and the proposed Riel site. A dc paralleling line is constructed between the proposed Riel site and Dorsey Station to provide HVDC transmission during an Interlake corridor loss. Before Bipole III is in service, the new line will be used for Bipole II and the existing Bipole I & II lines are paralleled for Bipole I, resulting in loss savings of about 78 MW at maximum generation.

Recommendation

Build an 800 km, \pm 500 kV dc transmission line between the proposed Bipole I and II emergency paralleling site near Radisson and the proposed Riel site, and build a dc paralleling line between the proposed Riel site and Dorsey station.

Project Scope

Includes the 500 kV dc transmission line from near Radisson to Riel, and a paralleling line from Riel to Dorsey.

Background

This project is being recommended based on the economics of up to 78 MW of HVDC transmission power loss savings and reliability benefits discussed in the report, Manitoba Hydro Transmission System Reliability and Enhancement Options, which will be released in the fall of 2001.

Justification (BCA and Link to Corporate/Business Unit Goals)

This transmission only alternative provides increased reliability to the Manitoba Hydro system. In normal steady-state operation, this item provides an increase in southern power of about 78 MW at full load due to decreased HVDC transmission losses.

Risk Analysis

Risk Analysis was documented in System Planning and Resource Planning and Market Analysis joint report on Manitoba Hydro Transmission System Reliability and Enhancement Options.

Related Projects And Reference Documents

SECTIONALIZATION OF LINE D602F AT RIEL

This project is recommended in the report, Minimum Transmission Requirements for HVDC Bulk System Reliability, which also recommends Sectionalization of the 500 kV line D602F at Riel.

These two projects are the first recommendations to which come out of the work associated with the report, Manitoba Hydro Transmission System Reliability and Enhancement Options, which will be released in the fall of 2001.

INTRODUCTION

The ongoing reliability of the bulk HVdc system has been a concern for many years. Of special significance is the susceptibility of our HVdc system to major events, generally referred to as catastrophic outages. Examples of recent major catastrophic events would be the double HVDC line loss experienced by Manitoba Hydro in September of 1996 and the Quebec ice storm in January 1998. In order to quantify the overall risk of catastrophic HVdc system outages, Manitoba Hydro, in conjunction with a number of consultants, produced a reliability assessment of its bulk HVdc facilities. The draft report, produced in the fall of 2000, showed a susceptibility of our system to these types of catastrophic outages, and that the problem is expected to get worse over time with the growth in domestic load.

Further analysis, which will be included in the final report in the fall of 2000, will confirm and extend the risks to which our HVdc facilities are subjected. This report will recommend minimum requirements to begin to address HVdc bulk system reliability issues. The final report may define further requirements.

RECOMMENDATIONS

1. Sectionalization of line D602F at the Riel site be placed in the budget with an in-service date of September 2008. Sectionalization will include development of the Riel site, 500/230 kV transformation, plus sectionalization of a number of 230 kV lines into Riel station. The estimated cost is \$73M in year 2001 dollars not including interest and escalation.
2. A 500 kV HVdc line be constructed on the east side of Lake Winnipeg from a point just south of the proposed Keeyask generating station to the Riel station with a further paralleling line constructed between Dorsey and Riel. The estimated cost is \$247M in year 2001 dollars not including interest and escalation with an in service date of October 2010.

BACKGROUND

HVdc catastrophic analysis revolves around two main risks. The first is the loss of the HVdc lines with possible additional loss of parallel ac transmission, which generally is not as severe as the catastrophic loss of converter equipment but with a much higher probability of occurrence due to the 900 km of exposure. The second is the loss of HVdc converter equipment that has a much lower probability of occurrence but with much more severe consequence with possible year or more repair times. The converter station risk will focus on Dorsey station due to the higher power concentration in that station as compared to either Radisson or Henday.

An important background to this report is included as Appendix A. This memorandum presents probabilities and outage durations related to Dorsey and the HVdc lines.

A second important memorandum is included as Appendix B. In this memorandum, a range for reliability worth is given plus an economic benefit is assigned to the reduction in losses from a third bipole transmission line. It should be noted that the recommendations contained herein are essentially driven by economic analysis but that the ultimate and full recommendations in the fall report may be partly driven by criteria under development.

Bipole III Line

The Bipole III line (figure 1a) includes two components in its justification. The first component is related to loss reduction. If the HVdc line is built in advance of any converter capacity, then the Bipole III conductors can be effectively paralleled with existing conductors, to reduce transmission losses in bringing Nelson River power to southern Manitoba (figure 1b). The concept would be to attach Bipole II converters to the proposed eastside Bipole III transmission line and to attach Bipole I converters to both of the existing HVdc lines in parallel. At full peak generating power, this results in a loss saving of 78 MW. The economic analysis in Appendix B shows that the new line is essentially justified on loss savings alone.

The second component relates to reliability and Appendix B shows significant reliability benefit to the presence of the Bipole III line. An important finding of recent analysis done on the susceptibility of the HVdc lines to ice storms is that such events may be widespread geographically, to the extent that the damage may overwhelm the capacity of the Corporation to restore the lines in relatively short order. The result is a possible two month outage to restore the lines. The winter time frame leads to possible difficulties in construction and also a higher load to serve. It should be noted that the Bipole III line will likely be constructed

to a higher standard than either Bipole I or II, making it less prone to catastrophic events.

