Presque Isle
Special Protection System
"Remedial Action Tripping Scheme" (RATS)

Version 3.0

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Acknowledgement

Different engineers from Planning, Protection and Operations have provided valuable input to this project. In particular, we would like to thank Steve Feak for the numerous discussions that provided valuable insight to this problem and his analysis for the proposed Plains Substation SPS, John Ratajczyk for providing historical background on the Presque Isle SPS development and Nick Giffin for helping with the 2007 planning studies and Sue Michels for documenting the existing Presque Isle SPS.

Main Revisions in Version 3.0

- Developed the intact system generation restrictions as an alternative to the Interim Solution. The restrictions (described in the section 4.1.3) were obtained by studying a high West to East transfer case and also studying the loss of the Dead River – Plains 345 kV line due to a 3 phase fault at the Dead River 345 kV substation (resulting in all but 20 MW of mine load to trip off line).

- Updated the Prior outage restrictions taking into account changes in the equipment ratings since the Version 2.0 of the report. The restrictions further assume that applying a three phase fault at the critical locations results in all but 20 MW of the mine load to trip off line.

- Added Appendix H which describes the thermal limits identified in the Prior Outage Restrictions.

Main Revisions in Version 2.0
(Revisions refer to the previous report that was posted on 9/14/2007)

- Added fault statistics for the Plains – Dead River 345 kV line from 2001 to 2007 in the Summary and in Section 5.1
- Updated the schedule of the Interim Solution
- Adding the voltage supervision feature to the Interim and the Permanent Solution in Section 2.6.3
- Corrected the 2010 one-line diagram, Figure 3.1.1, to include the Morgan – Highway 22 345 kV line
- Added Appendix G, which compares the SPS relay trip settings for the Immediate, Interim, and the Permanent Solutions
- Removed references to the Plains 345/138 kV transformer overload due to the loss of Plains – Morgan 345 kV line. This is due to the validation of the Plains 345/138 kV transformer Summer Emergency higher rating since the posting of the draft report

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1. Summary

The existing American Transmission Company (ATC) northern system, which includes the Upper Peninsula of Michigan area, has limited power transfer capabilities from the Presque Isle Power Plant to the Plains Substation. The local system has large mine loads connected at the Empire and Tilden Substations. These loads are known to be sensitive to voltage dips, which can be caused by transmission system faults. The loss of load at these substations as a result of fault conditions increases the post-contingent power flow and thus contributes to thermal loading and potential system instabilities.

There is an existing Special Protection System (SPS), commonly referred to as the Remedial Action Tripping Scheme (RATS) that is designed to mitigate unstable power swings by tripping Presque Isle Power Plant generating units for critical system faults. The amount of generation tripped depends on system conditions and is determined by planning studies. There is another existing Special Protection System at the Plains Substation that is designed to isolate a portion of the Upper Peninsula of Michigan from the rest of the ATC system for angular instabilities that originate from the Presque Isle Power Plant in the event of the Presque Isle SPS failure or events beyond the intended design of the Presque Isle SPS. The existing Plains Substation SPS is described in Appendix E.

The last planning study that specifically reviewed the Presque Isle SPS was performed in April 1999. Since then, both the area transmission system and system flows have changed. Given these changes, this report reviews and recommends updates to the existing SPS at the Presque Isle Power Plant.

TPL-001-0 System Performance Under Normal Conditions
The planning analyses in this study indicate the system responds as prescribed in the Reliability Standard TPL-001-0.

TPL-002-0 System Performance Following Loss of a Single Bulk Electric System Element
The planning analyses presented in this report show that the overall system stability has improved and hence a lower amount of generation tripping is required to meet system stability requirements. However, the analyses also show that the projected thermal overloads have worsened. In particular, the Empire – Forsyth 138 kV line can be thermally loaded as high as 139% of the existing summer emergency line rating for certain single contingency events with an otherwise intact system in 2007. Note that this report considers the loss of the faulted line and the loss of local mine load as a single contingency event due to the voltage sensitivity of the mine load. This decision is prompted by growing historical evidence of actual mine load performance during certain system faults.

The thermal overload of the Empire – Forsyth 138 kV line for the loss of the Presque Isle – Dead River – Plains transmission corridor indicates an inability of the system to respond as prescribed in Reliability Standard TPL-002-0, R1.3.7, specifically that the system is not within the applicable thermal rating limits following the loss of certain faulted transmission circuits with faults clearing in the time normally expected. In accordance with TPL-002-0, R2.1, this report provides a summary of the mitigation plan to achieve the required system performance throughout the planning horizon for TPL-002-0. This mitigation plan is described later in this summary.

TPL-003-0 System Performance Following Loss of Multiple Bulk Electric System Elements
Stability simulations of single line-to-ground faults on certain transmission circuits with delayed clearing due to a failed circuit breaker [i.e. Category C8 event] indicate an inability of the system to remain stable as prescribed in Reliability Standard TPL-003-0, R1.3.7 in the absence of the Plains Substation SPS. With the Plains Substation SPS, the system will respond as prescribed in Reliability Standard TPL-003-0.

Stability simulations of three phase faults in a system with the prior outage of a single generator, transmission circuit, or transformer [i.e. Category C3 event] indicate an inability of the system to remain stable as prescribed in Reliability Standard TPL-003-0, R1.3.7. In addition, thermal overload of system elements for the loss of a single transmission element with the prior outage of a single transmission element [i.e. Category C3 event] indicates an inability of the system to remain within the applicable thermal ratings as prescribed in Reliability Standard TPL-003-0, R1.3.7. In accordance with TPL-003-0, R2.1, this report provides a summary of the mitigation plan to achieve the required system performance throughout the planning horizon for TPL-003-0.

The Proposed Mitigation Plan

The proposed mitigation plan to achieve the required system performance throughout the planning horizon will be accomplished in three steps as follows**:**

1- *The Immediate Solution (generation re-dispatch)*
(Already implemented: Use existing SPS)
1.1 For system intact conditions, continue to operate to historical limits until the Interim Solution is implemented. Historical limits enforce local area generation restrictions whenever real-time Flow North flow exceeds 460 MW. Recent studies show that operating up to the historical limits may expose the local area to increased risk of overloads in response to certain types of faults within a relatively small electrical distance from the mine loads. Given that the risk is relatively low and isolated to the local area, ATC has opted not to impose dramatic generation limits and load curtailments between now and when the Interim Solution described in Section 2 below can be implemented.

For atypical scenarios where mine load is curtailed, ATC System Operations will work with the Midwest ISO to bind any constraint in real time in accordance with the Midwest ISO procedures and will continue to do this until the Empire – Forsyth 138 kV line uprate is completed. The Flow North restriction is approximately 279 MW when the combined Empire and Tilden mine load is 20 MW. However, the exact Flow North restriction will vary depending on the system conditions and the season. This mitigation strategy is generally comparable to other first contingency limits monitored and managed in real-time operations.

1.2 For the prior outage of a single transmission system element, continue to operate to historical limits until the Interim Solution is implemented. The historical Flow North limit is 150 MW for prior outage conditions, which may result in local generation restrictions.

2- *The Interim Solution (modify the existing SPS trip settings)*
(Available to implement subsequent to MRO and RFC reviews – actual implementation dependent on time until permanent solution)

2.1 Modify the existing SPS generation trip settings according to new stability trip settings as shown in Appendix G. Note that from 2001 to 2007, the Dead River – Plains 345 kV Line 85601 has experienced zero three-phase faults and one phase-to-phase fault. The modification of trip level settings will require a period of review by the Midwest Reliability Organization and the Reliability First Corporation.

2.2 For system intact conditions, enforce local area generation restrictions whenever real-time Flow North flow exceeds 460 MW. For atypical scenarios where mine load is curtailed, ATC System Operations will work with the Midwest ISO to bind any constraint in real time and will continue to do this until the Empire – Forsyth 138 kV line uprate is completed. The Flow North restriction is approximately 296 MW when the combined Empire and Tilden mine load is 20 MW. However, the exact Flow North restriction will vary depending on the system conditions and the season.

2.3 For the prior outage of a single transmission system element, restrict the net injection of real power at Presque Isle 138 kV bus as shown in Table 5.3.1

If at any time ATC determines that the Empire – Forsyth 138 kV line uprate described as the Permanent Solution will be implemented prior to summer 2008, then the implementation of the Interim Solution may be suspended dependent on the time until the Empire – Forsyth 138 kV line uprate is completed.

3- *The Permanent Solution (Uprate the Empire – Forsyth 138 kV line and modify SPS trip settings)*
(Estimated schedule is to implement: 12 months. The ATC goal is to have it completed prior to summer 2008.)

3.1 Modify the existing Presque Isle SPS generation trip settings according to new stability trip settings (see Tables 4.0.1 and 4.0.2). Please refer to Appendix G for a comparison of the Immediate, Interim, and Permanent Solution trip level settings.

3.2 Uprate the Empire – Forsyth 138 kV line to 302 MVA (257° F) by summer 2008. The uprate can be accomplished by raising the line clearance and replacing terminal equipment at both the Forsyth and Empire 138 kV Substations for an approximate cost of $2,500,000.

3.3 For the prior outage of a single transmission system element, restrict the net injection of real power at Presque Isle 138 kV bus as given in Table 4.2.1.

The proposed Permanent Solution (Uprate the Empire – Forsyth 138 kV line and modify SPS trip settings) is based on the potential retirement of the Presque Isle Power Plant units 3 and 4 prior to 2013 as stated on the United States Environmental Protection Agency website [1] on 4/29/2003.

The proposed Permanent Solution may require a planned outage of eight days at the Forsyth 138 kV Substation and four days at the Empire 138 kV Substation to upgrade all equipment rated less than 302 MVA. An outage may not be required to upgrade the clearance of the Empire – Forsyth 138 kV line. However, if any poles are discovered to be in poor condition, then outages will be required for individual pole replacements. The net injection of real power at the Presque Isle 138 kV bus will be restricted during these outages.

Table 1.1 shows the expected capabilities of the Flow North flowgate with the existing Presque Isle limits for three different mine load levels. These limits are calculated using Table A.3 (2007 planning cases with Confirmed Firm Transmission Service).

Table 1.1 Expected Intact System Flow North Capabilities for Each Solution

	Flow North Flowgate[1] Limit (MW)			
Mine Load (MW)	Historical Limits	Existing SPS Provides	Interim Solution	Permanent Solution
300	460	109[2]	460	460
150	460	141[2]	460	460
20	279[2]	279[2]	296[2]	460

1. The Flow North flowgate is defined by the sum of the real power flowing on the Dead River – Plains 345 kV line, the Perch Lake – Nordic 138 kV line, and the Forsyth – Arnold 138 kV line.
2. Measured Flow North using planning cases in Table A.3 (with Confirmed Firm Transmission Service). The exact Flow North restriction will vary depending on the system conditions and the season.

2. 2007 System Studies

2.1 System Description

The existing ATC 138 kV northern system, which includes the Upper Peninsula of Michigan area, has limited power transfer capabilities from the Presque Isle Power Plant (PIPP) to the Plains Substation. The local system has large mine loads connected at the Empire and Tilden Substations [2]. These loads are known to be sensitive to voltage dips, which can be caused by transmission system faults. The loss of load at these substations as a result of fault conditions increases the post-contingent power flow and thus contributes to thermal loading and potential system instabilities. The local system one-line diagram is shown in Figure 2.1.1.

The system has recently been improved with the projects listed below. However, the system still requires the use of a Special Protection System (SPS), which has historically been called the Remedial Action Tripping Scheme (RATS), to prevent unstable power swings by tripping a portion of the PIPP generation for critical faults on the transmission system.

Recent System Improvements:

1. The Perkins – Indian Lake 138 kV double circuit project (1999).
2. The conversion of the Plains – Thunder – Falls Tap 138 kV line to the Plains – Morgan 345 kV line (1999).
3. The Hiawatha – Indian Lake 69 kV rebuild (2004).
4. The rebuild and conversion of the Menominee – Rosebush – Amberg 69 kV line to 138 kV (2005).
5. The Plains – Amberg – Stiles 138 kV double circuit rebuild (2005-2006).

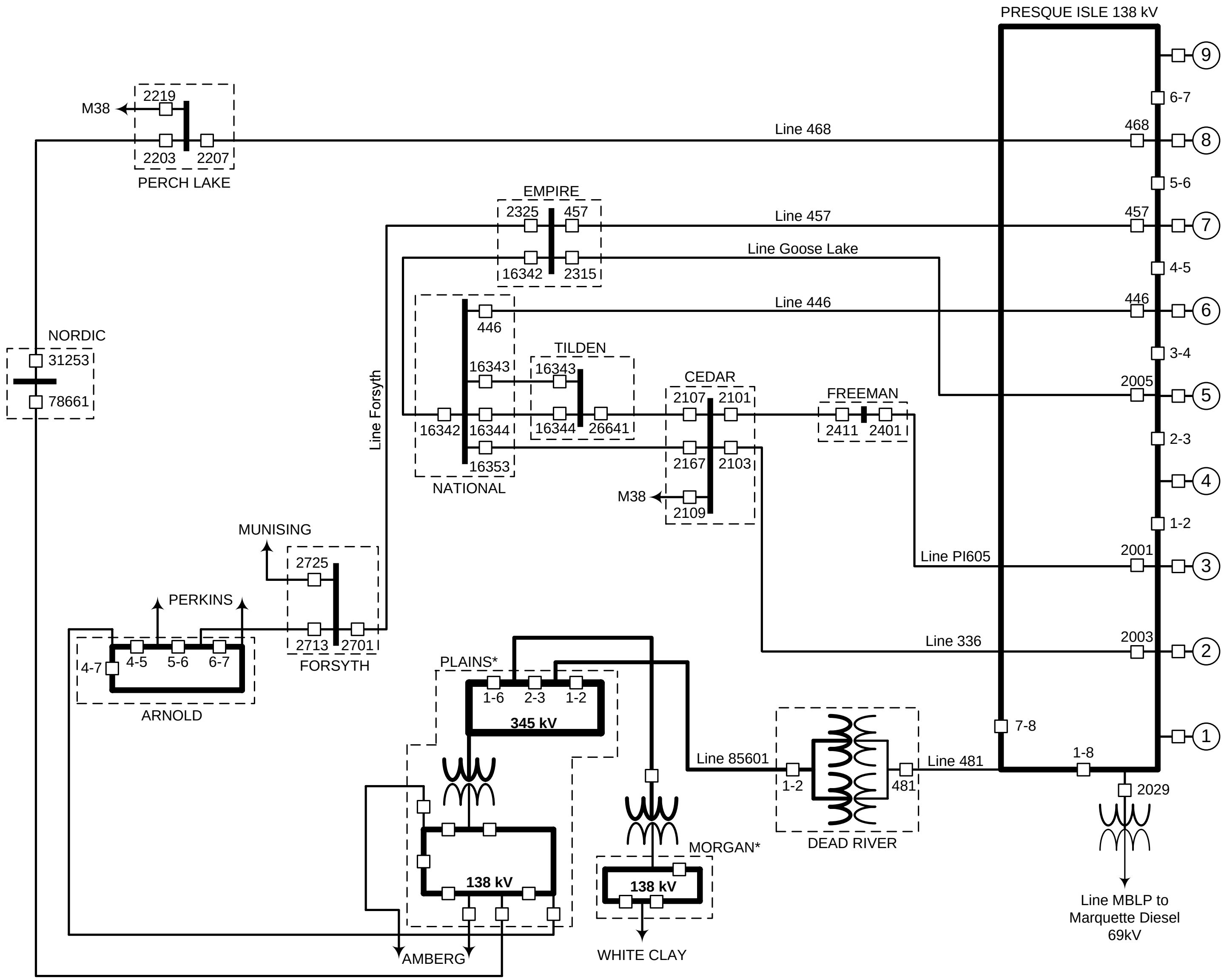

Figure 2.1.1 2007 Local System One-Line Diagram – Substations with * are Not Shown in Full Detail

2.2 The Existing Special Protection System

The existing Presque Isle SPS is comprised of protective relays which are set to sense certain faults within certain distances of specific transmission line terminals, as determined by system stability studies. Each relay's output contact sends a signal to the Generator Tripping Switch Selector panel QR9 (Switch Selector) located at the PIPP.

The existing SPS at Presque Isle is the primary automatic action employed to maintain stability in the Presque Isle area. If the Presque Isle SPS fails to respond properly during a system disturbance, an independent backup system, the Plains Substation SPS, is initiated to isolate a portion of the Upper Peninsula of Michigan from the rest of the ATC system.

2.2.1 Operation of the Existing SPS

A continuous measurement of the real power flow on the Dead River – Plains 345 kV line, the Perch Lake – Nordic 138 kV line, and the Forsyth – Arnold 138 kV line is made by the ATC Energy Management System (EMS). The total power flowing through these three lines is referred to as Flow North. Based on the sum of Flow North plus total mine load, an automatic calculation determines the amount of generation that needs to be tripped for each of three SPS trip levels: Maximum (Level 1), Intermediate (Level 2), and Minimum (Level 3). This information is provided to the plant operators by the ATC System Operators. The PIPP Plant Operators then configure the Switch Selector to predetermine which of the PIPP generating units to trip for each level, if a trip signal were to be received.