The construction of the Bipole III line will require a paralleling line between Riel and Dorsey stations. The paralleling line will be required to carry +/- 500 kV dc, with the appropriate switches at the Riel and Dorsey stations to allow paralleling. Physically, the paralleling line will appear as a three phase 500 kV ac transmission line. In the ultimate concept, when not operating in a paralleling mode, the new line may be operated as either 230 or 500 kV ac, depending on further analysis of the many options proposed. Until continuously operational converter capacity is established at Riel, the paralleling line will normally be operated at up to +/- 500 kV dc to reduce HVdc operational losses. At this time, it is not certain if the new line should be located on the north or south corridor around the city of Winnipeg.

D602F Sectionalization at Riel

Appendix B shows a range to the reliability worth for the loss of Dorsey station. A catastrophic Dorsey station loss would not only lose converter capacity, but also disable D602F 500 to 230 kV transformation, somewhat restrict 230 kV ac transmission from the north and restrict 230 kV transmission around Winnipeg. Riel sectionalization (figure 2) provides an alternate infeed for D602F power into southern Manitoba and helps with the restriction of 230 kV transmission around Winnipeg. Because of increased losses in the system, Riel sectionalization initially would normally be operated open. It does provide backup for a Dorsey 230/500 kV autotransformer loss.

The reliability analysis shows sufficient worth to justify the Riel sectionalization. It should be pointed out that of the \$73M cost of the Riel sectionalization, approximately \$47M is attributed to the development of the Riel site itself, costs which would need to be incurred if Bipole III were to proceed.

The Manitoba Situation

With over 70% of Manitoba's generating capacity in a single 900 km long corridor and with that power flowing through a single complex station in Dorsey, Manitoba Hydro can be considered unique in terms of its susceptibility amongst utilities in the first world. In consideration of this statement, it is important to define the basis for comparison.

- 1) High percentage of power concentrated in a single corridor or a single station: There are a limited number of situations worldwide where this statement is true and where there are insufficient alternative reserves to meet load. The 900 km length of the HVdc corridor is also longer than what is normally seen in critical corridors.

- 2) The consequences of not meeting load: Appendix C contains a memorandum from the Transmission System Operations division on the difficulties that would be experienced in managing a chronic supply shortage. The difficulties are especially onerous in the winter months, possibly leading to further damage and unserved load within the system from chronic low temperature switching. The winter months would bring an increased possibility of loss of life.
- 3) Time to restoration: The HVdc lines are a relatively simple restoration. However, as stated earlier, certain events may be so widespread that they would overwhelm the supplies at hand, delaying restoration. Dorsey station contains extensive specialized complex equipment of which there are only a few manufacturers. Complete devastation of the Dorsey station would take a monumental effort in resources and time to fix.

The first two points are sufficient, in our opinion, to make us unique in the world. The third point widens the gap. A survey performed earlier by Teshmont Consultants showed many utilities cover for the loss of a major station without benefit of a probabilistic analysis. Although probabilities are relatively low, a catastrophic event could still happen tomorrow and the consequences to Manitoba Hydro and the Manitoba economy would be severe.

CONCLUSIONS

Justification of D602F line sectionalization at the Riel site and building of an eastside HVdc transmission line has been made. The justification has been primarily on economics. The final report on HVdc bulk system reliability, scheduled for the fall of 2001, may recommend further reliability enhancements based on some combination of economics and criteria.