The calculation described above is performed continually by the ATC EMS computer. The actual settings of the Switch Selector are viewable by the ATC System Operators. If the settings deviate from the required tripping levels by more than 10 MW below or 40 MW above, an alarm is annunciated on the EMS. When the alarm is received, the ATC System Operator informs the Plant Operator that the Switch Selector needs to be changed to match the required tripping levels. According to the Interconnection Agreement between ATCLLC and We Energies, the "Generating Company shall be required to comply with the requests, orders, directives and requirements … of Transmission Provider, including those issued in its role of implementing the directives of the Security Coordinator. Any such requests, orders, directives or requirements of Transmission Provider must be… reasonably necessary to maintain the integrity of the Transmission System." It is important to note, though, that the PIPP Plant Operators have the ultimate responsibility to select which units are to be tripped for each level.

The Presque Isle SPS relays are installed in addition to the main protective relaying of the affected lines and act independently. Their primary objective is to sense a fault within a predetermined protection zone and send an instantaneous output signal (trip level 1 / trip level 2 / trip level 3) to the PIPP Switch Selector for generator trip activation. This provides the minimal time for tripping the PIPP generation for the selected trip level, thus preserving system stability. Trip levels 1, 2 and 3 refer to the maximum, intermediate and minimum trip levels as shown in Figures 2.2.1, 2.2.2, and 2.2.3. The conditions that describe the existing trip level settings are shown in Tables 2.2.1 and 2.2.2.

In accordance with MAIN Guide 10 Appendix B "Special Protection Systems", a parallel redundancy is applied to the SPS for the 345 kV lines (Dead River – Plains and Plains – Morgan) due to their voltage level and criticality for system stability. This redundancy is accomplished by using primary and secondary relays.

2.2.2 Relaying Requirements

In order to establish three SPS levels of generator tripping, the SPS relays must be able to discriminate between the different types of faults and correctly identify the fault location.

The Presque Isle SPS utilizes the SEL-321 and SEL- 311C relays to produce a separate output signal for each of the different types of faults. SPS relays installed on each of the seven 138 kV transmission lines emanating from PIPP use fiber optic cable to send tripping signals to the PIPP Switch Selector panel. SPS relays located at remote substations require communication channels for the relay signals to be sent and received at the plant. These communication channels, fiber-optic, analog microwave, and power line carrier, are independent from the communication channels for line protection.

An under-voltage relay, connected to the Presque Isle 138 kV bus #5 voltage transformer and installed on the Switch Selector panel, supervises all of the SPS trip outputs from the relaying located in the Presque Isle switchyard control house or at the Dead River Substation. It is installed to provide additional security to the system by ensuring any SPS trip signal from these relays is initiated by a fault. In addition to the voltage supervised trip signal sent upon immediate detection of a fault for any of the locations listed in Table 2.2.1, a trip signal that isn't enabled by voltage supervision is sent when any circuit breaker opens on the Presque Isle – Dead River – Plains – Morgan transmission corridor. Each circuit breaker that sends this signal is listed in Table 2.2.2.

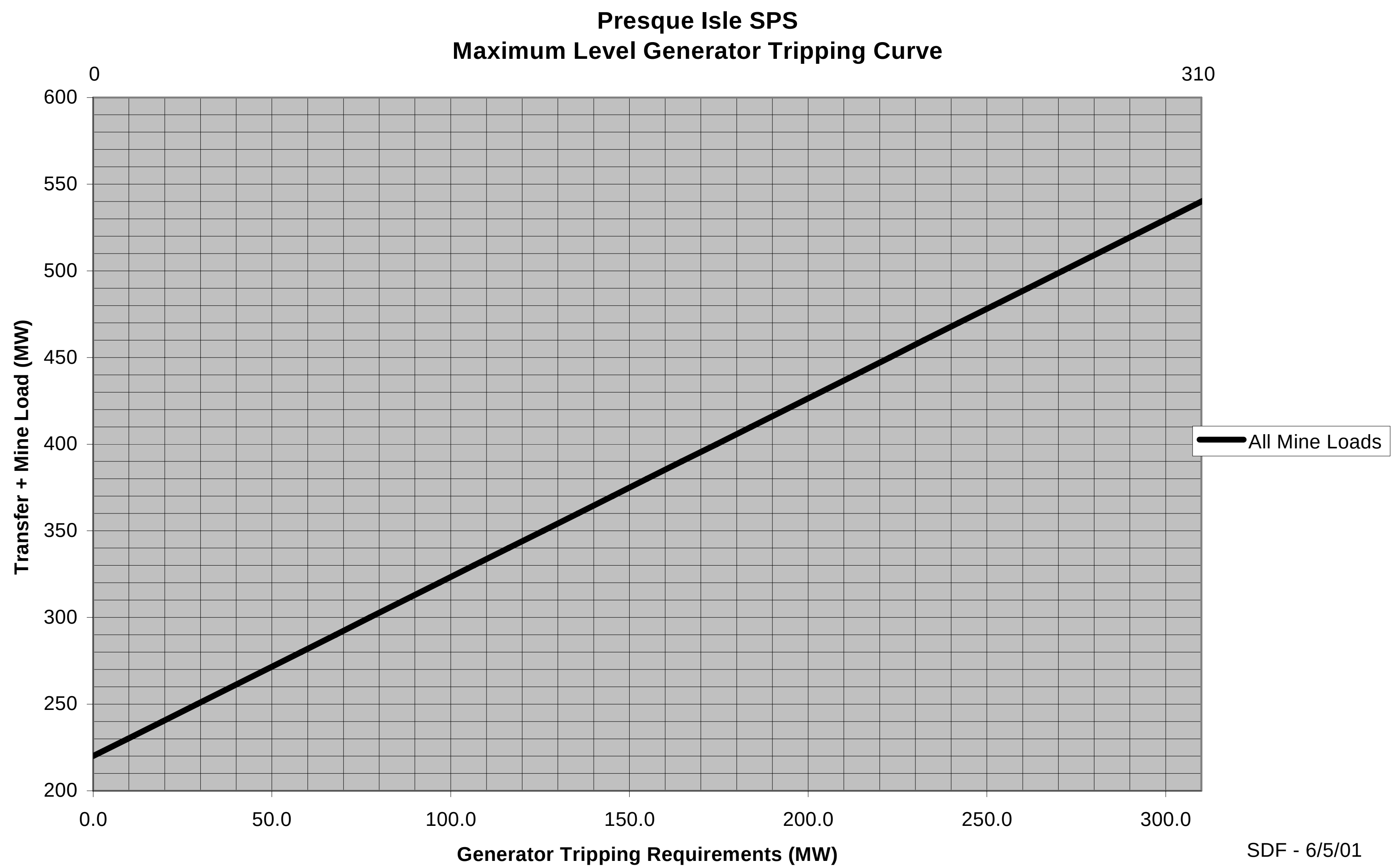

Figure 2.2.1 Presque Isle SPS Maximum Tripping Level – Level 1

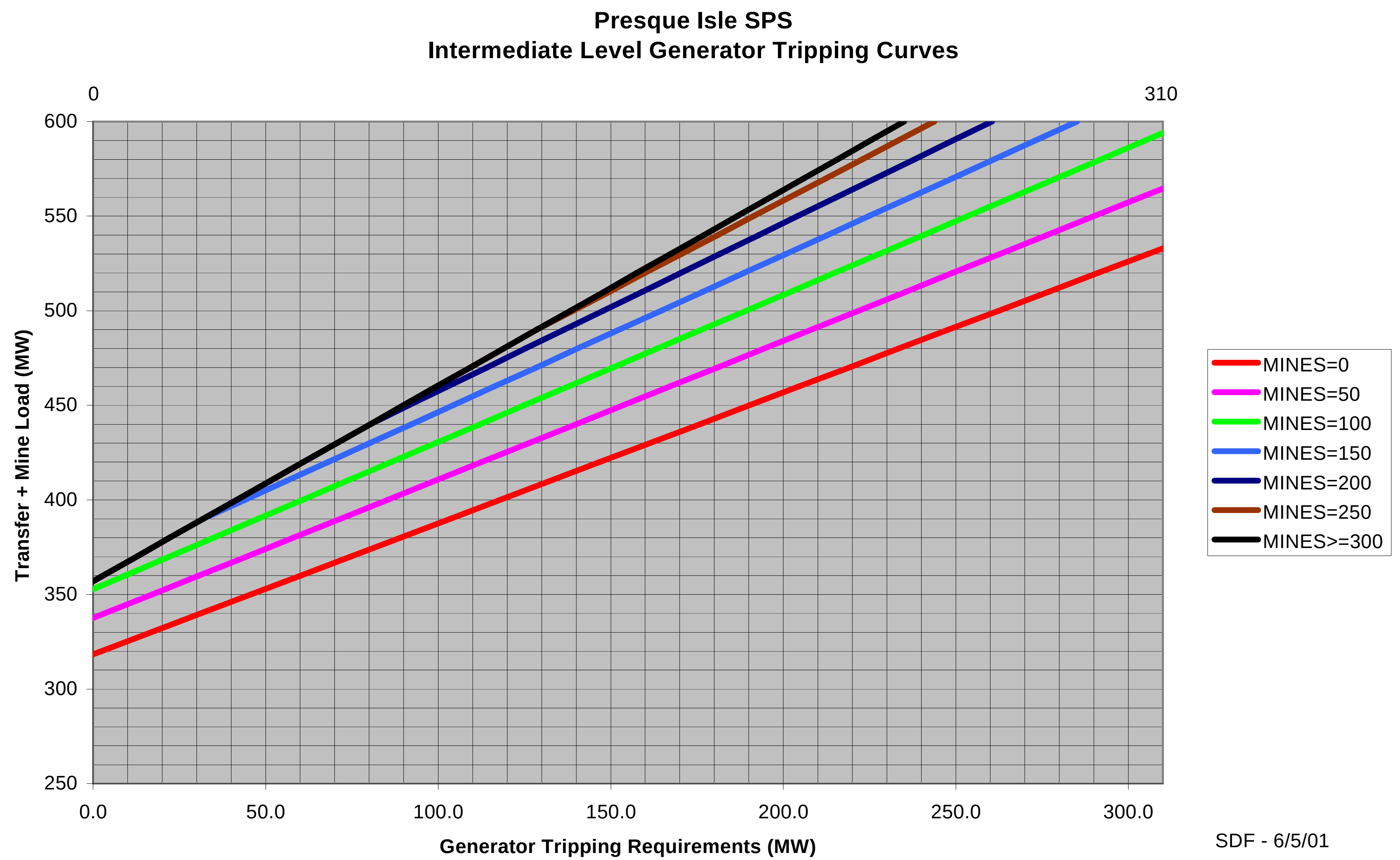

Figure 2.2.2 Presque Isle SPS Intermediate Tripping Level – Level 2

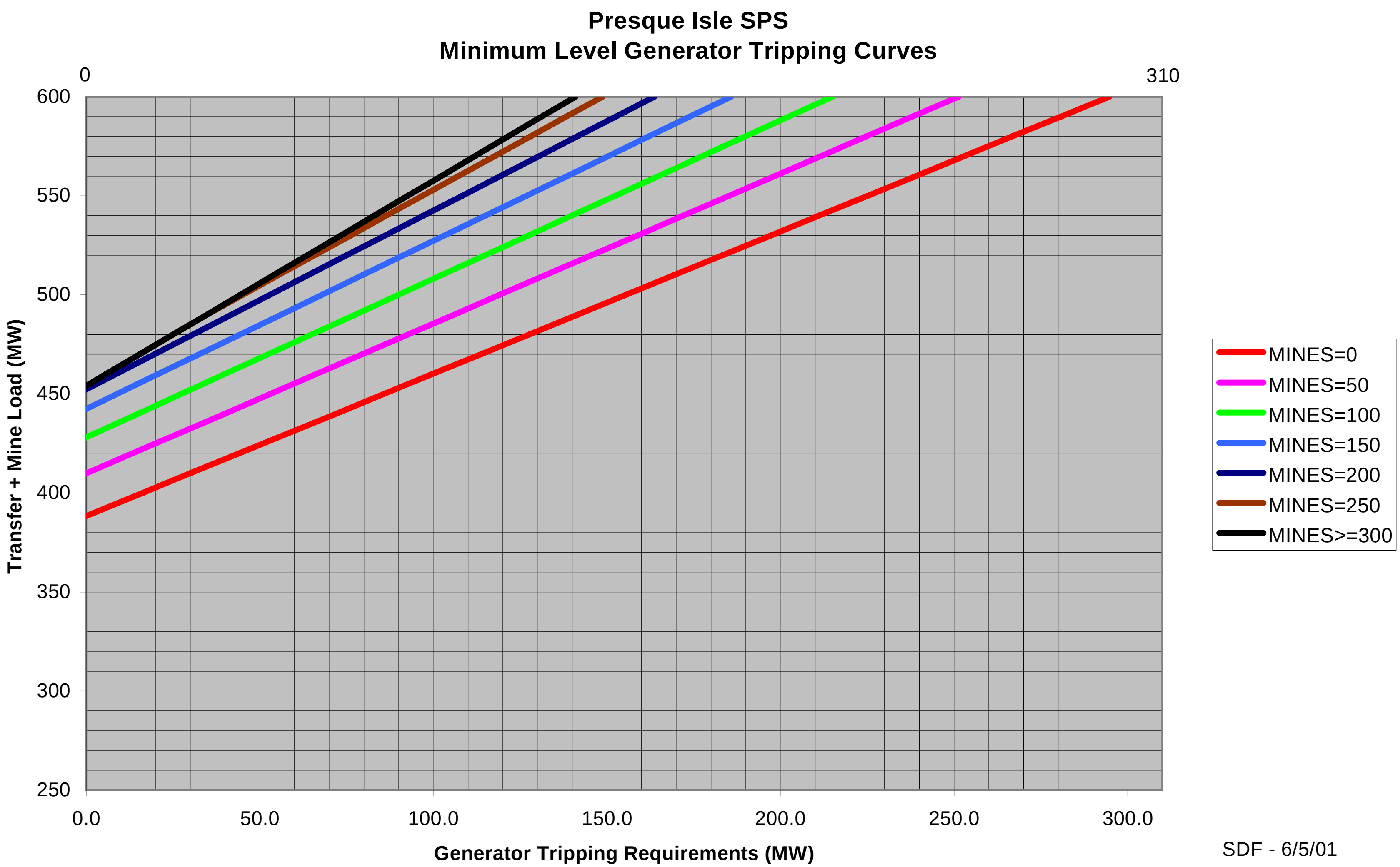

Figure 2.2.3 Presque Isle SPS Minimum Tripping Level – Level 3

The SPS requires that all generation tripped in level 3 be contained in level 2 and all generation tripped in level 2 be contained in level 1. This is required because when a trip level 1 is sent, both trip levels 2 and 3 are sent at the same time.

Table 2.2.1 Existing Presque Isle SPS, Relay Trip Level Settings

Relay Name	Relay at	Relay sees	Fault type[1]	Fault Location		Trip signal
SEL-311C[2]	DRV 345	Line 85601 and PLA 345/138	3PG/2PG/2PP	Anywhere		2
			1PG	Anywhere		3
SEL-311C[2]	PRI 138	Line 481 and both DRV 345/138	3PG/2PG/2PP	Anywhere		1
			1PG	Anywhere		2
SEL-321	PRI 138	Line 468	3PG	0 to 30%	Line 468	2
			3PG	30 to 50%	Line 468	3
			3PG	50 to 100%	Line 468	No trip
			2PG/2PP	0 to 50%	Line 468	3
			2PG/2PP	50 to 100%	Line 468	No trip
			1PG	Anywhere		No trip
SEL-321	EMP 138	Forsyth Line	3PG	0 to 70%	Forsyth Line	2
			3PG	70 to 100%	Forsyth Line	3
			2PG/2PP	Anywhere		3
			1PG	Anywhere		No trip
SEL-321	PRI 138	Line 457	3PG	0 to 25%	Line 457	2
			3PG	25 to 100%	Line 457	3
			2PG/2PP	Anywhere		3
			1PG	Anywhere		No trip
SEL-321	PRI 138	Goose Lake Line and Line 16342	3PG	0 to 25%	Goose Lake Line	2
			3PG	25 to 100%	Goose Lake Line	3
			3PG	0 to 100%	Line 16342	3
			2PG/2PP	Anywhere		3
			1PG	Anywhere		No trip
SEL-321	PRI 138	Line 446	3PG	0 to 25%	Line 446	2
			3PG	25 to 100%	Line 446	3
			2PG/2PP	Anywhere		3
			1PG	Anywhere		No trip
SEL-321	PRI 138	Lines PI605, Freeman605, 26641, 16343, and 16344	3PG	0 to 35%	Line PI605	2
			3PG	35 to 100%	Line PI605	3
			3PG	0 to 100%	Freeman605	3
			3PG	0 to 100%	Line 26641	3
			3PG	0 to 100%	Line 16343	3
			3PG	0 to 100%	Line 16344	3
			2PG/2PP	Anywhere		3
			1PG	Anywhere		No trip
SEL-321	PRI 138	Line PI336 and 16353	3PG	0 to 35%	Line PI336	2
			3PG	35 to 100%	Line PI336	3
			3PG	0 to 100%	Line 16353	3
			2PG/2PP	Anywhere		3
			1PG	Anywhere		No trip

1. Breaker open conditions are described in Table 2.2.2.
2. The SEL-321 relay provides a redundant trip signal.
3. The existing SPS has a voltage relay on the 138 kV Bus Section #5 at the Presque Isle Substation which supervises the SPS trips for faults on the lines that emanate from the PIPP and for faults on the Forsyth line. For these faults, the voltage would also have to drop below a threshold value before generation is tripped at the PIPP. The threshold value for the existing SPS is being checked as of the date of this report.

Table 2.2.2 Existing Presque Isle SPS, Breaker Open Trip Settings

Substation	Breaker(s) opened[1]	Trip signal[2]
PRI 138	BS18 and BS78	3
PLA 345	BS23 and BS16	3
PLA 345	BS12 and BS23	3
DRV 138	481	3
DRV 345	BS12	3
MGN 138	BS56 and BS67	3
MGN 345	BS12	3

1. All faults which cause these circuit breakers to open also result in the respective trip signals listed in Table 2.2.1. Therefore both trip signals from Tables 2.2.1 and 2.2.2 are sent.
2. There is no voltage supervision for the breaker open signals.

2.3 Mine Loads

On November 11-12, 1987, Mr. Richard L Nailen, Project Engineer in the Electrical Engineering Division of Wisconsin Electric visited the Tilden Mine near Ishpeming, Michigan and the Empire Mine at Palmer. The purpose of the visit was to gather information on the major motor loads and their controls for use in judging how such loads would respond during a severe fault on the power transmission system serving the mines. He worked with senior engineers John Adams at Tilden and Dennis Laituri at Empire. The information from the report in combination with motor data from many other sources (e.g., Sargent & Lundy 1973 study report SL-3069, IEEE 1983 paper PCIC-83-3 “Protection of Motors Against Unbalanced Voltage Operation”, Analysis of Faulted Power Systems” by Paul Anderson) were used in developing detailed motor models to represent the loads at Tilden and Empire mines in transient stability studies. This is the basis of the existing motor models used in current transient stability studies.

In addition, the report from Mr. Nailen indicates that the most likely cause for the interruption of major motor load at the mines is that of the a-c control voltage dropping low enough to open the motor starter on mill lubrication pumps (typically ¼ to 7½ hp) or vibrating screens (50 hp). This action will open an interlock in the mill starting motor circuit that results in the tripping of mill process line that will not re-energize automatically when the a-c voltage is restored. According to Mr. Nailen’s report, low voltage motor starters can be expected to drop out within 2 to 4 cycles when the contactor coil voltage dips to 65% of rated. He indicates that no standards govern this and identical contactors of different ages and service histories will exhibit different behavior. Original studies conducted by PTI had used a voltage dip of 70% of rated. An IEEE paper was also provided by PTI regarding the drop out of contactors on motor starters within 2-4 cycles when the contactor coil voltage dips to 70% or less. Efforts to locate the copy of this paper have been unsuccessful. These identified sources were the basis of modeling the motor load tripping used in the current transient stability studies. Table 2.3.1 shows mine load shedding incidents from August 1995 through June 1998 plus a recent event on July 8, 2007. These incidents confirm the sensitivity of mine loads to voltage dips.

All analysis in this report assumes equal distribution of the mine load between the Empire and Tilden Substations unless specifically noted otherwise.

Table 2.3.1 Mine Load Shedding Incidents from August 1995 through June 1998 and an Event on 7/08/2007

Fault type	Faulted element	Before (MW)	Mine load Tripped (MW)	After (MW)	Date
3PG	CDR 138 – TLD 138	269	234	35	06/06/97
2PG (7 miles from EMP)	PRI 138 – EMP 138[1]	257	133	124	07/08/2007
2PG	PRI 138 – EMP 138[1]	No data	145	No data	08/07/96
2PG	PRI 138 – EMP 138[1]	289	89	200	09/19/97
2PG	EMP 138 – FRY 138	No data	30	No data	07/13/97
1PG	PRI 138 Bus #7	302	72	230	06/16/96
1PG	PRI 138 Bus #7	269	116	153	09/12/96
1PG	PRI 138 Bus #1	No data	90	No data	06/28/98
1PG	PRI 138 – CDR 138	No data	0	No data	07/18/96
1PG	PRI 138 – CDR 138	No data	0	No data	08/25/98
1PG	PRI 138 – EMP 138[2]	No data	0	No data	05/06/96
1PG	NAT 138 – CDR 138	No data	0	No data	10/31/95
1PG	NAT 138 – CDR 138	No data	0	No data	10/31/95
1PG (3 miles from CDR)	CDR 138 – TLD 138	No data	45	No data	08/07/96
1PG	DRV 345 – PLA 345	No data	0	No data	10/19/95
1PG	DRV 345 – PLA 345	No data	0	No data	10/05/97
1PG	DRV 345 – PLA 345	No data	0	No data	03/29/98
Unknown	EMP 138 – FRY 138	No data	170	No data	08/03/95

1. Presque Isle – Empire 138 kV Line "Goose Lake"
2. Presque Isle – Empire 138 kV Line 457

2.4 Planning Cases

Planning cases used to study the steady state and the stability performance of the 2007 system are shown in Table 2.4.1 and Table 2.4.2. The summer 2007 peak as-built case is used as the basis for the east-to-west and west-to-east bias cases used in the analysis.

This as-built case without changes shows a high east-to-west bias defined by the power flow on the McGulpin – Straits double circuit 138 kV cables, so no modifications are needed to obtain a representative east-to-west case. The 2007 west-to-east bias case is defined by the power flow on the Indian Lake 138/69 kV parallel transformers and is created by modifying the as-built case with power transactions from Wisconsin and Illinois to Lower Michigan. The system split case is built by opening the 69 kV line between Hiawatha and Indian Lake Substations.

Table 2.4.1 Planning Cases Used for Steady State Analysis of the 2007 System

Peak Load Level	Flow pattern and system topology [1]	Mine load (MW)	PIPP net Output (MW)	Flow North (MW)	Trip Level 1 (MW)	Trip Level 2 (MW)	Trip Level 3 (MW)
50%	W to E	20	352	294	91.1	0.0	0.0
50%	W to E	20	440	379	173.5	103.4	0.0
50%	W to E	20	525	460	252.1	217.9	113.6
50%	W to E	20	556	490	281.2	260.3	154.6
50%	W to E	150	397	211	136.7	0.0	0.0
50%	W to E	150	484	295	218.2	98.2	0.0
50%	W to E	150	556	364	285.1	181.4	84.4
50%	W to E	300	556	215	286.1	152.8	58.8
70%	W to E	20	397	306	102.7	0.0	0.0
70%	W to E	20	471	377	171.6	100.6	0.0
70%	W to E	20	556	458	250.2	215.1	110.9
70%	W to E	150	426	207	132.8	0.0	0.0
70%	W to E	150	515	293	216.2	95.8	0.0
70%	W to E	150	556	331	253.1	141.6	45.5
70%	W to E	300	556	183	255.0	121.8	27.9
100%	E to W	20	407	306	102.7	0.0	0.0
100%	E to W	20	481	377	171.6	100.6	0.0
100%	E to W	20	556	448	240.5	200.9	97.3
100%	E to W	150	446	207	132.8	0.0	0.0
100%	E to W	150	525	293	216.2	95.8	0.0
100%	E to W	150	556	322	244.3	130.8	34.8
100%	E to W	300	556	173	245.3	112.2	18.3
100%	W to E	20	413	306	102.7	0.0	0.0
100%	W to E	20	487	377	171.6	100.6	0.0
100%	W to E	20	556	442	234.6	192.5	89.1
100%	W to E	150	442	208	133.8	0.0	0.0
100%	W to E	150	531	292	215.2	94.6	0.0
100%	W to E	150	556	316	238.5	123.5	27.8
100%	W to E	300	556	168	240.5	107.3	13.4

1. System topologies considered are system intact and also system split (open 69 kV at Hiawatha). Flow “W to E” denotes high West to East Flow pattern. Similarly, “E to W” denotes high East to West Flow pattern. For these studies, “E to W” is considered equivalent to the representation of Firm load patterns.

Table 2.4.2 Planning Cases Used to Analyze the Dynamic Stability of the 2007 System

Peak Load Level	System topology	Mine load (MW)	PIPP net output (MW)	Flow North (MW)
50%	Intact and Split [1]	20	352	294
50%	Intact and Split [1]	20	440	379
50%	Intact and Split [1]	20	525	460
50%	Intact and Split [1]	20	556	490
50%	Intact and Split [1]	150	397	211
50%	Intact and Split [1]	150	484	295
50%	Intact and Split [1]	150	556	364
50%	Intact and Split [1]	300	556	215

1. Split (open 69 kV at Hiawatha)

2.5 TPL-001-0 – Performance Review

Intact system analyses for 2007 did not identify any thermal overload, voltage violations or stability violations. The system meets the Reliability Standard TPL-001-0 performance requirements without the use of any SPS in 2007.

2.6 TPL-002-0 – Performance Review

2.6.1 Dynamic Stability Results – Trip Level Requirements to meet TPL-002-0

Table 2.6.1.1 shows the required Presque Isle SPS trip levels to achieve the required system performance as prescribed in the Reliability Standard TPL-002-0, R1.3.7. Appendix B shows detailed stability results for each case. Results indicate that the overall system stability has considerably improved since the last SPS performance study in 1999. However, the operation of the Presque Isle SPS is still required (albeit with lower trip requirements) to meet system performance as prescribed in the Reliability Standard TPL-002-0, R1.3.

Table 2.6.1.1 2007 Required Presque Isle SPS Relay Trip Level Settings

Relay Name	Relay at	Relay sees	Fault type[1]	Fault Location	Trip signal
SEL-311C[2]	DRV 345	Line 85601	3PG/2PG/2PP 1PG	Anywhere Anywhere	2 3
SEL-311C[2]	PRI 138	Line 481 and both DRV 345/138	3PG/2PG/2PP 1PG	Anywhere Anywhere	1 2
SEL-321	PRI 138	Line 468	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 30% line 468 30 to 100% line 468 Anywhere	3 No trip No trip
SEL-321	EMP 138	Line 457	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% line 457 25 to 100% line 457 Anywhere	3 No trip No trip
SEL-321	PRI 138	Goose Lake Line	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% Goose Lake line 25 to 100% Goose Lake line Anywhere	3 No trip No trip
SEL-321	PRI 138	Line 446	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% line 446 25 to 100% line 446 Anywhere	3 No trip No trip
SEL-321	PRI 138	Lines PI605	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 35% line PI605 35 to 100% line PI605 Anywhere	3 No trip No trip
SEL-321	PRI 138	Line PI336	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 35% line PI336 35 to 100% line PI336 Anywhere	3 No trip No trip

1. Breaker open conditions are described in Table 2.6.1.2.
2. The SEL-321 relay provides a redundant trip signal.
3. The existing SPS has a voltage relay on the 138 kV Bus Section #5 at the Presque Isle Substation which supervises the SPS trips for faults on the lines that emanate from the PIPP and for faults on the Forsyth line. For these faults, the voltage would also have to drop below a threshold value before generation is tripped at the PIPP. The threshold value for the existing SPS is being checked as of the date of this report.

Table 2.6.1.2 2007 Required Presque Isle SPS Breaker Open Trip Level Settings

Substation	Breaker(s) opened[1]	Trip signal[2]
PRI 138	BS18 and BS78	3
PLA 345	BS12 and BS23	3
DRV 138	481	3
DRV 345	BS12	3

1. All faults which cause these circuit breakers to open also result in the respective trip signals listed in Table 2.6.1.1. Therefore both trip signals from Tables 2.6.1.1 and 2.6.2.1 are sent.
2. There is no voltage supervision for the breaker open signals.

2.6.2 Dynamic Stability Results – Mine Load Tripping

The percentage of mine load that trips offline is measured in all dynamic simulations with the minimum required trip level to maintain system stability. The amount of mine load tripped for each fault type and fault location is shown in the stability results presented in Appendix B.

Table 2.6.2.1 shows the percentage of mine load tripping measured for faults on Dead River – Plains 345 kV line. Similarly Table 2.6.2.2 shows the percentage of mine load tripping measured for faults on Presque Isle - Dead River 138 kV line (including the Dead River 345/138 kV transformers). The values presented in these tables are the basis of the mine load tripping assumptions used in the thermal analysis.

Table 2.6.2.1 Mine Load Tripping (%) for Faults on Dead River – Plains 345 kV Line
Used for All Thermal Analysis

	All Presque Isle Output Levels	
	All Mine Load Levels	
Type	Distance = 00.1 to 40.0%	Distance = 40.0 to 99.9%
Line Open	0	0
1PG	0	0
2PG/2PP	50	0
3PG	100	50

Table 2.6.2.2 Mine Load Tripping (%) for Faults on Presque Isle – Dead River 138 kV Line
Used for All Thermal Analysis

	All Presque Isle Output Levels
Type	All Mine Load Levels
Line Open	0
1PG	50
2PG/2PP	100
3PG	100

2.6.3 Dynamic Stability Results – Voltage Relay Requirements

The existing Presque Isle SPS is enabled only when the voltage on any of the three phases at the Presque Isle Bus Section #5 is measured at less than a threshold value. The threshold value for the existing SPS is being checked as of the date of this report.

Dynamic stability simulations are monitored to determine an appropriate voltage threshold value. For intact system stability analysis, the per unit voltage at the Presque Isle 138 kV Substation is nearly identical to the voltage at the Empire and Tilden 13.8 kV buses. All faults that cause mine load to trip also cause a severe voltage depression at the Presque Isle 138 kV Substation. Prior outage stability analysis simulations show a larger difference between the generator and mine voltages. The outage of the Presque Isle – Empire 138 kV line (Goose Lake) with a high impedance fault on the Empire – Forsyth 138 kV line (Forsyth) is observed to cause the Empire 13.8 kV bus voltage to drop to approximately 0.7 p.u. (the threshold value which stability simulation indicate mine loads trip offline) and the Presque Isle 138 kV bus voltage drops to approximately 0.85 p.u. This simulation shows minimal mine load trip and does not require generation tripping to maintain stability. These results suggest a minimum voltage threshold value at the Presque Isle Bus Section #5 of 0.85 p.u. taking into account a 0.05 p.u. margin of error, the recommended voltage threshold at the Presque Isle Bus Section #5 is 0.9 p.u.

2.6.4 Thermal Results

Thermal analysis shows no thermal overloads except for outages on the Presque Isle – Dead River – Plains corridor. This outage results in the thermal overload of the Empire-Forsyth 138 kV line for different mine load levels and system conditions. Appendix A shows the loading of the Forsyth line for different conditions studied.

The worst case thermal line loading occurs for 100% peak load with high West to East flow shown in the Table 2.6.4.1. In this case, the Forsyth line can be loaded as high as 132% of the existing summer emergency rating when mine load is 300 MW, as high as 128% when mine load is 150 MW and as high as 139% when mine load is 20 MW.

With the system split (open 69 kV at Hiawatha), the thermal loading of the Forsyth line slightly improves as shown in the Table 2.6.4.2. In this case, the Forsyth line can be loaded as high as 120% of the existing summer emergency rating when mine load is 300 MW, as high as 117% when mine load is 150 MW and as high as 125% when mine load is 20 MW.

To meet TPL-002-0 standard, it is necessary to resolve the worst case overload of 139%. This can be accomplished either by uprating the Forsyth line as described in the Section 4 or by issuing a trip level 1 (maximum trip) signal for any fault or line switching across the Presque Isle – Dead River – Plains transmission corridor as described in Section 5.2.

In Tables 2.6.4.1 and 2.6.4.2, the notation "A -> B" is used to show the existing trip level and the required trip level. If this notation is not used then the existing trip level setting is adequate to mitigate all thermal overloads for the particular condition.