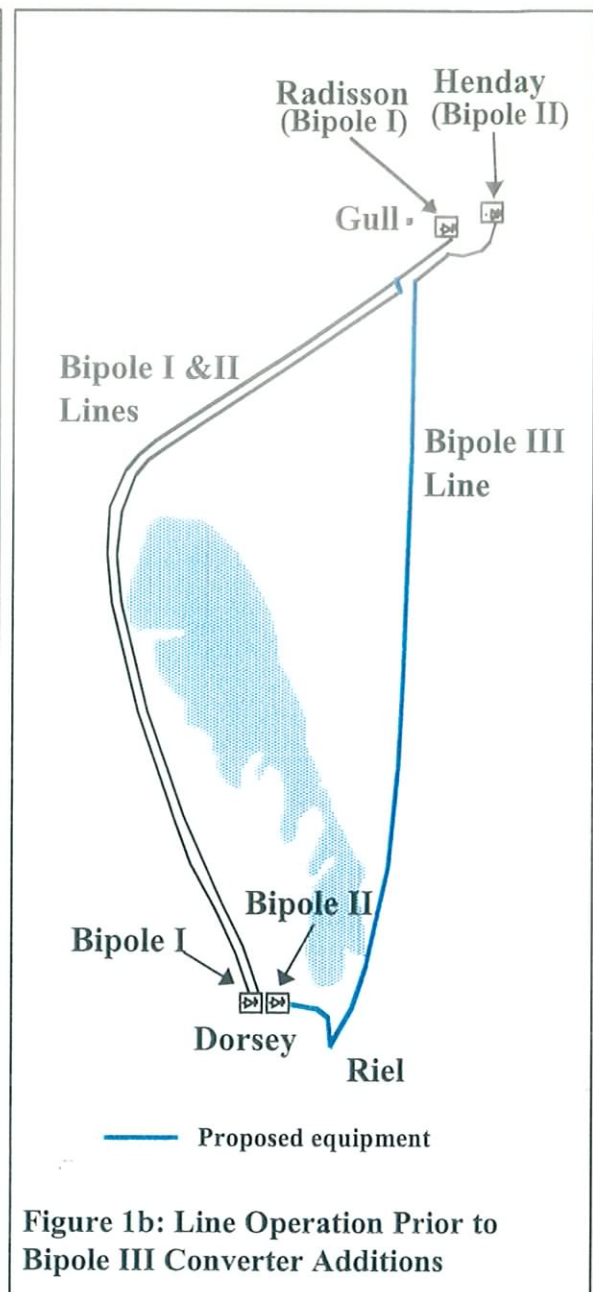
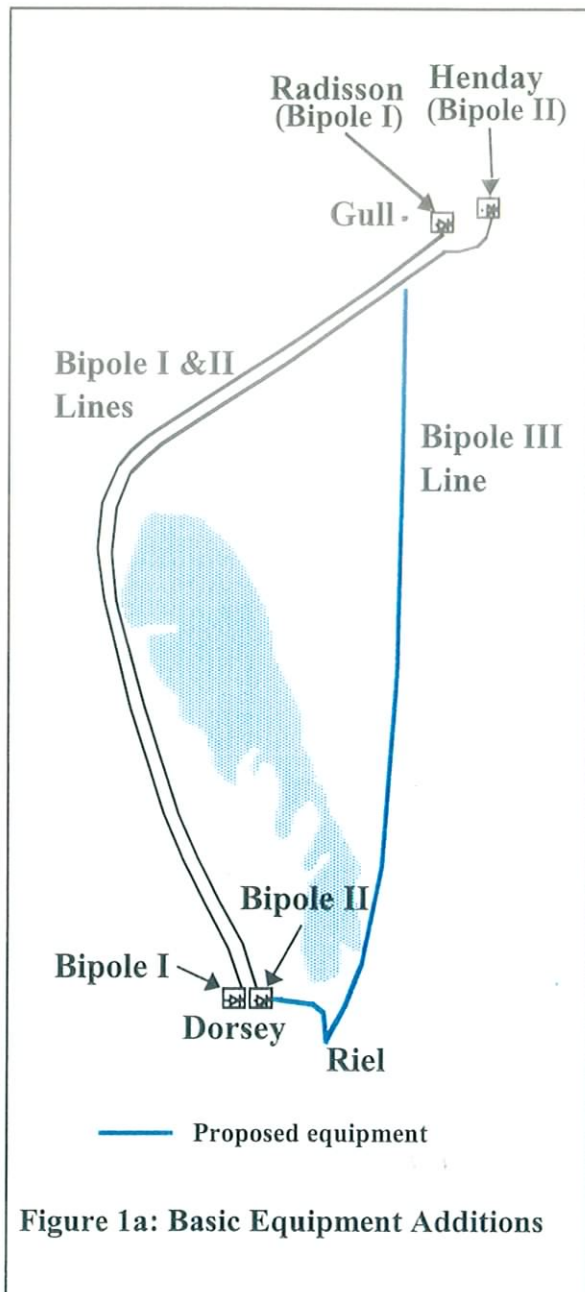


Figure 1: T2 - ± 500 kV line as a spare for Bipole I & II

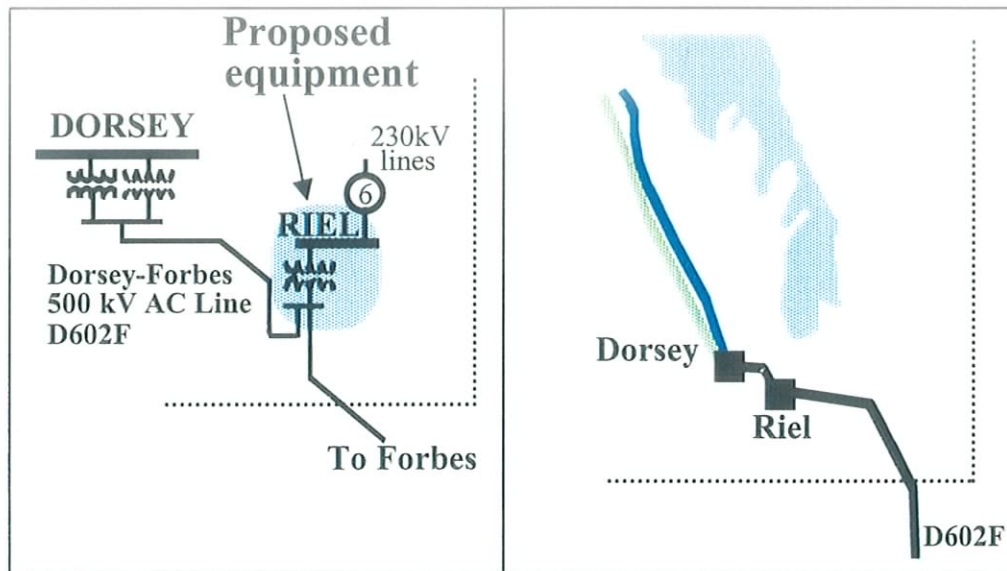


Figure 2: T1 - Sectionalization of D602F at Riel

APPENDIX A

TO See Below

FILE 6-7A

SUBJECT PROBABILITIES AND OUTAGE DURATIONS FOR HVDC FACILITIES

The attached table provides probabilities and associated outage durations for Dorsey station and for the HVdc lines. This document is an update of an earlier memorandum [1] and is based on recent work done by Teshmont and its sub-contractors. Probabilities are not given for Radisson and Henday because converter station arguments are dominated by Dorsey.

The structure of the table is to divide the probabilities into three distinct categories. Category I is classified as very severe, category II severe, and category III of concern. Category III items are remote enough that reliability benefits need not be assigned, however the Corporation should remain diligent that Category III threats do not rise in significance.

Many of the probabilities seen in the table will not be explicitly found in any of the supporting documentation. Rather, the probabilities and concepts in the supporting documentation corroborate the category probability, even after improvements that have been suggested, as in fire.

It is believed that this is the fairest and most defensible treatment of probabilities given the uncertainties in analysis.

[1] J.B. Davies to C.V. Thio, Reliability Numbers for Bipole III Studies, File 6-7A, 2000 05 02.

Original signed by J.B. Davies

JBD/memo.riskIII

Cc: V.J. Steciuk
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HVDC FACILITIES RISK TABLE

Category ¹	Event Located at Converter Station (Dorsey) ²				Event Located Along HVDC Transmission Line		
	Event Description	Probability ³	Season	Outage ⁷ Duration	Event Description	Probability ³	Season Outage ⁷ Duration
Category I (very severe)	Fire ⁶ , Terrorism, Sabotage	0.001 (1/1000 yr.)	Winter or Summer	2 months	Terrorism, Sabotage, ice storm	0.02 (1/50 yr.)	Winter ⁵ 2 weeks
		0.001 (1/1000 yr.)	Winter or Summer	6 months		0.0033 (1/300 yr.)	Winter ⁵ 2 months
Category II (severe)	Tornado, Microburst	0.00046 (1/2200 yr.)	Summer	1 month	Tornado, Microburst	0.056 (1/18 yr.)	Summer 1 week
		0.00025 (1/4000 yr.)	Winter or Summer	1-3 years ⁸		0.033 (1/30 yr.)	Summer 2 weeks
Category III ⁴ (of concern)	Train Derailment, Airplane Crash, Flooding				Airplane Crash		

Notes:

- 1) The combination of frequency, time of year, and outage duration makes Category I events very severe for the Corporation. Similarly, Category II events are severe and category III are of concern. Separation was done in each of the categories for converter stations and the HVDC lines.
- 2) Converter station outage is represented by Dorsey since it is most problematic. It should be understood that Radisson and Henday are subject to mostly the same catastrophes but with different probabilities and outage durations.
- 3) All category probabilities are consistent with probabilities and risks derived in individual reports.
- 4) Probabilities were not developed for Category III events, as they are deemed remote enough as to not have a significant calculable reliability benefit. Good practice would consist of maintaining those probabilities low, for example by warning aircraft to avoid Dorsey or the lines.
- 5) In Category I – HVDC Lines, the event is listed as only winter even though terrorism or sabotage could occur at any time of year. It is likely ice storm probabilities dominate (no explicit probability was advocated for terrorism/sabotage). Regardless winter will be most onerous.
- 6) The fire probability assumes a full and aggressive campaign in dealing with existing fire issues raised by the consultant. Otherwise the probability is much higher. The 6 month outage especially includes some weighting due to terrorism/sabotage.
- 7) Outage duration refers to recovering sufficient facility to meet load.
- 8) Although sufficient power would be available to cover load in about one year, it could take up to three years for full restoration.

APPENDIX B

MANITOBA HYDRO
INTEROFFICE MEMORANDUM

FROM	B.C. Hinton Resource Planning & Market Analysis Department Power Planning and Operations Division	TO	P. Thompson Manager Resource Planning & Market Analysis Department Power Planning and Operations Division
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DATE July 3, 2001**FILE****SUBJECT** **RELIABILITY BENEFITS UPDATE**

The results of the Teshmont et al risk studies have been aggregated and summarized within a recent memo (J.B. Davies, June 22, 2001). Within this memo, the risks have been categorized into three groupings, namely, very severe, severe and of concern. Within this update, reliability benefits related to system enhancements have been analyzed with respect to risk categories I and II. The results of this update are summarized within this memo.

Probabilistic and Outage Cost Evaluation

The probabilistic evaluations related to catastrophic events and the mitigating effect of transmission and generation enhancements have been updated with respect to the revised probabilities and outage durations (memo from J.B. Davies, dated June 22, 2001). These updated results were calculated using the same model as was used in the draft progress report "Manitoba Hydro Transmission System Reliability and Enhancement Options", (Fall 2000).

Catastrophic outages, such as the loss of the Dorsey station or the two existing HVDC lines, results in immediate curtailment of exports, initiation of full imports and possible brownouts and/or rotating blackouts to the domestic Manitoba market. The economic impact of the outage is valued by multiplying the specific energy quantity by the unit cost of the energy. Within this study, the cost of emergency import energy and curtailed export energy is assumed to be \$ 100 / MWh. The emergency nature of this energy is reflected in the cost being approximately twice the domestic rate. The societal costs for unserved domestic energy is assumed to be \$ 10 / kWh (\$ 10,000 / MWh). System rotating blackouts would result in lost industrial production, lost commercial business, great residential inconvenience and loss of physical safety. The societal cost for unserved energy reflects the customer's willingness to pay for mitigation to avoid such energy deficits. Studies in the developed world have shown this cost to range from \$ 5 to \$ 15 / kWh, possibly higher. Further clarification of the value of unserved energy will be undertaken during the next few months.

Given a specific catastrophic outage, the available system capacity and energy was stacked against the net southern domestic Manitoba load. With respect to the Dorsey outage, without the Riel sectionalization, a typical capacity stack for a January on-peak hour is given in Table 1. The capacity deficit is given as 886 MW for this particular on-peak hour and the off-peak capacity deficit is 694 MW. Fiscal year 2016 was used as a typical year for the study period, 2008 to 2036.

The ISD for the Riel sectionalization, including 500 kv tap, was assumed to be in year 2008. The ISD for the 500 kv line (T2) was assumed to be in year 2010.