Table 2.6.4.1 Empire – Forsyth 138 kV Line Loading for the Loss of Dead River – Plains 345 kV Line with High West to East Flows

	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	487	413	556	531	442	556
Flow North (MW)				442	377	306	316	292	208	168
Flow North + Mine (MW)				462	397	326	466	442	358	468
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				235	172	103	239	215	134	240
MW tripped for Level 2 (curve)				192	101	0	124	95	0	107
MW tripped for Level 3 (curve)				89	0	0	28	0	0	13
Empire-Forsyth Over load %	No mine load trip			Not Converged	134	113	112	106	82	68
Required lower PIPP (MW)	No mine load trip			365	360	360	490	490	490	556
Required MW reduction	No mine load trip			191	127	53	66	41	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	137	115	141	130	105	116
Required lower PIPP (MW)	50% mine load trip			350	350	350	400	400	400	490
Required MW reduction	50% mine load trip			206	137	63	156	131	42	66
Empire-Forsyth Over load %	100% mine load trip			Not Converged	141	119	Not Converged	157	127	Not Converged
Required lower PIPP (MW)	100% mine load trip			325	325	325	325	325	325	325
Required MW reduction	100% mine load trip			231	162	88	231	206	117	231
Worst Case % Loading Beyond RATS				130	139	127	127	128	130	132
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2 -> 1 (39 MW)	2 -> 1 (61 MW)	2 -> 1 (88 MW)	2 -> 1 (107 MW)	2 -> 1 (111 MW)	2 -> 1 (117 MW)	2 -> 1 (124 MW)
		2PG / 2PP	50	2 -> 1 (14 MW)	2 -> 1 (36 MW)	2 -> 1 (63 MW)	2 -> 1 (32 MW)	2 -> 1 (36 MW)	2 -> 1 (42 MW)	2
		1PG	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
		open line	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
	40 to 100%	3PG	50	2 -> 1 (14 MW)	2 -> 1 (36 MW)	2 -> 1 (63 MW)	2 -> 1 (32 MW)	2 -> 1 (36 MW)	2 -> 1 (42 MW)	2
		2PG / 2PP	0	2	2 -> 1 (26 MW)	2 -> 1 (53 MW)	2	2	2	2
		1PG	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
		open line	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2 -> 1 (14 MW)	2 -> 1 (36 MW)	2 -> 1 (63 MW)	2 -> 1 (32 MW)	2 -> 1 (36 MW)	2 -> 1 (42 MW)	2
		open line	0	2	2 -> 1 (26 MW)	2 -> 1 (53 MW)	2	2	2	2

Table 2.6.4.2 Empire – Forsyth 138 kV Line Loading for the Loss of Dead River – Plains 345 kV Line with the System Split at Hiawatha Substation

	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				100 Split	100 Split	100 Split	100 Split	100 Split	100 Split	100 Split
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	481	407	556	443	437	556
Flow North (MW)				448	377	306	322	293	207	173
Flow North + Mine (MW)				468	397	326	472	443	357	473
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				240	172	103	244	216	133	245
MW tripped for Level 2 (curve)				201	101	0	131	96	0	112
MW tripped for Level 3 (curve)				97	0	0	35	1	0	18
Empire-Forsyth Over load %	No mine load trip			Not Converged	125	110	105	81	80	60
Required lower PIPP (MW)	No mine load trip			400	400	400	530	556	556	556
Required MW reduction	No mine load trip			156	81	7	26	0	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	128	113	130	104	102	106
Required lower PIPP (MW)	50% mine load trip			390	390	390	450	450	446	530
Required MW reduction	50% mine load trip			166	91	17	106	0	0	26
Empire-Forsyth Over load %	100% mine load trip			Not Converged	131	117	Not Converged	127	126	Not Converged
Required lower PIPP (MW)	100% mine load trip			370	370	370	370	370	370	370
Required MW reduction	100% mine load trip			186	111	37	186	73	67	186
Worst Case % Loading Beyond RATS				118	125	116	117	<100	118	120
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2 -> 1 (10 MW)	2 -> 1 (37 MW)	2 -> 1 (55 MW)	2	2 -> 1 (67 MW)	2 -> 1 (74 MW)
		2PG / 2PP	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		1PG	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
	40 to 100%	3PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		2PG / 2PP	0	2	2	2 -> 1 (7 MW)	2	2	2	2
		1PG	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		open line	0	2	2	2 -> 1 (7 MW)	2	2	2	2

2.6.5 Steady State Voltage Results

Steady state voltage analysis shows no voltage violations when the PIPP is regulating the point of transmission interconnection voltage to 1.02 p.u. as required by ATC Operating Procedure TOP-20GN-10C: "Under Contingency Operations involving a single contingency impacting the interconnection point, the generation operator shall maintain the voltage at 1.02 p.u. of nominal system voltage or other level as communicated by the ATC transmission operator."

2.7 TPL-003-0 – Performance Review

The applicable contingencies for TPL-003-0 are:

1. Permanent single phase fault on a transmission circuit with delayed clearing (due to a stuck breaker) [i.e. Category C8 event].
2. Permanent single phase or three phase faults (whichever is worse) for a system with a prior outage of a generator, transmission circuit, or transformer [i.e. Category C3 event].

2.7.1 Breaker Failure Results

Table 2.7.1.1 shows the cases which result in potential instabilities for single phase faults with breaker failure even with operation of the existing Presque Isle SPS or the Permanent Solution. For these cases, there exists a separate SPS at the Plains Substation which is designed to isolate a portion of the Upper Peninsula of Michigan from the rest of the ATC system for angular instabilities that originate from the PIPP. The planned and controlled separation of this portion of the Upper Peninsula of Michigan from the rest of the ATC system is an acceptable solution to meet TPL-003-0 requirements. A description of the Plains Substation SPS is found in Appendix E.

Table 2.7.1.1 Single Phase Fault, Breaker Failure Scenarios Requiring the Plains Substation SPS

Case #	Faulted Bus	To Bus	Existing Trip Level	Stuck Breaker	Existing Backup Clearing Time	CCT [1]	CCT [2]	Element Cleared
1	PRI 138	PLK 138	No Trip	468 @ PRI	14.0	10.5	12.0	PRI # 8
2	PRI 138	EMP 138	No Trip	457 @ PRI	14.0	11.0	12.5	PRI # 7
3	PRI 138	NAT 138	No Trip	446 @ PRI	14.0	11.0	13.0	PRI # 6
4	PRI 138	CDR 138	No Trip	2003 @ PRI	14.0	9.5	12.5	PRI – FRE 138, PRI 138/69, PRI # 3
5	PRI 138	FRE 138	No Trip	2001 @ PRI	14.0	9.5	12.5	PRI – CDR 138, PRI 138/69, PRI # 3
6	PRI 138	EMP 138	No Trip	2005 @ PRI	14.0	11.0	12.5	PRI # 5
7	DRV 345	PLA 345	3	BK1-2 @ DRV	14.9	11.5	>16.0	Dead River 345/138 kV transformers
8	PRI 138	DRV 138	2	CB1-8 @ PRI	12.7	9.5	11.0	PRI – CDR 138, PRI 138/69, PRI – FRE 138
9	PRI 138	DRV 138	2	CB 7-8 @ PRI	12.7	10.0	9.0	PRI # 9
10	DRV 138	DRV 345	2	481	11.7	10.0	10.0	none

1. Critical Clearing Times (CCT) for Presque Isle = 525 MW, Flow North=460 MW and Mine = 20 MW.
2. Critical Clearing Times (CCT) for Presque Isle = 556 MW, Flow North=215 MW and Mine = 300 MW.

2.7.2 Prior Outage Results

TPL-003-0 standards for permanent single phase or three phase faults (whichever is worse) for a system with a prior outage are met by restricting the net injection of real power at the Presque Isle 138 kV bus for prior outage conditions. Table 2.7.2.1 shows the restrictions for the existing Presque Isle SPS to meet dynamic stability and thermal performance. Stability prior outage analysis assumes 300 MW or 20 MW of mine load pre-contingency and 30 MW net export from the City of Marquette.

Table 2.7.2.1 Required Prior Outage Restrictions for the Existing Presque Isle SPS for 2007

Prior Outage	Stability			Thermal		
	Worst Next Contingency[3]	Limiting Element	Maximum allowed MW injection at the Presque Isle 138 kV bus	Worst Next Contingency[3]	Limiting Element[2]	Maximum allowed MW injection at the Presque Isle 138 kV bus
EMP 138 – FRY 138	3PG fault @ DRV 138 – PRI 138	Angular stability	280 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	290 Year Round
PRI 138 – DRV 138 or DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular stability	280 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	290 Year Round
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	Angular stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	310 Year Round
PLK 138 – NRD 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	290/310 Summer/Winter
NRD 138 – PLA 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	290/310 Summer/Winter
PRI 138 – PLK 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	300/320 Summer/Winter
CDR 138 – M38 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	360/380 Summer/Winter
ARN 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	420 Year Round
EMP 138 – NAT 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	515 Summer Only

1. The highlighted cell is the most restrictive condition for each prior outage.
2. Please refer to Appendix H for a description of the applicable thermal limits. Validation of equipment rating may allow for a less severe restriction.
3. Applying 3 phase to ground fault at the selected locations results in all but 20 MW of mine load to trip off line.

Table 2.7.2.2 shows a more detailed summary of the thermal prior outage analysis based on DC load flow analysis and assuming a 100% mine load trip and no generator tripping. Each thermal limit developed in Table 2.7.2.2 is further verified with full AC load flow solution and assuming all but 20 MW of mine load to trip off line to develop the limits in Table 2.7.2.1.

Table 2.7.2.2 Prior Outage Thermal Restrictions for 2007 (assumes Marquette at 30 MW)

Prior Outage	Worst Next Contingency	Limiting Element	Rating (MVA)	PIPP Maximum Output (MW)	Dist. Factor (%)	Solution for Limiting Element
PRI 138 – DRV 138 or DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	191	235	92.1	No
EMP 138 – FRY 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	235	92.1	No
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	202	260	91.4	Yes
NRD 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	202	260	71.2	Yes
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	FRY 138/69 XFMR	48[2]	265	14.2	No
PRI 138 – PLK 138	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	202	270	73.0	Yes
PRI 138 – PLK 138	3PG fault @ DRV 345 – PLA 345	CDR 138 – M38 138	96[2]	270	27.0	No
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	295	75.5	No
NRD 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	56	320	24.2	No
CDR 138 – M38 138	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	202	330	57.6	Yes
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	FRY 138 – ARN 138	245	350[3]	84.1	No
ARN 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	380[3]	60.1	No
PRI 138 – PLK 138	3PG fault @ DRV 345 – PLA 345	FRY 138 – ARN 138	245	380[3]	67.3	No
EMP 138 – NAT 138	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	191	475[3]	33.7	No

1. Assumptions:
    a. Table 2.7.3 does not include any trip level 2 for 3PG faults @ DRV 345 – PLA 345 because the analysis is limited to a single planning case and is intended to show a conservative restriction.
    b. Table 2.7.3 assumes 100% mine loading tripping for all contingencies.
    c. Table 2.7.3 does not include limits with a distribution factor < 10%.
2. The listed rating has yet to be validated in the ATC Substation Equipment and Line Data database. For all limits that have not yet been validated the next most limiting element is included in the table.
3. These restrictions may be eliminated by generator tripping.

3. 2010 System Studies

3.1 System Description

Figure 3.1.1 shows the one-line diagram for the system in 2010. Additional transmission projects will be constructed by 2010 that affect the requirements for the Presque Isle SPS. The system is reviewed to determine if the Presque Isle SPS is still required for the system to meet NERC reliability standards TPL-001-0, TPL-002-0 and TPL-003-0. The additional transmission projects are listed in Table 3.1.1. Also, the local generation assumptions made in the analyses are listed in Table 3.1.2. The transmission projects listed in Table 3.1.3 may be constructed in the future and are included as sensitivities only for the worst thermal and stability conditions discovered.

Table 3.1.1 Transmission Projects Assumed Complete by 2010

Project	Expected In-Service Year
Relocate/rebuild/rename the Cedar 138/69 kV Substation to North Lake Substation	Q4 2008
Installation of 69 kV and 138 kV capacitor banks in Munising, Ontonagon, and other substations in the Upper Peninsula of Michigan	Ongoing
Installation of a second 345/138 kV transformer at Plains Substation	Q4 2009
Cranberry – Conover – Plains 138 kV project	Q1 2010
Morgan – Werner West 345 kV project	Q4 2009
Gardner Park – Highway 22 345 kV project	Q4 2009

Table 3.1.2 Generation Assumed Online by 2010

Generating Station	Modeled Output (MW)
Presque Isle Power Plant	≤ 547
City of Marquette (Net Export)	30
White Pine Mine	35

Table 3.1.3 Transmission Sensitivities Affecting the Presque Isle SPS

Project	Potential In-Service Year[1]
Rebuild Hiawatha – Pine River 69 kV single circuit to 138 kV single circuit	2009
Convert Indian Lake – Hiawatha 69 kV double circuit (single circuit energized) to 138 kV double circuit energized	2010
Rebuild Munising – Timber – Seney – Blaney Park 69 kV and convert to 138 kV	2012
Rebuild Holmes – Chalk Hills – Nathan – Powers – Harris – Chandler 69 kV to a single circuit 138 kV line from Holmes to Chandler, the sections from Nathan to Powers to Harris and Delta to Chandler are rebuilt as double circuit 138-69 kV lines with a 25 MVA 138/69 kV transformer installed at Powers Substation	2013

1. Based on the ATC 2006 Ten Year Assessment at www.atc10yearplan.com.

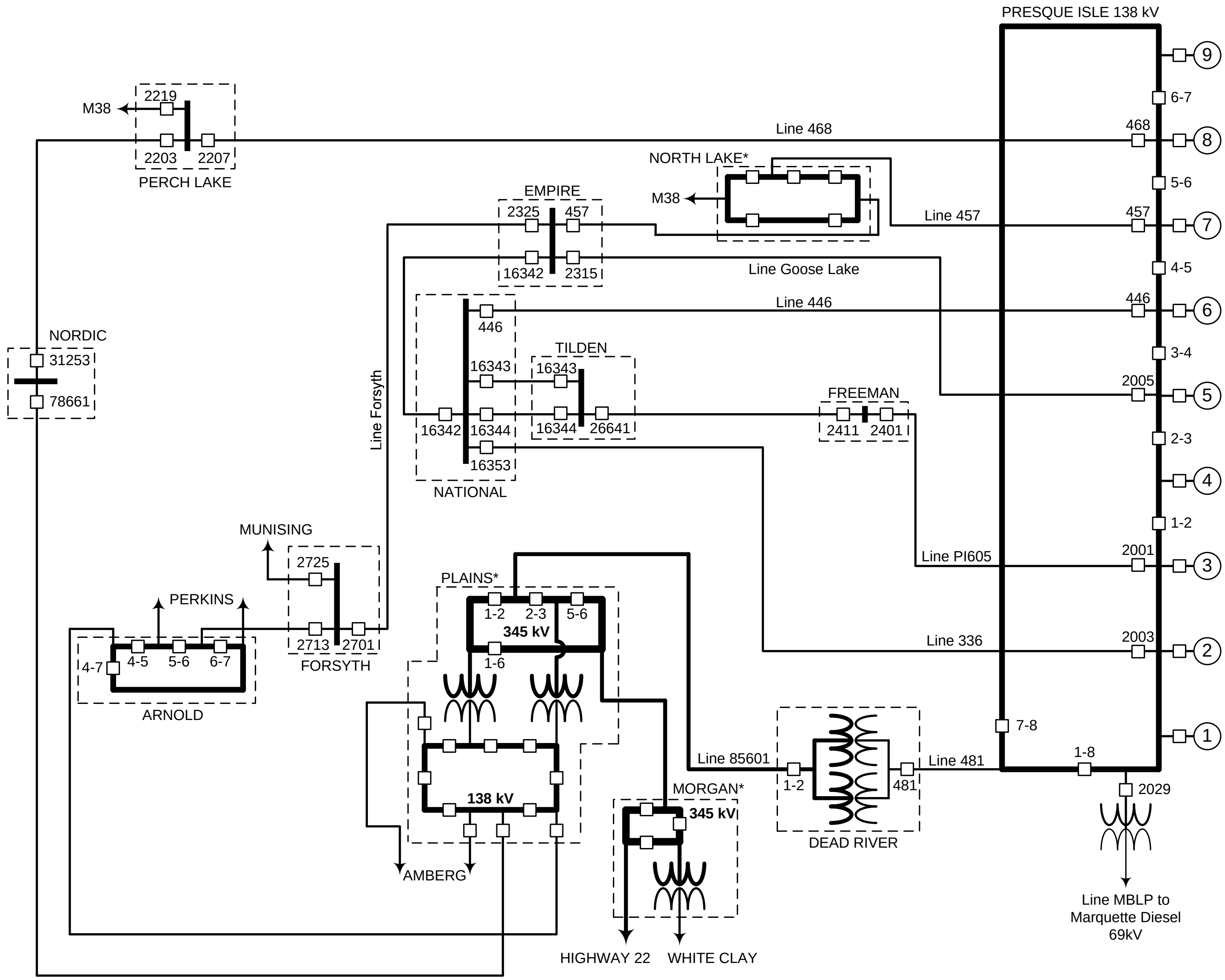

Figure 3.1.1 2010 Local System One-Line Diagram – Substations with * are Not Shown in Full Detail

3.2 The Special Protection System

In order to evaluate the need for the Presque Isle SPS in 2010, the 2010 study initially assumes the system is not equipped with an existing Special Protection System at Presque Isle.

3.3 Mine Loads

Mine load dynamic models used in the 2010 analysis are identical to those used in the 2007 analysis. Please refer to Section 2.3 for a description of the mine load models.

3.4 Planning Cases

All planning cases representing 2010 contain the assumed transmission projects and generation levels listed in Tables 3.1.1 and 3.1.2. Transmission topology within the American Transmission Company footprint is identical in all cases unless specifically noted otherwise. The list of cases examined is found in Appendix C.

Variations between the planning cases include three load levels representing the different seasons of 2010. The ATC load levels analyzed are 50%, 80% and 100% of the summer peak load expected in 2010.

For each load level four system flow scenarios are considered. The first scenario models only Confirmed Firm transmission service with the system intact. The second scenario models Confirmed Firm transmission service with the system split at the Hiawatha 69 kV Substation. The third and fourth scenarios model high flows through the Upper Peninsula of Michigan, as described below.

The high East to West flow scenario is defined by the power flow on the McGulpin – Straits double circuit 138 kV cables approaching 100 MVA. These planning cases are created by exporting power from Michigan to Illinois. First, Ludington is set to generating mode and then load is decreased in Michigan to allow an increased export to Illinois. Load is increased in Illinois to accept the increased import from Michigan.

The high West to East flow scenario is defined by the power flow on the Indian Lake 138/69 kV parallel transformers approaching 104 MVA – slightly less than the existing summer emergency rating of either individual transformer. These cases are created by exporting power from Illinois to Michigan. In this scenario, Ludington is set to pumping mode and then Michigan load is increased while Illinois load is decreased to allow the increased power exchange from Illinois to Michigan.

For either high through flow scenario, no changes are made in the ATC footprint with the exception of allowing control area swing buses to produce power required for the additional losses created by the higher through flows.