The quantity of import energy that may be imported from neighbouring utilities greatly affects the intensity of the catastrophic outage and the reliability benefits resulting from transmission and/or generation enhancements. Energy imports depend upon the transmission capacity of the inter-connecting transmission links and upon the availability of surplus energy at neighbouring utilities. With respect to transmission capacity, the average quantity of import energy has been assumed to be equal to 1200 MW, this represents approximately 300 MW from Saskatchewan, 200 MW from Ontario and 700 MW from the USA, including D602F and the Glenboro-Harvey line. Given the Dorsey outage, including the loss of the 500 kv switchyard, the total import limit has been assumed to be equal to 900 MW (i.e. a net loss of 300 MW). These quantities reflect the capability to import energy over an extended period of time. During the catastrophic outage, the import capacities would vary considerably given the emergency conditions under which the imports are delivered.

At the time of the disturbance, MH may have swung from being a net exporter (up to 2000 MW) to being a net importer (up to 1200 MW). Hence, MAPP would experience a net loss of up to 3200 MW. As a result, MAPP may not be able to supply 1200 MW on a continuous, long-term basis. With respect to the availability of import energy, the following import scenarios have been studied:

(a) Continuous Import

Continuous import (on-peak and off-peak) of 900 MW during the outage event. D602F is assumed to provide net addition of 300 MW of continuous energy import.

<u>Event</u>	Total Import Capacity	
	<u>On-Peak</u>	<u>Off-Peak</u>
Dorsey outage, including loss of 500 kv switchyard	900 MW	900 MW
Dorsey outage, with Riel sectionalization	1200 MW	1200 MW
Loss of existing HVdc lines	1200 MW	1200 MW

(b) Off-Peak Import

Continuous import (on-peak and off-peak) of 900 MW. D602F is assumed to provide a net addition of 300 MW of off-peak energy import.

<u>Event</u>	Total Import Capacity	
	<u>On-Peak</u>	<u>Off-Peak</u>
Dorsey outage, including loss of 500 kv switchyard	900 MW	900 MW
Dorsey outage, with Riel sectionalization	900 MW	1200 MW
Loss of existing HVdc lines	900 MW	1200MW

The impacts of the Dorsey outage and HVdc line outage are shown in Tables 2 and 3 with respect to the above import scenarios. The events listed under Categories I and II are assumed to be mutually independent and hence the reliability benefits may be summed algebraically.

For import scenario (a), the impacts of the outages and the reliability benefits of the associated enhancement measures are shown in Table 2. The combined impact of the Dorsey outages on the existing system results in 5030 GWh of unserved domestic energy. Given the risk of occurrence (J.B. Davies, June 22, 2001), the expected unserved energy is equal to 2.7 GWh/y, consisting of 2.0 and 0.8 GWh of unserved energy for categories I and II, respectively. Sectionalization at Riel reduces the unserved energy by approximately 50 %. The reliability benefit associated with Riel sectionalization is equal to 78 M \$ Cdn (PV 2001) at a discount rate of 10%. At a 6.18% discount rate, the reliability benefits associated with Riel sectionalization is equal to 138 M \$ Cdn (PV 2001). Unserved energy is essentially eliminated with the addition of 1000 MW of energy at the south, exclusive of Riel sectionalization. The resulting reliability benefits are equal to 143 and 252 M \$ Cdn (PV 2001) for discount rates of 10% and 6.18%, respectively.

Import scenario (b) restricts the quantity of on-peak energy. This causes a reduction in the reliability benefit associated with the Riel sectionalization to 43 M \$ (Cdn) at a discount rate of 10% (Table 3). At the 6.18% discount rate, the reliability benefit is equal to 76 M \$ Cdn. Unserved energy is essentially eliminated with the availability of an additional 1000 MW of energy in southern Manitoba. This could be achieved with 1000 MW of HVdc converter equipment in southern Manitoba. The resulting reliability benefits are equal to 143 and 252 M \$ Cdn (PV 2001) for discount rates of 10% and 6.18%, respectively.

The total reliability benefits related to the Dorsey outage are summarized as follows:

<u>Enhancement Measure</u>	PV Reliability Benefits			
	Continuous		Off-Peak	
	Import	10%	Import	10%
	<u>6.18%</u>	<u>10%</u>	<u>6.18%</u>	<u>10%</u>
Riel sectionalization	138	78	76	43
w/ 1000 MW @ south	252	143	252	143
w/ 1000 MW @ south and Riel sectionalization	254	144	253	144

The cost to establish the Riel station and construct the 500 kv tap is equal to 73 M \$ Cdn (Base \$). The present value of the Riel construction cost is equal to 49 and 57 M \$ Cdn (2001 PV) at discount rates of 10% and 6.18%, respectively. As shown in the above table, the reliability benefits for the Riel sectionalization range from 43 to 78 M \$ Cdn for the two import scenarios at a discount rate of 10%. Given the uncertainties in the analyses, the Riel sectionalization is considered to be marginally economic for the 10% discount rate. Similarly, the reliability benefits range from 76 to 138 M \$ Cdn for the two import scenarios at a discount rate of 6.18%. The Riel sectionalization is economic at the 6.18% discount rate.

With respect to the HVdc line outage, the reliability benefits of the 500 kv line (T2) range from 50 to 87 M \$ Cdn for the two import scenarios at a discount rate of 10%. Similarly, the reliability benefits range from 94 to 162 M \$ Cdn for the two import scenarios and a discount rate of 6.18%.

Transmission Loss Reduction

Construction of a 500 kv line provides reliability benefits, as described in the preceding section, and production benefits, which are summarized herein. Transmission losses are reduced through the paralleling of HVdc energy onto the two existing lines and the proposed 500 kv line.

At peak loading, the addition of the 500 kv line would result in a loss reduction of approximately 78 MW (Memo from K. Kent dated Feb. 2, 2001). The convolution of the loss reduction with respect to the historic HVdc loading is shown in Figure 1 for both on-peak and off-peak periods. The area under the curves represents the energy gain resulting from the loss reduction. The average annual energy from loss reduction is equal to 274 and 124 GWh/y for on-peak and off-peak periods, respectively.

The direct relation between loss reduction and added capacity at Dorsey provides firm on-peak energy that can be valued as a (5x16) sale. The capacity of this sale is assumed to be equal to the 78 MW (i.e. loss reduction at peak HVdc loading). Additional energy, over the requirements of this 78 MW firm contract, has been valued as short-term opportunity energy.

With reference to the 2001 Power Resource Plan, the NPV for the T2 option, resulting from reduced system losses only, is equal to zero at a discount rate of 10%.

The following table demonstrates the weighted averaging for the various price scenarios. Refer to Section 3.3 (The 2001 Power Resource Plan) for additional information on the evaluation of the T2 option.

T2 NET PRESENT VALUE					
	Net Benefit of Gas/Export Price and GHG Scenario				Weighted Average Benefit
	Medium-Low	Medium-High	Medium GHG	High GHG	
Probability Weighting	10%	10%	65%	15%	
<i>Advanced Plant Export Options – Without Reliability Benefits</i>					
T2 500 kV HVDC line-10	-37	-12	1	26	0

As shown in the preceding section, the reliability benefits of the 500 kv line (T2) provides additional benefits ranging from 50 to 87 M \$ Cdn at a discount rate of 10%.

Summary

The establishment of the Riel station, including the 500 kv tap, is marginally economic under conservative economic analyses. The PV cost for the establishment of Riel and the 500 kv tap is estimated to be equal to 49 M \$ Cdn (2001 PV at 10% discount rate). Conservative assessment of the reliability benefits to offset the category I and II events (fire, terrorism, sabotage, ice storm, tornado and microburst) has been estimated to range from 43 to 78 M \$ Cdn (2001 PV) with respect to the two importation schemes.

At a discount rate of 6.18%, the Riel sectionalization is economic under conservative economic analyses. The PV cost for the Riel sectionalization is equal to 57 M \$ Cdn. The associated reliability benefits range from 76 to 138 M \$ Cdn with respect to the two import scenarios.

The assumed availability of import energy significantly affects the impact of the specific outage and hence the reliability benefit associated with the transmission enhancement.

With respect to production benefits exclusively, the development of the 500 kv transmission line (T2) results in a zero net benefit (2001 PV at 10 % discount rate) for energy loss reduction. The reliability benefit associated with T2 ranges from 50 to 87 M \$ Cdn for the two import scenarios.

The 2001 Power resource Plan recommends development of Wuskwatim (2019) and Gull (2020) as part of the 2001 Integrated Financial Forecast and 20-Year Capitol Plan. Development of the Riel sectionalization and 500 kv line (T2) can be considered as an advancement as part of the Gull / Bipole III development. However, the Riel sectionalization and 500 kv line are not contingent upon the future development of Gull.

Table 1
Typical Winter On-Peak Hour: January 2017
Dorsey Outage, w/o Bipole III

	Capacity (MW)	Capacity (MW)
System Load		
Manitoba domestic load	4095	
- Northern load	<u>643</u>	
Net Southern load	3452	3452
Available Supply (Peak Capacity)		
Grand Rapids	500	
Winnipeg River Plants	560	
Jenpeg / Kelsey (ac)	200	
Selkirk GS	138	
Brandon Unit 5	105	
Brandon Units 6 & 7	298	
Import from: Ontario	200	
Sask	200	
US	<u>500</u>	
Gross Supply	2701	
- Reserve (5%)	<u>135</u>	
Net Supply	2566	<u>2566</u>
Capacity Deficit On-Peak Hour		886
Similar, Capacity Deficit Off-Peak Hour		694

Table 2

System Reliability

Case (a): Continuous 1200 MW Import

Category I (Very Severe: Fire, Terrorism, Sabotage, Ice Storm)

Probability and Duration of Outages:

Dorsey results combine scenarios: 1 in 1000 yr, 2 months, winter or summer
 1 in 1000 yr, 6 months, winter or summer

HVDC Lines results combine scenarios: 1 in 50 yr, 2 weeks, winter
 1 in 300 yr, 2 months, winter

Scenario	Average Unserved Energy (GWh)	Expected Unserved Energy (GWh)	PV Reliability Benefits 6.18% Discount Rate (\$M 2001 Cdn)	PV Reliability Benefits 10.00% Discount Rate (\$M 2001 Cdn)
Dorsey				
Existing System	1959	2.0	-	-
w/ 500 kV Tap	901	0.9	98	56
w/ 1000 MW @ Southern Manitoba	12	0.0	131	103
w/ 1000 MW @ Southern Manitoba & 500 kV Tap	0	0.0	132	104
HVDC Lines				
w/o 500 kV Line (T2)	233	12	-	-
w/ 500 kV Line (T2)	0	0.0	93	50

Category II (Severe: Tornado, Microburst)

Probability and Duration of Outages:

Dorsey results combine scenarios: 1 in 2200 yr, 1 month, summer
 1 in 4000 yr, 1 year, winter or summer

HVDC Lines results combine scenarios: 1 in 18 yr, 1 week, summer
 1 in 30 yr, 2 weeks, summer