During case creation an engineering judgment was made not to create 50% summer peak load cases with high West to East flows because the load shifts required were expected to be on the order of 50% of the initial Michigan load within the planning base case.

For each load level and system flow scenario, Presque Isle generation output is varied from 386 MW to 547 MW to see the affect of output on mine load tripping, system stability, and thermal loading. However, most of the planning cases have Presque Isle set to either 547 MW, the maximum output with units 3 – 9 online, or 431 MW, the maximum output with units 3 and 4 retired and units 5 – 9 online.

To model the historical variation of the mine loads, four initial mine load levels are examined in both stability and thermal analysis. These mine load levels are 20 MW, 125 MW, 225 MW, and 300 MW and the load is evenly split between the Empire and Tilden mines. Dynamic stability simulations utilize PSS/E user models to simulate mine load sensitivity to voltage during fault conditions. The results of dynamic simulation show that the Empire and Tilden mine loads can remain 100% online for some faults but trip offline completely for other faults depending on the distance from and type of fault simulated. To account for the variety of mine load tripping, each thermal planning case is analyzed for post-contingent loading considering five possible mine load tripping percentages of 0%, 25%, 50%, 75%, and 100%.

Additional analysis is made on a case with Confirmed Firm transmission service to consider the affect of an unequal distribution of load between the mines. This analysis considers two load scenarios. In the first scenario, Empire has 200 MW of load and Tilden 100 MW of load. In the second scenario, Empire has 100 MW of load and Tilden has 200 MW of load. The only faults that show a difference in tripping percentages are three-phase to ground faults at 0.1% and 40.0% distance from Dead River 345 kV Substation on the Dead River – Plains 345 kV line. The variation in load distribution caused, at most, a 6% difference in the total amount of load tripped. This difference in percentage tripping is covered by the assumption that all thermal analysis uses the worst simulated mine load tripping percentage rounded up to the next 25% interval. This assumption is shown in Section 3.6, Table 3.6.2.3.

3.5 TPL-001-0 – Performance Review

Intact system analyses for 2010 did not identify any thermal overload, voltage violations or stability violations. The system meets Reliability Standard TPL-001-0 performance requirements without the use of any SPS in 2010.

3.6 TPL-002-0 – Performance Review

3.6.1 Dynamic Stability Results – Trip Level Requirements

Dynamic stability simulations show no system instabilities except for faults on the Presque Isle – Dead River – Plains corridor. Because of this, no trip level (no generation tripping) settings are recommended for faults on all other transmission facilities that are currently part of the Presque Isle SPS. However, the operation of the Presque Isle SPS is still required (albeit with lower trip requirements) to achieve the required system performance in 2010 for Reliability Standard TPL-002-0, R1.3.7.

Dynamic stability simulations show no system instabilities for line switching, 1PG (single phase fault to ground), or 2PG/2PP faults anywhere on the Dead River – Plains 345 kV line. However, when mine loads are low 3PG faults require trip level 3 (Minimum Tripping) unless Presque Isle units 3 and 4 are retired. The required trip levels based on mine load, Presque Isle output, and distance from the Dead River 345 kV Substation are shown in Table 3.6.1.1.

Table 3.6.1.1 Required Trip Level Settings for 3PG Faults on Dead River – Plains 345 kV Line

	Presque Isle Output > 431 MW				Presque Isle 3 & 4 Retired			
Dist.	MI020	MI125	MI225	MI300	MI020	MI125	MI225	MI300
00.1%	3	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip
40.0%	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip
99.9%	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip

Based on the results shown in Table 3.6.1.1, the recommended trip level settings for 3PG faults on the Dead River – Plains 345 kV line are shown in Table 3.6.1.2.

Table 3.6.1.2 Recommended Trip Level Settings for 3PG Faults on Dead River – Plains 345 kV Line

	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Dist.	All Mine Load Levels	All Mine Load Levels
00.1 to 40.0%	3	No Trip
40.0 to 99.9%	No Trip	No Trip

Dynamic stability simulations show no system instabilities for line switching or 1PG faults anywhere on the Presque Isle – Dead River 138 kV line. Simulations show that generation tripping is required for 2PG/2PP and 3PG faults at all mine load levels and distances from Presque Isle. The required trip levels based on mine load, Presque Isle output, and distance from the Presque Isle 138 kV Substation are shown in Table 3.6.1.3. Due to the short length of the Presque Isle – Dead River 138 kV line, stability results are identical regardless of the location of the fault.

Table 3.6.1.3 Required Trip Level Settings for Faults on Presque Isle – Dead River 138 kV Line

	Presque Isle Output > 431 MW				Presque Isle 3 & 4 Retired			
Type	MI020	MI125	MI225	MI300	MI020	MI125	MI225	MI300
Line Open	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip
1PG	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip	No Trip
2PG/2PP	3	2	2	2	3	2	2	2
3PG	2	2	2	1	3	2	2	2

Based on the results shown in Table 3.6.1.3, the recommended trip level settings for faults on Presque Isle – Dead River 138 kV line is shown in Table 3.6.1.4. If Presque Isle units 3 and 4 are retired a lower trip level can be recommended for 3PG faults.

Table 3.6.1.4 Recommended Trip Level Settings for Faults on Presque Isle – Dead River 138 kV Line

	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Type	All Mine Load Levels	All Mine Load Levels
Line Open	No Trip	No Trip
1PG	No Trip	No Trip
2PG/2PP	2	2
3PG	1	2

3.6.2 Dynamic Stability Results – Mine Load Tripping

The percentage of mine load that trips offline is measured in all dynamic simulations with the minimum required trip level to maintain system stability.

Dynamic stability simulations show no mine load tripping for line switching or 1PG faults anywhere on the Dead River – Plains 345 kV line. The measured percentage of mine load tripping offline for 2PG/2PP faults based on mine load, Presque Isle output, and distance from the Dead River 345 kV Substation is shown in Table 3.6.2.1. The measured percentage of mine load tripping offline for 3PG faults is shown in Table 3.6.2.2.

Table 3.6.2.1 Mine Load Tripping (%) for 2PG/2PP Faults on Dead River – Plains 345 kV Line

	Presque Isle Output > 431 MW				Presque Isle 3 & 4 Retired			
Dist.	MI020	MI125	MI225	MI300	MI020	MI125	MI225	MI300
00.1%	16	17	19	20	18	25	36	36
40.0%	0	0	0	0	0	0	0	0
99.9%	0	0	0	0	0	0	0	0

Table 3.6.2.2 Mine Load Tripping (%) for 3PG Faults on Dead River – Plains 345 kV Line

	Presque Isle Output > 431 MW				Presque Isle 3 & 4 Retired			
Dist.	MI020	MI125	MI225	MI300	MI020	MI125	MI225	MI300
00.1%	69	66	69	66	84	84	84	84
40.0%	43	39	43	43	46	46	46	46
99.9%	27	28	28	28	27	30	36	36

Based on the results shown in Tables 3.6.2.1 and 3.6.2.2, the percentage of mine load tripping assumed for 3PG faults on the Dead River – Plains 345 kV line for all thermal analyses is shown in Table 3.6.2.3.

Table 3.6.2.3 Mine Load Tripping (%) for Faults on Dead River – Plains 345 kV Line
Used for All Thermal Analysis

	All Presque Isle Output Levels	
	All Mine Load Levels	
Type	Distance = 00.1 to 40.0%	Distance = 40.0 to 99.9%
Line Open	0	0
1PG	0	0
2PG/2PP	50	0
3PG	100	50

Dynamic stability simulations show no mine load tripping for line switching on the Presque Isle – Dead River 138 kV line. The measured percentage of mine load tripping offline for 1PG, 2PG/2PP, and 3PG faults based on mine load and Presque Isle output is shown in Table 3.6.2.4.

Table 3.6.2.4 Mine Load Tripping (%) for Faults on Presque Isle – Dead River 138 kV Line

	Presque Isle Output > 431 MW				Presque Isle 3 & 4 Retired			
Type	MI020	MI125	MI225	MI300	MI020	MI125	MI225	MI300
Line Open	0	0	0	0	0	0	0	0
1PG	49	49	49	49	49	49	49	49
2PG/2PP	100	100	100	100	100	100	100	100
3PG	100	100	100	100	100	100	100	100

Based on the results shown in Table 3.6.2.4, the percentage of mine load tripping assumed for faults on the Presque Isle – Dead River 138 kV line for all thermal analyses is shown in Table 3.6.2.5.

Table 3.6.2.5 Mine Load Tripping (%) for Faults on Presque Isle – Dead River 138 kV Line
Used for All Thermal Analysis

	All Presque Isle Output Levels
Type	All Mine Load Levels
Line Open	0
1PG	50
2PG/2PP	100
3PG	100

3.6.4 Thermal Results

Thermal analysis shows no thermal overloads except for outages on the Presque Isle – Dead River – Plains corridor. The worst case thermal loading when mine load equals 225 MW, the assumed base scenario, occurs for a 3PG fault at 0.1% distance on the Dead River – Plains 345 kV line with stability required trip level 3 setting. A summary of worst case line loadings is listed in Table 3.6.4.1. Table 3.6.4.2 gives a more detailed description of the worst case loading of the Empire – Forsyth 138 kV line. All other detailed line loading summaries are listed in Appendix D.

Table 3.6.4.1 Summary of Worst Case Line Loadings (Overloads in Bold Type)

		Worst Case Line Loading (MVA)							
		Presque Isle Output > 431 MW				Presque Isle 3 & 4 Retired			
Line	SE Rating (MVA)	No Trip Level	Trip Level 3	Trip Level 2	Trip Level 1	No Trip Level	Trip Level 3	Trip Level 2	Trip Level 1
EMP 138 – FRY 138	202	**307**	**287**	**237**	< 200	**249**	**249**	**239**	< 198
PRI 138 – PLK 138	202	**220**	188	< 188	< 188	176	176	< 176	< 176
PLK 138 – NRD 138	191	**222**	**197**	< 163	< 163	184	184	< 184	< 184
FRY 138 – ARN 138	245	**258**	226	< 226	< 226	211	211	< 211	< 211
ARN 138 – PLA 138	202	**223**	200	< 200	< 200	188	188	< 188	< 188

The most frequently overloaded facility is the Empire – Forsyth 138 kV line. The Empire – Forsyth 138 kV line is also found to have the highest percentage loading among the facilities monitored. With transmission sensitivities, no trip level settings, and an assumed 100% mine load trip; the Empire – Forsyth 138 kV line is overloaded beyond the conductor current carrying capability. In this extreme scenario, a generation reduction scheme is necessary even if the line clearance is raised to the maximum temperature of 300° F. A reconductor or a rebuild could also be considered in lieu of an uprate and a generation reduction scheme. This case is further analyzed to consider a post-contingent total mine load of 20 MW. In this scenario the Empire – Forsyth 138 kV line loading is 328 MVA, less than the maximum allowable rating of the existing conductor (i.e. 337 MVA rating at 300°F conductor temperature).

Table 3.6.4.2 shows the worst case loading of the Empire – Forsyth 138 kV line when Presque Isle units 3 and 4 are still operating and the worst loading when those units are assumed retired. The table also gives the details of the planning case which resulted in the worst case loading. Tables showing the same data for the other lines with potential overloads are shown in Appendix D.

The worst case results are studied for each of the four transmission sensitivities by themselves and all four of the transmission sensitivities together.

Table 3.6.4.2 Worst Case Loading of the Empire – Forsyth 138 kV Line in MVA

Existing Rate B = 202 MVA Limited by: Conductor Summer Emergency Temperature Limit Conductor Characteristics: 605.0 kcmil ACSR 26/7 Squab (167° F) Uprate to 230° F increases the summer emergency rating to 278 MVA (1165 A) Uprate to 257° F increases the summer emergency rating to 302 MVA (1264 A) Uprate to 275° F increases the summer emergency rating to 318 MVA (1332 A) Uprate to 300° F increases the summer emergency rating to 337 MVA (1413 A) 300° F is the Maximum Emergency Temperature Rating per ATC Standards Contingency: Presque Isle – Dead River 138 kV Line or Dead River 345/138 kV Paralleled Transformers or Dead River – Plains 345 kV Line		
	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Stability Required Trip Level	Trip Level 3	No Trip Level
w/o sensitivities No Trip Level Trip Level 3 Trip Level 2 Trip Level 1	 307 MVA 287 237 < 200	 249 MVA 249 239 < 198
with sensitivities No Trip Level Trip Level 3 Trip Level 2 Trip Level 1	 **340** MVA 317 259 190	 275 MVA 275 259 184
Worst Case Attributes Load Level Transfer PIPP Output Mine Load Flow North Trip Level 1 Trip Level 2 Trip Level 3	 80 % High West to East 547 MW 225 MW 264 MVA 261 MW 135 MW 39 MW	 80 % High West to East 431 MW 225 MW 154 MVA 154 MW 22 MW Does Not Exist

3.6.5 Steady State Voltage Results

Steady state voltage analysis shows no voltage violations when the PIPP is regulating the point of transmission interconnection voltage to 1.02 p.u. as required by ATC Operating Procedure TOP-20GN-10C: "Under Contingency Operations involving a single contingency impacting the interconnection point, the generation operator shall maintain the voltage at 1.02 p.u. of nominal system voltage or other level as communicated by the ATC transmission operator."

3.7 TPL-003-0 – Performance Review

The applicable contingencies for TPL-003-0 are:

1. Permanent single phase fault on a transmission circuit with delayed clearing (due to a stuck breaker) [i.e. Category C8 event].
2. Permanent single phase or three phase faults (whichever is worse) for a system with a prior outage of a generator, transmission circuit, or transformer [i.e. Category C3 event].

3.7.1 Breaker Failure Results

Table 3.7.1.1 shows the cases which result in potential instabilities for single phase faults with breaker failure even with operation of the Presque Isle SPS. For these cases, there exists a separate SPS at the Plains Substation which is designed to isolate a portion of the Upper Peninsula of Michigan from the rest of the ATC system for angular instabilities that originate from the PIPP. The planned and controlled separation of this portion of the Upper Peninsula of Michigan from the rest of the ATC system is an acceptable mitigation plan to achieve the required system performance as prescribed in the Reliability Standard TPL-003-0, R1.3.7. A description of the Plains Substation SPS is found in Appendix E.

In addition to the breaker failure scenarios identified in Table 3.7.1.1, all of the Presque Isle 138 kV outlets were studied for single phase faults with failed breakers at the Presque Isle Substation and at the substation on the opposite end of the outlet. Selected breaker failure scenarios were also tested near the Empire and Tilden Substations. All of these scenarios were found to have a Critical Clearing Time greater than or equal to 15.0 cycles with an expected backup clearing time less than 15.0 cycles resulting in a stable system.

Table 3.7.1.1 Single Phase Fault, Breaker Failure Scenarios Requiring the Plains Substation SPS

Case #	Faulted Bus	To Bus	Existing Trip Level	Stuck Breaker	Existing Backup Clearing Time (Cycles)	CCT[1]	CCT[2]	Element(s) Cleared
1	PRI 138	DRV 138	No Trip	CB1-8	12.7	9.0	10.0	PIPP unit 3 PRI 138 – FRE 138 PRI 138 – NAT 138 PRI 138/69 XFMR
2	PRI 138	DRV 138	No Trip	CB7-8	12.7	9.0	11.5[3]	PIPP unit 9
3	DRV 138	PRI 138	No Trip	481	11.7	< 9.0[4]	9.5[4]	DRV 345/138 XFMR

1. Critical Clearing Times (CCT) for the PIPP = 547 MW, Flow North = 388 MW, and Mine Load = 150 MW.
2. Critical Clearing Times (CCT) for the PIPP = 431 MW, Flow North = 266 MW, and Mine Load = 150 MW.
3. This CCT is dependent on PIPP unit 9 operating (i.e. PIPP units 3 and 4 retired).
4. These CCTs have degraded between the 2007 and 2010 analysis because the 2007 analysis requires trip level 2 and the 2010 analysis does not utilize generator tripping for 1PG faults on PRI 138 – DRV 138.

3.7.2 Prior Outage Results

TPL-003-0 standards for permanent single phase or three phase faults (whichever is worse) for a system with a prior outage are met by restricting the net injection of real power at the Presque Isle 138 kV bus for prior outage conditions. Tables 3.7.2.1 and 3.7.2.2 show the restrictions for the existing Presque Isle SPS to meet dynamic stability and thermal performance. See Tables 3.7.2.3 – 3.7.2.6 for a summary of both the thermal and stability prior outage analysis. Thermal prior outage analysis assumes a 100% mine load trip and no generator tripping. Both thermal and stability analyses assume a 30 MW net export from the City of Marquette. Stability prior outage analysis assumes 150 MW of mine load pre-contingency. For low mine load levels (20 MW), there exists a separate SPS at the Plains Substation which is designed to isolate the Upper Peninsula of Michigan from the rest of the ATC system for angular instabilities that could originate from the PIPP. The planned and controlled separation of the Upper Peninsula of Michigan from the rest of the ATC system is an acceptable solution to meet Reliability Standard TPL-003-0.

Table 3.7.2.1 Required Prior Outage Restrictions for the 2010 Presque Isle SPS Assuming Presque Isle Units 3 & 4 Operating

	Stability			Thermal		
Prior Outage	Worst Next Contingency	Limiting Element	Restriction on net injection at the Presque Isle 138 kV bus (MW)	Worst Next Contingency	Limiting Element[3]	Restriction on net injection at the Presque Isle 138 kV bus (MW)
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular stability	330 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	275 Year Round
FRY 138 – ARN 138	2PG/PP fault @ PRI 138 – DRV 138	Angular stability	330 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	275 Year Round
EMP 138 – FRY 138	2PG/PP fault @ PRI 138 – DRV 138	Angular stability	280 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	275 Year Round
NRD 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	310 Year Round
PRI 138 – PLK 138	1PG fault @ PRI 138 – DRV 138	Angular stability	530 Year Round	3PG fault @ DRV 345 – PLA 345	NLK 138 – M38 138	335 Year Round[2]
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	Angular stability	380 Year Round	3PG fault @ DRV 345 – PLA 345	MSS 69 – BRU 69	360 Year Round
EMP 138 – PRI 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP Bus Section 1-2	490 Summer Only
EMP 138 – NAT 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	445 Summer Only
NLK 138 – M38 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – PLK 138	475 / 530 Summer / Winter
ARN 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	475 Year Round

1. The highlighted cell is the most restrictive condition for each prior outage.
2. Validation of equipment rating may allow for a less severe seasonal restriction.
3. Please refer to Appendix H for a description of the applicable thermal limits.

Table 3.7.2.2 Required Prior Outage Restrictions for the 2010 Presque Isle SPS Assuming Presque Isle Units 3 & 4 Retired

Prior Outage	Stability			Thermal		
	Worst Next Contingency	Limiting Element	Restriction on net injection at the Presque Isle 138 kV bus (MW)	Worst Next Contingency	Limiting Element[3]	Restriction on net injection at the Presque Isle 138 kV bus (MW)
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular stability	330 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	275 Year Round
FRY 138 – ARN 138	2PG/PP or 3PG fault @ PRI 138 – DRV 138	Angular stability	330 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	275 Year Round
EMP 138 – FRY 138	3PG fault @ PRI 138 – DRV 138	Angular stability	230 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	275 Year Round
NRD 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	310 Year Round
PLK 138 – NRD 138	3PG fault @ PRI 138 – DRV 138	Angular stability	330 Year Round	3PG fault @ DRV 345 – PLA 345	MSS 69 – BRU 69	360 Year Round
PRI 138 – PLK 138	3PG fault @ PRI 138 – DRV 138	Angular stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	NLK 138 – M38 138	335 Year Round[2]
ARN 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular stability	430 Year Round	None	None	None Year Round
EMP 138 – PRI 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP Bus Section 1-2	440 Summer Only
EMP 138 – NAT 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	445 Summer Only

1. The highlighted cell is the most restrictive condition for each prior outage.
2. Validation of equipment rating may allow for a less severe seasonal restriction.
3. Please refer to Appendix H for a description of the applicable thermal limits.

Table 3.7.2.3 2010 Prior Outage Thermal Restrictions Assuming Presque Isle Units 3 & 4 Operating

Prior Outage	Worst Next Contingency	Limiting Element	SE Rating (MVA)	PIPP Maximum Output (MW)	Dist. Factor (%)	Solution for Limiting Element
PRI 138 – DRV 138 or DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	191	245	88.7	No
EMP 138 – FRY 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	245	88.7	No
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	FRY 138/69 XFMR	48[3]	265	13.6	No
NRD 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	56	280	25.5	No
PRI 138 – PLK 138	3PG fault @ DRV 345 – PLA 345	NLK 138 – M38 138	96[3]	305	28.0	No
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	320	73.1	No
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	MSS 69 – BRU 69	34	330	11.7	No[2]
EMP 138 – PRI 138	3PG fault @ DRV 345 – PLA 345	EMP Bus Section 1-2	178	410	37.8	No
EMP 138 – NAT 138	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	166	415	36.8	No
NLK 138 – M38 138	3PG fault @ DRV 345 – PLA 345	PRI 138 – PLK 138	202	445	43.8	No
ARN 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	445	59.9	No
EMP 138 – PRI 138	3PG fault @ DRV 345 – PLA 345	EMP 138 – NAT 138	202	490	37.8	No

1. Assumptions:
    a. Table 3.7.2.3 does not include any trip level 3 for 3PG faults @ DRV 345 – PLA 345 because the trip level 3 is often 0 MW and is highly dependent on the system flow scenario (e.g. High East to West).
    b. Table 3.7.2.3 assumes 100% mine loading tripping for all contingencies.
    c. Table 3.7.2.3 does not include limits with a distribution factor < 10%.
    d. Table 3.7.2.3 assumes Empire – Forsyth 138 kV line uprate completed
2. The Mass – Bruce Crossing 69 kV line is limited by a relay at the Mass 69 kV Substation. The second limiting factor is the line conductor with a summer emergency rating of 43 MVA.
3. The listed rating has yet to be validated in the ATC Substation Equipment and Line Data database. For all limits that have not yet been validated the next most limiting element is included in the table.
4. All analysis assumes the City of Marquette has a net export of 30 MW.

Table 3.7.2.4 2010 Prior Outage Thermal Restrictions Assuming Presque Isle Units 3 & 4 Retired

Prior Outage	Worst Next Contingency	Limiting Element	SE Rating (MVA)	PIPP Maximum Output (MW)	Dist. Factor (%)	Solution for Limiting Element
PRI 138 – DRV 138 or DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	191	245	88.7	No
EMP 138 – FRY 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	245	88.7	No
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	FRY 138/69 XFMR	48[3]	265	13.6	No
NRD 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	56	280	25.5	No
PRI 138 – PLK 138	3PG fault @ DRV 345 – PLA 345	NLK 138 – M38 138	96[3]	305	28.0	No
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	191	320	73.1	No
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	MSS 69 – BRU 69	34	330	11.7	No[2]
EMP 138 – PRI 138	3PG fault @ DRV 345 – PLA 345	EMP Bus Section 1-2	178	410	37.8	No
EMP 138 – NAT 138	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	166	415	36.8	No

1. Assumptions:
    a. Table 3.7.2.4 assumes the recommended no trip level for all 3PG faults @ DRV 345 – PLA 345.
    b. Table 3.7.2.4 assumes 100% mine loading tripping for all contingencies.
    c. Table 3.7.2.4 does not include limits with a distribution factor < 10%.
    d. Table 3.7.2.4 assumes Empire – Forsyth 138 kV line uprate completed.
2. The Mass – Bruce Crossing 69 kV line is limited by a relay at the Mass 69 kV Substation. The second limiting factor is the line conductor with a summer emergency rating of 43 MVA.
3. The listed rating has yet to be validated in the ATC Substation Equipment and Line Data database. For all limits that have not yet been validated the next most limiting element is included in the table.
4. All analysis assumes the City of Marquette has a net export of 30 MW.

Table 3.7.2.5 2010 Prior Outage Stability Restrictions Assuming Presque Isle Units 3 & 4 Operating

Prior Outage	Worst Next Contingency	Trip Level[1]	Generation Tripped (MW)	PIPP Maximum Output (MW)	Mine Load Tripped (%)
EMP 138 – FRY 138	2PG/PP fault @ PRI 138 – DRV 138	2	0	250	100
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	No Trip	0	300	100
FRY 138 – ARN 138	2PG/PP fault @ PRI 138 – DRV 138	2	0	300	100
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	3	0	350	84
PRI 138 – PLK 138	1PG fault @ PRI 138 – DRV 138	No Trip	0	500	46

1. See Tables 3.6.1.2 and 3.6.1.4 for the recommended trip level settings.
2. The prior outage of the following lines do not require that the PIPP generation be restricted for system stability if the recommended trip level settings are implemented: Arnold – Plains 138 kV, Nordic – Plains 138 kV, Presque Isle – Empire 138 kV, Empire – National 138 kV, North Lake – M38 138 kV, Presque Isle – North Lake 138 kV, Presque Isle – National 138 kV, Presque Isle – Freeman 138 kV

Table 3.7.2.6 2010 Prior Outage Stability Restrictions Assuming Presque Isle Units 3 & 4 Retired

Prior Outage	Worst Next Contingency	Trip Level[1]	Generation Tripped (MW)	PIPP Maximum Output (MW)	Mine Load Tripped (%)
EMP 138 – FRY 138	3PG fault @ PRI 138 – DRV 138	2	0	200	100
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	No Trip	0	300	100
FRY 138 – ARN 138	2PG/PP or 3PG fault @ PRI 138 – DRV 138	2	0	300	100
PLK 138 – NRD 138	3PG fault @ PRI 138 – DRV 138	2	0	300	100
ARN 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	2	33	400	100
PRI 138 – PLK 138	3PG fault @ PRI 138 – DRV 138	2	34	400	100
NRD 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	2	33	400	100

1. See Tables 3.6.1.2 and 3.6.1.4 for the recommended trip level settings.
2. The prior outage of the following lines do not require that the PIPP generation be restricted for system stability if the recommended trip level settings are implemented: Presque Isle – Empire 138 kV, Empire – National 138 kV, North Lake – M38 138 kV, Presque Isle – North Lake 138 kV, Presque Isle – National 138 kV, Presque Isle – Freeman 138 kV

4. The Permanent Solution

(Estimated schedule is to implement is 12 months. The goal is to have it completed prior to summer 2008.)

1. Update the Presque Isle SPS trip levels to the values required by the stability results in Section 2.6. The trip level MW settings communicated to the PIPP Plant Operator are absolute minimums, the units selected for each trip level must be generating real power greater than or equal to the trip level MW settings communicated. No under-tripping is allowed.
2. Uprate the Forsyth line to 257° F and replace terminal equipment to meet TPL-002-0 steady state performance for the loss of Presque Isle – Dead River – Plains transmission corridor.
3. Restrict the net injection of real power at the Presque Isle 138 kV bus for prior outage conditions as defined in the section 4.2.
4. Under appropriate conditions, split the Upper Peninsula of Michigan at the Hiawatha Substation to limit pre-contingency generation re-dispatch or for the prior outage restriction of the net injection of real power at the Presque Isle 138 kV bus.
5. An operating guide line for the Permanent Solution needs to be developed to take into account items 3 and 4 described above.

Tables 4.0.1 and 4.0.2 show the required Presque Isle SPS trip level settings using the 2007 stability results described in the Section 2.6.

Table 4.0.1 Required Presque Isle SPS Relay Trip Level Settings for the Permanent Solution

Relay Name	Relay at	Relay sees	Fault type[1]	Fault Location		Trip Signal[3]
SEL-311C[2]	DRV 345	Line 85601	3PG/2PG/2PP 1PG	Anywhere Anywhere		2 3
SEL-311C[2]	PRI 138	Line 481 and both DRV 345/138	3PG/2PG/2PP 1PG	Anywhere Anywhere		1 2
SEL-321	PRI 138	Line 468	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 30% 30 to 100% Anywhere	line 468 line 468	3 No trip No trip
SEL-321	EMP 138	Line 457	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% 25 to 100% Anywhere	line 457 line 457	3 No trip No trip
SEL-321	PRI 138	Goose Lake Line	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% 25 to 100% Anywhere	Goose Lake line Goose Lake line	3 No trip No trip
SEL-321	PRI 138	Line 446	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% 25 to 100% Anywhere	line 446 line 446	3 No trip No trip
SEL-321	PRI 138	Lines PI605	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 35% 35 to 100% Anywhere	line PI605 line PI605	3 No trip No trip
SEL-321	PRI 138	Line PI336	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 35% 35 to 100% Anywhere	line PI336 line PI336	3 No trip No trip

1. Breaker open conditions are described in Table 4.0.2.
2. The SEL-321 relay provides a redundant trip signal.
3. The existing SPS has a voltage relay on the 138 kV Bus Section #5 at the Presque Isle Substation which supervises the SPS trips for faults on the lines that emanate from the PIPP and for faults on the Forsyth line. For these faults, the voltage would also have to drop below a threshold value before generation is tripped at the PIPP. The threshold value for the existing SPS is being checked as of the date of this report. The recommended voltage threshold is 0.90 p.u. for the Permanent Solution.

Table 4.0.2 Required Presque Isle SPS Breaker Open Trip Level Settings for the Permanent Solution

Substation	Breaker(s) opened[1]	Trip signal[2]
PRI 138	BS18 and BS78	3
PLA 345	BS12 and BS23	3
DRV 138	481	3
DRV 345	BS12	3

1. All faults which cause these circuit breakers to open also result in the respective trip signals listed in Table 4.0.1. Therefore both trip signals from Tables 4.0.1 and 4.0.2 are sent.
2. There is no voltage supervision for the breaker open signals.

The Forsyth line has an emergency rating of 202 MVA limited by the 605.0 kcmil ACSR 26/7 Squab conductor operating at 167° F. By raising the line clearance and replacing some terminal equipment, the line can be operated at 257° F to obtain a summer emergency rating of 302 MVA.

Analysis of planning cases representing 2007, detailed in Section 2, shows that the worst case conditions result in the Forsyth line loading to be as high as 281 MVA (139%). Analysis of the planning cases representing 2010 indicates that the Forsyth line loading to be as high as 307 MVA (152%) with units 3 and 4 in-service and as high as 249 MVA (124%) with units 3 and 4 retired.

Based on these results, it is recommended that the Forsyth line clearance be raised to 257° F (302 MVA). If the PIPP units 3 and 4 remain in-service beyond 2010, the Forsyth line could be uprated to the maximum 300° F temperature to obtain a 337 MVA emergency rating. Until the retirement of PIPP units 3 and 4, some pre-contingency re-dispatch may be required in unusual and extreme system scenarios (e.g., mine load curtailed to 20 MW and the Upper Peninsula of Michigan can't be split to reduce flows) even with an uprate of the Forsyth line to 302 MVA.

The potential thermal overload of the Forsyth line is improved if the System Operator takes action to split the Upper Peninsula of Michigan transmission system to eliminate through flow. Table 2.6.3.2 indicates the worst case overload is 125% with the system split. With the system split, it would be sufficient to uprate the Forsyth line to 230° F (278 MVA) in the 2007 analysis and 257° F (302 MVA) in the 2010 analysis.

To achieve the recommended rating, the line clearance must be raised and some equipment must be replaced at both the Forsyth and Empire Substations. Table 4.0.3 identifies the substation equipment that requires replacement or modification of any sort. Table 4.0.4 shows the cost estimates for the complete replacement of all substation equipment rated below 337 MVA. Table 4.0.5 shows the cost estimates for the different levels of increased line clearances reviewed.

Table 4.0.3 Equipment Upgrades Required for the Uprate of the Empire – Forsyth 138 kV Line

Required Rating (MVA)	Line Conductor Temp (° F)	Existing Equipment	Existing Rating (MVA)	Solution
302	257	B-Phase Line Trap (1) at Forsyth Substation	214	Replace
302	257	Current Transformers (3) at Forsyth Substation	287	Replace / Reset
302	257	Bus Conductors at Forsyth Substation & at Empire Substation	< 302	Replace
337	300	Bus Conductors at Forsyth Substation & at Empire Substation	< 337	Replace

1. Each increase in rating requires that all lower rating required upgrades be implemented as well.

Table 4.0.4 Cost Estimates for Substation Equipment Upgrades Required for the Uprate of the Empire – Forsyth 138 kV Line

Required Rating (MVA)	Line Conductor Temp (° F)	Substation	Cost Estimate ($ 2007)
337	300	Forsyth	203,000
337	300	Empire	94,000

1. Assumes equipment rated less than 337 MVA will be replaced at both substations

Table 4.0.5 Cost Estimates for Line Clearance Increases
Required for the Uprate of the Empire – Forsyth 138 kV Line

Required Rating (MVA)	Line Conductor Temp (° F)	Cost Estimate ($ 2007)
302	257	2,122,000
337	300	2,675,000

4.1 Alternative Solutions Considered

4.1.1 Increase the Trip Levels across the PIPP – Dead River – Plains Corridor

Analysis of planning cases representing both 2007 and 2010 indicate that applying a trip level 1 across the Presque Isle – Dead River – Plains transmission corridor will eliminate the need to uprate the Forsyth line. Within this approach, multiple options are considered as listed below.

1. *Applying trip level setting 1 and pre-contingency re-dispatch*

Option #1 is to apply a trip level 1 across the Presque Isle – Dead River – Plains transmission corridor for all fault conditions that result in the loss of mine load. Real time contingency analysis would then be required to identify all faults and line switching events that do not result in the loss of mine load but would still cause thermal overload of the Forsyth line. These contingencies would require pre-contingency generation re-dispatch. This solution increases the exposure of the PIPP to tripping for multi-phase faults across Presque Isle – Dead River – Plains. In addition, resolving potential thermal overloads using pre-contingency generation re-dispatch is considered acceptable only as an interim solution since the study of year 2010 identified a continuing need for a higher Forsyth line rating. This alternative is proposed as an interim solution in Section 5 until the Forsyth line uprate is completed.

Implementation of this option requires a review of the proposed SPS modifications from both the Reliability First Corporation (RFC) and the Midwest Reliability Organization (MRO) because it is considered a functional change to the existing Presque Isle SPS. SPS documentation must be submitted to the MRO and the RFC at least 120 calendar days prior to the in service date of the proposed SPS modifications. If the MRO and the RFC review the proposed SPS changes without significant delays, then the estimated schedule to implement this alternative is approximately 6 months.