Scenario	Average Unserved Energy (GWh)	Expected Unserved Energy (GWh)	PV Reliability Benefits 6.18% Discount Rate (\$M 2001 Cdn)	PV Reliability Benefits 10.00% Discount Rate (\$M 2001 Cdn)
Dorsey				
Existing System	3071	0.8	-	-
w/ 500 kV Tap	1103	0.4	39	22
w/ 1000 MW @ Southern Manitoba	19	0.0	71	40
w/ 1000 MW @ Southern Manitoba & 500 kV Tap	1	0.0	72	41
HVDC Lines				
w/o 500 kV Line (T2)	0	0.0	-	-
w/ 500 kV Line (T2)	0	0.0	0	0

Category I and II Combined

Scenario	Average Unserved Energy (GWh)	Expected Unserved Energy (GWh)	PV Reliability Benefits 6.18% Discount Rate (\$M 2001 Cdn)	PV Reliability Benefits 10.00% Discount Rate (\$M 2001 Cdn)
Dorsey				
Existing System	5030	2.7	-	-
w/ 500 kV Tap	2304	1.3	138	78
w/ 1000 MW @ Southern Manitoba	31	0.0	252	143
w/ 1000 MW @ Southern Manitoba & 500 kV Tap	1	0.0	254	144
HVDC Lines				
w/o 500 kV Line (T2)	234	12	-	-
w/ 500 kV Line (T2)	0	0.0	94	50

Value of unserved energy (\$/kwh): 10

Table 3

System Reliability

Case (b): 900 MW On Peak Import; 1200 Off Peak Import

Category I (Very Severe: Fire, Terrorism, Sabotage, Ice Storm)

Probability and Duration of Outages:

Dorsey results combine scenarios: 1 in 1000 yr, 2 months, winter or summer
1 in 1000 yr, 6 months, winter or summer

HVDC Lines results combine scenarios: 1 in 50 yr, 2 weeks, winter
1 in 300 yr, 2 months, winter

Scenario	Average Unserved Energy (GWh)	Expected Unserved Energy (GWh)	PV Reliability Benefits 6.13% Discount Rate (\$M 2001Cdn)	PV Reliability Benefits 10.00% Discount Rate (\$M 2001Cdn)
Dorsey				
Existing System	1958	2.0	-	-
w/ 500 kV Tap	1374	1.4	54	31
w/ 1000 MW @ Southern Manitoba	12	0.0	131	103
w/ 1000 MW @ Southern Manitoba & 500 kV Tap	8	0.0	132	103
HVDC Lines				
w/ 500 kV Line (T2)	380	19	-	-
w/ 500 kV Line (T2)	0	0.0	152	82

Category II (Severe: Tornado, Microburst)

Probability and Duration of Outages:

Dorsey results combine scenarios: 1 in 2200 yr, 1 month, summer
1 in 4000 yr, 1 year, winter or summer

HVDC Lines results combine scenarios: 1 in 13 yr, 1 week, summer
1 in 30 yr, 2 weeks, summer

Scenario	Average Unserved Energy (GWh)	Expected Unserved Energy (GWh)	PV Reliability Benefits 6.13% Discount Rate (\$M 2001Cdn)	PV Reliability Benefits 10.00% Discount Rate (\$M 2001Cdn)
Dorsey				
Existing System	3071	0.8	-	-
w/ 500 kV Tap	2147	0.5	22	12
w/ 1000 MW @ Southern Manitoba	9	0.0	71	40
w/ 1000 MW @ Southern Manitoba & 500 kV Tap	14	0.0	71	41
HVDC Lines				
w/ 500 kV Line (T2)	3	0.1	-	-
w/ 500 kV Line (T2)	0	0.0	10	5

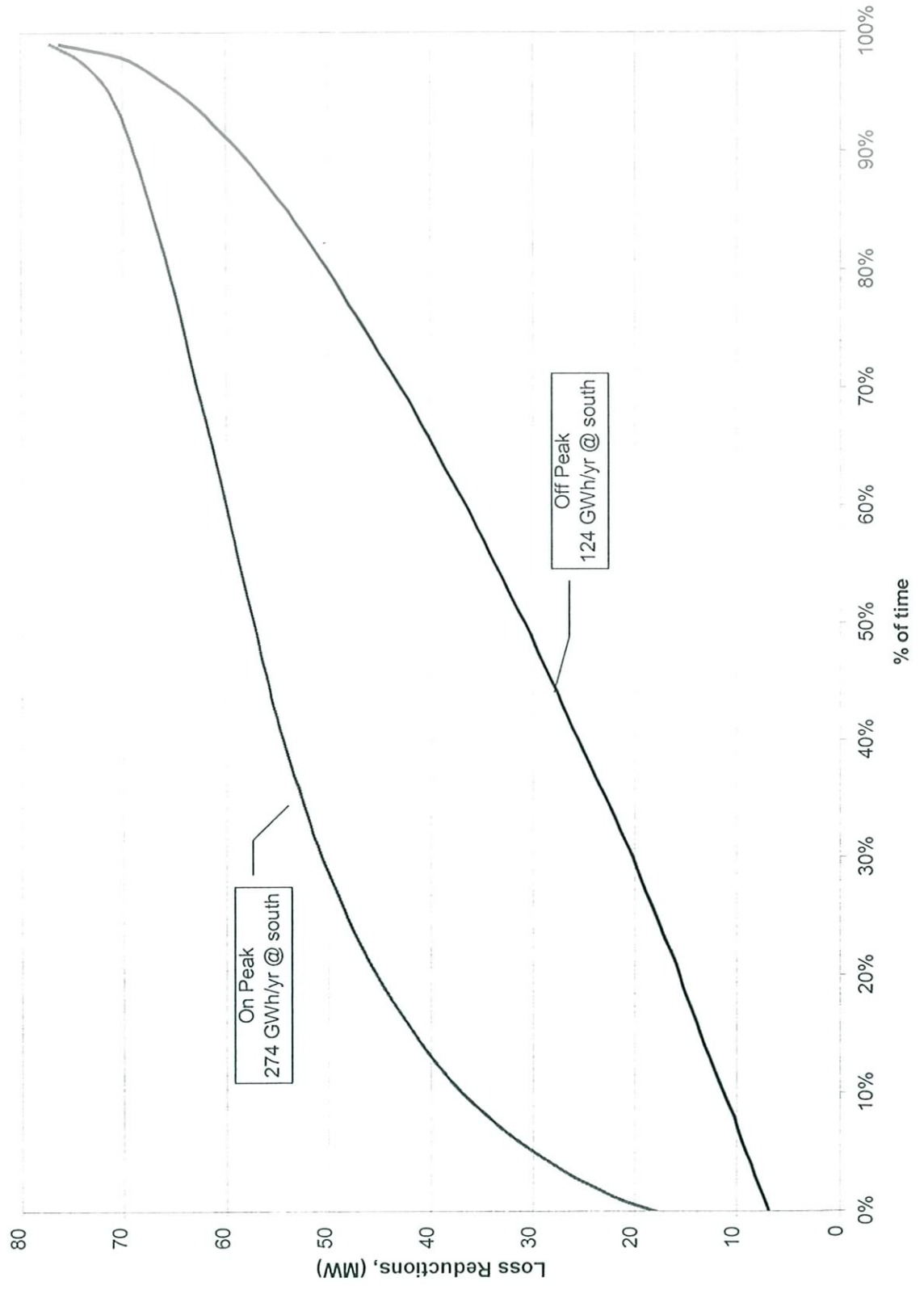
Category I and II Combined

Scenario	Average Unserved Energy (GWh)	Expected Unserved Energy (GWh)	PV Reliability Benefits 6.13% Discount Rate (\$M 2001Cdn)	PV Reliability Benefits 10.00% Discount Rate (\$M 2001Cdn)
Dorsey				
Existing System	5029	2.7	-	-
w/ 500 kV Tap	3522	19	76	43
w/ 1000 MW @ Southern Manitoba	31	0.0	252	143
w/ 1000 MW @ Southern Manitoba & 500 kV Tap	23	0.0	253	144
HVDC Lines				
w/ 500 kV Line (T2)	383	2.0	-	-
w/ 500 kV Line (T2)	0	0.0	152	87

Value of unserved energy (\$/kwh):

10

Figure 1
Loss Reductions for T2 Scheme
On and Off Peak Loading



APPENDIX C

MANITOBA HYDRO
INTEROFFICE MEMORANDUM

FROM T.E. Tymofichuk,
Division Manager
Transmission System Operations
453 Dovercourt Drive

TO E. Wojczynski
Division Manager
Power Planning & Op Group
(4) 820 Taylor

DATE 2001.03.28

FILE

SUBJECT SYSTEM OPERATIONAL ISSUES FOR CATASTROPHIC HVDC OUTAGES

Following a catastrophic loss of HVDC generation on the Manitoba Hydro system there are various factors may have to be considered to manage a chronic energy shortage to Manitoba Hydro customers.

1. There can be times, especially during cold weather and during an extended outage, where a sub-transmission system may encounter cold load pickup that exceeds the protection settings on the source supply breakers. This can induce the need to temporarily sectionalize lines or to isolate portions of the load until the load stabilizes. System Operators may direct restoration by sectionalizing lines and connecting load progressively until the load resumes it's normal cycling pattern. This will specifically be the case where lines are normally heavily loaded.
2. Experience has shown that frequent load switching, especially in cold weather, can stress switching equipment. It is the operating policy of System Control to suspend non-emergency switching at temperatures below -30° C. Equipment such as breakers, reclosers, motor operated disconnects and switches has a tendency to fail when operated in these extreme temperatures.
3. System Control has developed procedures for System Operator controlled load shedding. An EMS based program will allow the System Operators to quickly shed load in an emergency. This program has 6 predetermined lists of breakers with identified critical loads protected. The operator can determine how many MW are required to be shed in an emergency and initiate the program. It will trip breakers until the requested target is met. It is possible to program this application to rotate shed load either automatically or manually with operator intervention. Critical loads such as pumping stations (gas, oil, water and sewage), all major hospitals, major prisons, Winnipeg Airport and critical stations service loads to major terminals have been identified and removed from planned rotational load shedding procedures.

Automatic under-frequency protection does not discriminate critical loads and would trip all such load in a disturbance that results in a major frequency excursion.

Therefore, there would be thousands of customers disrupted in a catastrophic outage that would interrupt loads such as nursing homes, hospitals, schools, office buildings, traffic control, etc. In extreme conditions such as we see in Manitoba in the winter months, the general public would be ill-prepared to handle a large extended outage due to a catastrophic HVDC loss. System Control could restore some of the identified critical loads depending on available resources and import capability but it may be inadequate. Both electric and gas customers could be without heating sources. EMO would be overloaded with emergency calls, not to mention our staff.

The consequences for a major and lengthy HVDC Generation supply failure on our system are extremely serious especially during the winter peak load period. We need only be reminded of the societal impacts of the January 1998 ice storm in Eastern Canada. These consequences need to be evaluated when deferrals of capital projects are contemplated, projects that would reduce the consequences immensely.