2. *Modifying trip level settings in real time to eliminate the need for pre-contingency generation re-dispatch*

Option #2 is to apply a trip level 1 across the Presque Isle – Dead River – Plains transmission corridor for all fault conditions that result in the loss of mine load and use modified SPS relay settings when a thermal overload is identified. This alternative also requires the use of real time contingency analysis to identify all other fault and switching events that do not result in the loss of mine load but could result in the potential thermal overload of the Forsyth line. However, in this approach, after the next contingency overload is identified, the ATC System Operator would update the SPS relay trip level setting to eliminate the need for pre-contingency re-dispatch. This solution increases the exposure of the PIPP to tripping. In addition, it further complicates the Presque Isle SPS scheme by requiring constant operator monitoring and intervention. Hence, this is not a good candidate for a permanent solution.

Implementation of this option requires a review of the proposed SPS modifications from both the RFC and the MRO because it is considered a functional change to the existing Presque Isle SPS. SPS documentation must be submitted to the MRO and the RFC at least 120 calendar days prior to the in-service date of the proposed SPS modifications. If the MRO and the RFC review the proposed SPS changes without significant delays, then the estimated schedule to implement this alternative is approximately 9 months.

3. *Applying trip level setting 1 for any circuit breaker open event on the Presque Isle – Dead River – Plains transmission corridor*

Option #3 is to maintain all stability recommendations in Table 4.0.1 but upgrade the trip level signal sent when a breaker opens. The recommended setting shown in Table 4.0.2 is trip level 3. Option #3 would require a trip level 1 setting for all six circuit breakers listed in Table 4.0.2. Table 4.1.1.1 shows the outage data from January 1997 through January 2007.
This solution increases the exposure of the PIPP generating units to maximum tripping (trip level 1) and thus is likely to be deemed unacceptable by the plant owner (i.e. We Energies). One of the advantages of this method is that it does not require pre-contingency generation re-dispatch to mitigate the potential overload of the Forsyth line for low mine load conditions or for atypical high west to east flows.

Implementation of this option requires a review of the proposed SPS modifications from both the RFC and the MRO because it is considered a functional change to the existing Presque Isle SPS. SPS documentation must be submitted to the MRO and the RFC at least 120 calendar days prior to the in-service date of the proposed SPS modifications. If the MRO and the RFC review the proposed SPS changes without significant delays, then the estimated schedule to implement this alternative is approximately 6 months.

4. *Applying trip level setting 3 for the first circuit breaker open event on the Presque Isle – Dead River – Plains transmission corridor and a trip level setting 1 if the breaker locks open*

Option #4 is a permutation of Option #3, but Option #4 allows the possibility of a circuit breaker reclosing to solve the expected thermal overload. This option still sends the appropriate trip level to maintain system stability as listed in Table 4.0.1, but only trips generation when the affected circuit breaker is guaranteed to have attempted a final reclose. Discussion with the ATC System Protection Department suggests the actual implementation of this solution is rather difficult as it requires placing timers to measure how long the breaker is open. Hence, this alternative is likely to be deemed unacceptable.

Implementation of this option requires a review of the proposed SPS modifications from both the RFC and the MRO because it is considered a functional change to the existing Presque Isle SPS. SPS documentation must be submitted to the MRO and the RFC at least 120 calendar days prior to the in-service date of the proposed SPS modifications. If the MRO and the RFC review the proposed SPS changes without significant delays, then the estimated schedule to implement this alternative is approximately 6 to 9 months.

Table 4.1.1.1 Presque Isle SPS Relevant Transmission Outage History

Transmission Line	Line Length (miles)	Momentary Outages (≤ 60 seconds)	Sustained Outages (> 60 seconds)	Average Duration of All Outages (minutes)
PRI 138 – DRV 138	0.5	1	2	73.2
DRV 345 – PLA 345	76.3	12	6	111.8

4.1.2 Improving the Voltage Ride-Through Capability of the Mine Loads

There are devices that can protect sensitive loads from voltage sags. These devices typically inject a series voltage to compensate for the transmission voltage loss and are primarily effective during single phase faults. These solutions have been used by INTEL to protect some of their semiconductor fabrication facilities. The cost of such devices is the same order of magnitude as uprating the Forsyth line. However, since these solutions do not address potential thermal overloads when the mine load level is low or when the fault is a multi-phase fault, this application of technology does not present any significant advantage over the other alternatives listed.

4.1.3 Generation Restrictions

Table 4.1.2.1 shows the intact system generation restrictions that need to be implemented as an alternative to the Interim Solution (described in Chapter 5). The intact system generation restrictions limits were obtained by studying a high West to East transfer case and also studying the loss of the Dead River – Plains 345 kV line due to a 3 phase fault at the Dead River 345 kV substation (resulting in all but 20 MW of mine load to trip off line). Note that for the prior outage conditions, additional generation restrictions are still required as shown in Table 2.7.2.1.

Table 4.1.2.1 Required Generation Restrictions to Meet TPL-002
(Until the Permanent Solution is Implemented)

Mine load level	Maximum allowed MW injection at the Presque Isle 138 kV bus		
	Summer	Spring/Fall	Winter
Any	420 MW	470 MW	No limit (SPS resolves limit)

4.2 Prior Outage Restrictions

TPL-003-0 standards for permanent single phase or three phase faults (whichever is worse) for a system with a prior outage are met by restricting the net injection of real power at the Presque Isle 138 kV bus for prior outage conditions. Table 4.2.1 shows the restrictions for the existing Presque Isle SPS to meet dynamic stability and thermal performance in 2007.

Table 4.2.1 Required Prior Outage Restrictions for after the Implementation of the Permanent Solution

Prior Outage	Stability			Thermal		
	Worst Next Contingency[3]	Limiting Element	Maximum allowed MW injection at the Presque Isle 138 kV bus	Worst Next Contingency[3]	Limiting Element[2]	Maximum allowed MW injection at the Presque Isle 138 kV bus
EMP 138 – FRY 138	3PG fault @ DRV 138 – PRI 138	Angular stability	280 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	290 Year Round
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular stability	280 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	290 Year Round
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	Angular stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	310 Year Round
PLK 138 – NRD 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	ARN 138 – FRY 138	405 Year Round
NRD 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	NRD 138/69	315 Year Round
PRI 138 – PLK 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	CDR 138 – M38 138	320 Year Round
CDR 138 – M38 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – PLK 138	475 Year Round
ARN 138 – PLA 138	3PG fault @ DRV 345 – PLA 345	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	420 Year Round
EMP 138 – NAT 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	515 Summer Only

1. The highlighted cell is the most restrictive condition for each prior outage.
2. Please refer to Appendix H for a description of the applicable thermal limits. Validation of equipment rating may allow for a less severe seasonal restriction.
3. Applying 3 phase to ground fault at the selected locations results in all but 20 MW of mine load to trip off line.

5. The Immediate and Interim Solutions

5.1 Description

The Immediate Solution:
(No change to SPS needed and already implemented)

1. Continue to operate to historical limits until the Interim Solution is implemented. Historical limits enforce local area generation restrictions whenever real-time Flow North flow exceeds 460 MW. For atypical scenarios where mine load is curtailed, ATC System Operations will work with MISO to bind any constraint in real time and will continue to do this until the Forsyth line uprate is completed. The Flow North restriction is approximately 296 MW when the combined Empire and Tilden mine load is 20 MW. Under appropriate conditions, split the Upper Peninsula of Michigan transmission system at the Hiawatha or Indian Lake Substation post-contingency to limit local area generation re-dispatch.

   For atypical scenarios where mine load is curtailed, ATC System Operations will work with the Midwest ISO to bind any constraint in real time in accordance with the Midwest ISO procedures and will continue to do this until the Forsyth line uprate is completed. The Flow North restriction is approximately 279 MW when the combined Empire and Tilden mine load is 20 MW. However, the exact Flow North restriction will vary depending on the system conditions and the season. This mitigation strategy is generally comparable to other first contingency limits monitored and managed in real-time operations.

2. For the prior outage of a single transmission system element, continue to operate to historical limits until the Interim Solution is implemented. The historical Flow North limit is 150 MW for prior outage conditions, which may result in local generation restrictions

The Interim Solution:
(Available to implement subsequent to MRO and RFC reviews – actual implementation dependant on time until permanent solution)

1. Modify the existing SPS generation trip settings according to new stability trip settings as shown in Appendix G. Note that from 2001 to 2007, the Dead River – Plains 345 kV Line 85601 has experienced zero three-phase faults and one phase-to-phase fault. The modification of trip level settings will require a period of review by the Midwest Reliability Organization and the Reliability First Corporation.
2. For system intact conditions, enforce local area generation restrictions whenever real-time Flow North flow exceeds 460 MW. For atypical scenarios where mine load is curtailed, ATC System Operations will work with the Midwest ISO to bind any constraint in real time and will continue to do this until the Forsyth line uprate is completed. The Flow North restriction is approximately 296 MW when the combined Empire and Tilden

mine load is 20 MW. However, the exact Flow North restriction will vary depending on the system conditions and the season.

3. For the prior outage of a single transmission system element, restrict the net generation injection at Presque Isle 138 kV bus as given in Table 5.3.1.
4. An operating guide line needs to be developed to take into account items 2 and 3 of the Interim Solution described above.

Implementation of the Interim Solution requires a review of the proposed SPS modifications from both the RFC and the MRO because it is considered a functional change to the existing Presque Isle SPS. SPS documentation must be submitted to the MRO and the RFC at least 120 calendar days prior to the in service date of the proposed SPS modifications. If the MRO and the RFC review the proposed SPS changes without significant delays, then the estimated schedule to implement this alternative is approximately 6 months.

If at any time ATC determines that the Forsyth line uprate described as the Permanent Solution will be implemented prior to summer 2008, then the implementation of the Interim Solution may be suspended dependant on time until Forsyth line uprate is completed.

Tables 5.1.1 and 5.1.2 show the Presque Isle SPS required trip levels to meet the stability and thermal requirements defined in item 1 and item 2. For atypical scenarios where mine load is curtailed pre-contingency, item 3 uses pre-contingency generation re-dispatch to anticipate and resolve any potential overload of the Forsyth line until the Forsyth line uprate is completed.

Table 5.1.1 Required Presque Isle SPS Relay Trip Level Settings for the Interim Solution

Relay Name	Relay at	Relay sees	Fault type	Fault location	Trip Signal[4]
SEL-311C[1]	DRV 345	Line 85601	3PG 2PG/2PP 2PG/2PP 1PG	Anywhere 0 to 40% line 85601 40 to 100% line 85601 Anywhere	1[2] 1[2] 2[3] 3[3]
SEL-311C[1]	PRI 138	Line 481 and both DRV 345/138	3PG/2PG/2PP 1PG	Anywhere Anywhere	1[2] 1[2]
SEL-321	PRI 138	Line 468	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 30% line 468 30 to 100% line 468 Anywhere	3 No trip No trip
SEL-321	EMP 138	Line 457	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% line 457 25 to 100% line 457 Anywhere	3 No trip No trip
SEL-321	PRI 138	Goose Lake Line	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% Goose Lake line 25 to 100% Goose Lake line Anywhere	3 No trip No trip
SEL-321	PRI 138	Line 446	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 25% line 446 25 to 100% line 446 Anywhere	3 No trip No trip
SEL-321	PRI 138	Lines PI605	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 35% line PI605 35 to 100% line PI605 Anywhere	3 No trip No trip
SEL-321	PRI 138	Line PI336	3PG/2PG/2PP 3PG/2PG/2PP 1PG	0 to 35% line PI336 35 to 100% line PI336 Anywhere	3 No trip No trip

1. The SEL-321 relay provides a redundant trip signal.
2. These faults could result in mine load to trip off line and also the loss of the faulted line. This leads to potential generation instabilities and also the potential overload of the Forsyth line. Potential instabilities and thermal overloads are addressed by a trip level 1 as shown. Uprating the Forsyth line resolves potential thermal overloads and the trip signal severity could be dropped to a trip level 2.
3. Potential thermal overload of the Forsyth line is possible for atypical conditions (low mine load levels or high west to east flow conditions). For atypical scenarios where mine load is curtailed, ATC System Operations will work with the Midwest ISO to bind any constraint in real time and will continue to do this until the Forsyth line uprate is completed. The Flow North restriction is approximately 296 MW when the combined Empire and Tilden mine load is 20 MW.
4. The existing SPS has a voltage relay on the 138 kV Bus Section #5 at the Presque Isle Substation which supervises the SPS trips for faults on the lines that emanate from the PIPP and for faults on the Forsyth line. For these faults, the voltage would also have to drop below a threshold value before generation is tripped at the PIPP. The threshold value for the existing SPS is being checked as of the date of this report. The recommended voltage threshold is 0.90 p.u. for the proposed Interim Solution.

Table 5.1.2 Required Presque Isle SPS Breaker Open Trip Level Settings for the Interim Solution

Substation	Breaker(s) opened[1]	Trip signal[2]
PRI 138	BS18 and BS78	3
PLA 345	BS12 and BS23	3
DRV 138	481	3
DRV 345	BS12	3

1. All faults which cause these circuit breakers to open also result in the respective trip signals listed in Table 4.0.1. Therefore both trip signals from Tables 4.0.1 and 4.0.2 are sent.
2. There is no voltage supervision for the breaker open signals.

5.2 Alternative Interim Solution

A conceptual alternative to the proposed interim solution is to:

1. Update the Presque Isle SPS trip levels to the values required by the stability results in Section 2.6.
2. Apply a trip level 1 across the Presque Isle – Dead River – Plains transmission corridor for faults that result in the mine load tripping offline.
3. Monitor the loading of the Forsyth line for the loss of the Presque Isle – Dead River – Plains transmission corridor with the ATC EMS Real Time Contingency Analyzer (RTCA). The ATC System Operator calculates a thermal trip level to resolve post-contingent thermal overloads. If this minimum value is less than the trip level 3 at the PIPP then the ATC System Operator will communicate the thermal trip to the PIPP Plant Operator as the updated trip level 3. This option should never require pre-contingency re-dispatch of the PIPP for overload of any 138 kV outlets leading to the Plains Substation when the transmission system is intact. The distribution factors used to determine the thermal trip level are shown in Table 5.2.1. The distribution factors are rounded because linear distribution factors can't adequately consider the affect of reactive power loading and because distant transmission outages may cause minor changes to the distribution of power through the transmission network.
4. Restrict the net injection of real power at the Presque Isle 138 kV bus for prior outage conditions, as shown in Section 5.3.

Table 5.2.1 Distribution Factors for Thermal Trip Level Calculation to Prevent the Overload of the Forsyth 138 kV Line

Presque Isle Power Plant		Empire Mine		Tilden Mine	
Calculated DF (%)	Implemented DF (%)	Calculated DF (%)	Implemented DF (%)	Calculated DF (%)	Implemented DF (%)
50.7	45.0	55.6	60.0	52.2	60.0

1. Distribution factors calculated using linear transfer methods with power delivered to all MISO generation excluding the PIPP.

The minimum thermal trip level will be calculated as follows:

$$\mathbf{Trip_{MW} = (Line_{MVA} + EMP_{MW} \times TLD_{MW} + EMP_{DF} \times TLD_{DF}) / PIPP_{DF}}$$

$Trip_{MW}$: Minimum Thermal Trip Level (MW)

$Line_{MVA}$: RTCA Calculated (No Mine or Generator Tripping) Post-Contingent Forsyth Line Loading (MVA)

EMP_{MW}: Pre-Contingent Load at the Empire Mine (MW)

TLD_{MW}: Pre-Contingent Load at the Tilden Mine (MW)

EMP_{DF}: Distribution Factor of the Empire Mine on the Forsyth Line for Loss of Presque Isle – Dead River (%)

TLD_{DF}: Distribution Factor of the Tilden Mine on the Forsyth Line for Loss of Presque Isle – Dead River (%)

$PIPP_{DF}$: Distribution Factor of the PIPP on the Forsyth Line for Loss of Presque Isle – Dead River (%)

5.3 Prior Outage Restrictions until the Forsyth Upgrade is Complete

TPL-003-0 standards for permanent single phase or three phase faults (whichever is worse) for a system with a prior outage are met by restricting the net injection of real power at the Presque Isle 138 kV bus for prior outage conditions. Table 5.3.1 shows the restrictions for the existing Presque Isle SPS to meet dynamic stability and thermal performance.

Table 5.3.1 Required Prior Outage Restrictions during the Interim Solution

Prior Outage	Stability			Thermal		
	Worst Next Contingency[3]	Limiting Element	Maximum allowed MW injection at the Presque Isle 138 kV bus	Worst Next Contingency[3]	Limiting Element[2]	Maximum allowed MW injection at the Presque Isle 138 kV bus
EMP 138 – FRY 138	3PG fault @ DRV 138 – PRI 138	Angular stability	280 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	290 Year Round
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular stability	280 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	290 Year Round
FRY 138 – ARN 138	3PG fault @ DRV 345 – PLA 345	Angular stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	310 Year Round
PLK 138 – NRD 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	290/310 Summer/Winter
NRD 138 – PLA 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	290/310 Summer/Winter
PRI 138 – PLK 138	3PG fault @ PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	300/320 Summer/Winter
CDR 138 – M38 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – FRY 138	360/380 Summer/Winter
ARN 138 – PLA 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	420 Year Round
EMP 138 – NAT 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	515 Summer Only

1. The highlighted cell is the most restrictive condition for each prior outage.
2. Please refer to Appendix H for a description of the applicable thermal limits. Validation of equipment rating may allow for a less severe restriction.
3. Applying 3 phase to ground fault at the selected locations results in all but 20 MW of mine load to trip off line.

6. Presque Isle SPS Modifications after summer 2010

6.1 Without Presque Isle Units 3 and 4

With the Presque Isle units 3 and 4 retired and the Forsyth line uprate completed (as described in the Section 4), the only additional requirement is to implement the Presque Isle trip settings shown in Table 6.1.1

Table 6.1.1 Long Term Presque Isle SPS Trip Level Settings Assuming Units 3 and 4 Retired

Relay Name	Relay at	Relay sees	Fault type	Fault location	Trip signal
SEL-311C[1]	PRI 138	Line 481 and both DRV 345/138	3PG/2PG/2PP 1PG	Anywhere Anywhere	2 No trip

1. The SEL-321 relay provides a redundant trip signal.
2. No trip requirements for circuit breaker open conditions.

6.1.1 Prior Outage Restrictions

Prior outage restrictions are listed in Table 6.1.1.1. The prior outage stability analysis assumes pre-contingent total mine load of 150 MW. The prior outage thermal analysis assumes post-contingent (post "Worst Next Contingency") total mine load of 0 MW with Confirmed Firm transmission service modeled. Trip levels may allow for less severe restrictions depending on the actual system flows and associated trip levels. Table 6.1.1.1 is intended to show a conservative restriction.

Table 6.1.1.1 Required Prior Outage Restrictions for the 2010 Presque Isle SPS Assuming Presque Isle Units 3 & 4 Retired

Prior Outage	Stability			Thermal		
	Worst Next Contingency	Limiting Element	Restriction on net injection at the Presque Isle 138 kV bus (MW)	Worst Next Contingency	Limiting Element[3]	Restriction on net injection at the Presque Isle 138 kV bus (MW)
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular Stability	330 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	290 Year Round
FRY 138 – ARN 138	2PG/PP or 3PG fault @ PRI 138 – DRV 138	Angular Stability	330 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	290 Year Round
EMP 138 – FRY 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	230 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	275 Year Round
NRD 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	310 Year Round
PLK 138 – NRD 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	330 Year Round	3PG fault @ DRV 345 – PLA 345	MSS 69 – BRU 69	360 Year Round
PRI 138 – PLK 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	430 Year Round	3PG fault @ DRV 345 – PLA 345	NLK 138 – M38 138	335 Year Round[2]
ARN 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	430 Year Round	None	None	None Year Round
EMP 138 – PRI 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP Bus Section 1-2	440 Summer Only
EMP 138 – NAT 138	3PG fault at PRI 138 – DRV 138	Angular stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	445 Summer Only

1. Highlighted cell is the most restrictive condition for each prior outage.
2. Validation of equipment rating may allow for a less severe seasonal restriction.
3. Please refer to Appendix H for a description of the applicable thermal limits.

6.2 With Presque Isle Units 3 and 4

With the Forsyth line uprate completed (as described in the Section 4), the required transmission fixes are to uprate the facilities shown in Table 6.2.1 and to retain the Presque Isle SPS for faults on the Presque Isle – Dead River – Plains 345 kV corridor as shown in Table 6.2.2. These recommendations do not consider transmission sensitivities described in the Section 3.

Table 6.2.1 Recommended Long Term Transmission System Projects Assuming Units 3 and 4 Operating

Line	Line Length (miles)	SE Rating (MVA)	Worst Loading (MVA) with No Trip Level & 100% Mine Trip	Recommended Upgrade
EMP 138 – FRY 138	17.5	202	307	Uprate to 318 MVA (275° F)
PRI 138 – PLK 138	36.7	202	220	Uprate to 278 MVA (230° F)
PLK 138 – NRD 138	29.6	191	222	Uprate to 278 MVA (230° F)
FRY 138 – ARN 138	16.6	245	258	Uprate to 278 MVA (230° F)
ARN 138 – PLA 138	32.8	202	223	Uprate to 278 MVA (230° F)

Table 6.2.2 Recommended Long Term Presque Isle SPS Trip Level Settings Assuming Units 3 and 4 Operating

Relay Name	Relay at	Relay sees	Fault type	Fault location	Trip signal
SEL-311C[1]	DRV 345	Line 85601	3PG 3PG 2PG/2PP/1PG	0 to 40% line 85601 40 to 100% line 85601 Anywhere	3 No trip No trip
SEL-311C[1]	PRI 138	Line 481 and both DRV 345/138	3PG 2PG/2PP 1PG	Anywhere Anywhere Anywhere	1 2 No trip

1. The SEL-321 relay provides a redundant trip signal.
2. No trip requirements for circuit breaker open conditions.

6.2.1 Prior Outage Restrictions

Prior outage restrictions are listed in Table 6.2.1.1. The prior outage stability analysis assumes pre-contingent total mine load of 150 MW. The prior outage thermal analysis assumes post-contingent (post "Worst Next Contingency") total mine load of 0 MW with Confirmed Firm transmission service modeled. Trip levels may allow for less severe restrictions depending on the actual system flows and associated trip levels. Table 6.2.1.1 is intended to show a conservative restriction.

Table 6.2.1.1 Required Prior Outage Restrictions for the 2010 Presque Isle SPS Assuming Presque Isle Units 3 & 4 Operating

Prior Outage	Stability			Thermal		
	Worst Next Contingency	Limiting Element	Restriction on net injection at the Presque Isle 138 kV bus (MW)	Worst Next Contingency	Limiting Element[3]	Restriction on net injection at the Presque Isle 138 kV bus (MW)
PRI 138 – DRV 138 DRV 345 – PLA 345	3PG fault @ EMP 138 – FRY 138	Angular Stability	330 Year Round	3PG fault @ EMP 138 – FRY 138	PLK 138 – NRD 138	290 Year Round
FRY 138 – ARN 138	2PG/PP fault @ PRI 138 – DRV 138	Angular Stability	330 Year Round	3PG fault @ DRV 345 – PLA 345	FRY 138/69	290 Year Round
EMP 138 – FRY 138	2PG/PP fault @ PRI 138 – DRV 138	Angular Stability	280 Year Round	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	275 Year Round
NRD 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	NRD 138/69 XFMR	310 Year Round
PRI 138 – PLK 138	1PG fault @ PRI 138 – DRV 138	Angular Stability	530 Year Round	3PG fault @ DRV 345 – PLA 345	NLK 138 – M38 138	335 Year Round[2]
PLK 138 – NRD 138	3PG fault @ DRV 345 – PLA 345	Angular Stability	380 Year Round	3PG fault @ DRV 345 – PLA 345	MSS 69 – BRU 69	360 Year Round
EMP 138 – PRI 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP Bus Section 1-2	440 Summer Only
EMP 138 – NAT 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – EMP 138	445 Summer Only
NLK 138 – M38 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PRI 138 – PLK 138	475 / 530 Summer / Winter
ARN 138 – PLA 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	PLK 138 – NRD 138	475 Year Round
EMP 138 – PRI 138	3PG fault @ PRI 138 – DRV 138	Angular Stability	No limit (SPS resolves stability)	3PG fault @ DRV 345 – PLA 345	EMP 138 – NAT 138	520 Summer Only

1. Highlighted cell is the most restrictive condition for each prior outage.
2. Validation of equipment rating may allow for a less severe seasonal restriction.
3. Please refer to Appendix H for a description of the applicable thermal limits.

6.3 Suggestions for Retiring the Presque Isle SPS

Although none of the conceptual solutions listed below have been simulated, engineering judgment indicates that these conceptual solutions may permit retirement of all or a portion of the remaining Presque Isle SPS. All conceptual solutions would require detailed analysis to determine the feasibility of each suggestion and the appropriate justification for any project would need to be developed.

1. Build a 138 kV line from Dead River Substation to Marquette Diesel 69 kV Substation. Install a 138/69 kV transformer at Marquette Diesel Substation. Rebuild Line MBLP Presque Isle – Marquette 69 kV and convert to 138 kV. This project could eliminate the system instabilities for faults on the Presque Isle – Dead River 138 kV line. However, the Dead River 345/138 kV transformers are presently protected as a single element and the individual transformer ratings are too low to allow separate protective devices for N-1 contingencies. Therefore, this conceptual solution would also require replacement of the two 345/138 kV transformers with higher rated units, the addition of high and low side transformer circuit breakers and changes to the transformer protection at Dead River.

2. Install a 345/138 kV transformer at the existing Forsyth Substation and tap into the Dead River – Plains 345 kV line. This project could eliminate system instabilities by decreasing the impedance from Presque Isle to Plains following a fault on the Presque Isle – Dead River 138 kV line. However, this project may require additional work on the lower voltage lines emanating from the Forsyth Substation due to increased system flows and higher fault currents.

3. Install a 345/138 kV transformer at the existing Arnold Substation and tap into the Dead River – Plains 345 kV line. This project could eliminate system instabilities by decreasing the impedance from Presque Isle to Plains following a fault on the Presque Isle – Dead River 138 kV line. However, this project may require additional work on the lower voltage lines emanating from the Arnold Substation due to increased system flows and higher fault currents.

4. An additional extra high voltage outlet from the constrained area to the Plains Substation. This conceptual solution would likely need to be combined with #1 above to achieve the necessary improvements to mitigate both the steady-state and stability violations.

7. References

[1] "Wisconsin Electric Power Company (WEPCO) Clean Air Act Civil Settlement," Amended Consent Decree, pp 15. http://www.epa.gov/compliance/resources/decrees/civil/caa/wepcoamend-cd.pdf

[2] "Special Protection System Documentation, Presque Isle Remedial Action Tripping Scheme" located on K:\System Protection\SPS\SPS_004 Presque Isle RATS

[3] "Plains Power Swing Relays - Special Protection System Documentation" located on K:\System Protection\SPS\SPS_006 Plains Power Swing

Appendix A: 2007 Power Flow Study Results

In the following tables the notation "A -> B" is used to show the existing trip level and the required trip level. If this notation is not used then the existing trip level setting is adequate to mitigate all thermal overloads for the particular condition.

Table A.1 Thermal Loading of the Forsyth Line for the Loss of Plains – Dead River 345 kV, 50% Peak Load with High West to East Flow

		Contingency: Dead River - Plains 345 kV								
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				050 W to E	050 W to E	050 W to E	050 W to E	050 W to E	050 W to E	050 W to E
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	440	352	556	484	397	556
Flow North (MW)				460	379	294	364	295	211	215
Flow North + Mine (MW)				480	399	314	514	445	361	515
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				252	174	91	285	218	137	286
MW tripped for Level 2 (curve)				218	103	0	181	98	0	153
MW tripped for Level 3 (curve)				114	3	0	84	3	0	59
Empire-Forsyth Over load %	No mine load trip			Not Converged	121	96	114	83	71	69
Required lower PIPP (MW)	No mine load trip			365	365	365	495	495	495	556
Required MW reduction	No mine load trip			191	75	0	61	0	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	124	99	139	118	93	115
Required lower PIPP (MW)	50% mine load trip			355	355	355	405	405	405	495
Required MW reduction	50% mine load trip			201	85	0	151	79	0	61
Empire-Forsyth Over load %	100% mine load trip			Not Converged	128	101	Not Converged	142	115	Not Converged
Required lower PIPP (MW)	100% mine load trip			345	345	345	345	345	345	345
Required MW reduction	100% mine load trip			211	95	7	211	139	52	211
Forsyth Line Worst Case % Loading Beyond RATS				121	121	101	108	112	116	116
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2	2 -> 1 (7 MW)	2 -> 1 (30 MW)	2 -> 1 (41 MW)	2 -> 1 (52 MW)	2 -> 1 (58 MW)
		2PG / 2PP	50	2	2	2	2	2	2	2
		1PG	0	3 -> 2 (77 MW)	3 -> 2 (72 MW)	3	3	3	3	3
		open line	0	3 -> 2 (77 MW)	3 -> 2 (72 MW)	3	3	3	3	3
	40 to 100%	3PG	50	2	2	2	2	2	2	2
		2PG / 2PP	0	2	2	2	2	2	2	2
		1PG	0	3 -> 2 (77 MW)	3 -> 2 (72 MW)	3	3	3	3	3
		open line	0	3 -> 2 (77 MW)	3 -> 2 (72 MW)	3	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2	2	2	2	2	2
		open line	0	2	2	2	2	2	2	2

Table A.2 Thermal Loading of the Forsyth Line for the Loss of Plains – Dead River 345 kV, 70% Peak Load with High West to East Flow

		Contingency: Dead River - Plains 345 kV								
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				070 W to E	070 W to E	070 W to E	070 W to E	070 W to E	070 W to E	070 W to E
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	471	397	556	515	426	556
Flow North (MW)				458	377	306	331	293	207	183
Flow North + Mine (MW)				478	397	326	481	443	357	483
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				250	172	103	253	216	133	255
MW tripped for Level 2 (curve)				215	101	0	142	96	0	122
MW tripped for Level 3 (curve)				111	0	0	45	1	0	28
Empire-Forsyth Over load %	No mine load trip			Not Converged	129	107	113	103	79	67
Required lower PIPP (MW)	No mine load trip			370	370	370	495	495	495	556
Required MW reduction	No mine load trip			186	101	27	61	20	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	131	110	137	127	102	114
Required lower PIPP (MW)	50% mine load trip			360	360	360	405	405	405	495
Required MW reduction	50% mine load trip			196	111	37	151	110	21	61
Empire-Forsyth Over load %	100% mine load trip			Not Converged	135	113	Not Converged	152	124	Not Converged
Required lower PIPP (MW)	100% mine load trip			350	350	350	350	350	350	350
Required MW reduction	100% mine load trip			206	121	47	206	165	76	206
Worst Case % Loading Beyond RATS				121	129	114	124	124	124	125
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2 -> 1 (20 MW)	2 -> 1 (47 MW)	2 -> 1 (64 MW)	2 -> 1 (69 MW)	2 -> 1 (76 MW)	2 -> 1 (84 MW)
		2PG / 2PP	50	2	2 -> 1 (10 MW)	2 -> 1 (37 MW)	2 -> 1 (9 MW)	2 -> 1 (14 MW)	2 -> 1 (21 MW)	2
		1PG	0	3 -> 2 (75 MW)	3 -> 1 (101 MW)	3 -> 1 (27 MW)	3 -> 2 (16 MW)	3 -> 2 (19 MW)	3	3
		open line	0	3 -> 2 (75 MW)	3 -> 1 (101 MW)	3 -> 1 (27 MW)	3 -> 2 (16 MW)	3 -> 2 (19 MW)	3	3
	40 to 100%	3PG	50	2	2 -> 1 (10 MW)	2 -> 1 (37 MW)	2 -> 1 (9 MW)	2 -> 1 (14 MW)	2 -> 1 (21 MW)	2
		2PG / 2PP	0	2	2 -> 1 (0 MW)	2 -> 1 (27 MW)	2	2	2	2
		1PG	0	3 -> 2 (75 MW)	3 -> 1 (101 MW)	3 -> 1 (27 MW)	3 -> 2 (16 MW)	3 -> 2 (19 MW)	3	3
		open line	0	3 -> 2 (75 MW)	3 -> 1 (101 MW)	3 -> 1 (27 MW)	3 -> 2 (16 MW)	3 -> 2 (19 MW)	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2 -> 1 (10 MW)	2 -> 1 (37 MW)	2 -> 1 (9 MW)	2 -> 1 (14 MW)	2 -> 1 (21 MW)	2
		open line	0	2	2 -> 1 (0 MW)	2 -> 1 (27 MW)	2	2	2	2

Table A.3 Thermal Loading of the Forsyth Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with High East to West Flow (Obtained by modeling Confirmed Firm Transmission Services)

	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				100 E to W	100 E to W	100 E to W	100 E to W	100 E to W	100 E to W	100 E to W
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	481	407	556	525	446	556
Flow North (MW)				448	377	306	322	293	207	173
Flow North + Mine (MW)				468	397	326	472	443	357	473
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				240	172	103	244	216	133	245
MW tripped for Level 2 (curve)				201	101	0	131	96	0	112
MW tripped for Level 3 (curve)				97	0	0	35	1	0	18
Empire-Forsyth Over load %	No mine load trip			Not Converged	124	109	104	96	74	58
Required lower PIPP (MW)	No mine load trip			400	400	400	540	540	540	556
Required MW reduction	No mine load trip			156	81	7	16	0	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	128	112	130	121	97	105
Required lower PIPP (MW)	50% mine load trip			390	390	390	460	460	460	530
Required MW reduction	50% mine load trip			166	91	17	96	65	0	26
Empire-Forsyth Over load %	100% mine load trip			Not Converged	132	116	Not Converged	148	121	Not Converged
Required lower PIPP (MW)	100% mine load trip			380	380	380	380	380	380	380
Required MW reduction	100% mine load trip			176	101	27	176	145	66	176
Worst Case % Loading Beyond RATS				118	124	114	116	116	120	118
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2 -> 1 (0 MW)	2 -> 1 (27 MW)	2 -> 1 (45 MW)	2 -> 1 (49 MW)	2 -> 1 (66 MW)	2 -> 1 (64 MW)
		2PG / 2PP	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		1PG	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
	40 to 100%	3PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		2PG / 2PP	0	2	2	2 -> 1 (7 MW)	2	2	2	2
		1PG	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		open line	0	2	2	2 -> 1 (7 MW)	2	2	2	2

Table A.4 Thermal Loading of the Forsyth Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with the System Split

	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				100 Split	100 Split	100 Split	100 Split	100 Split	100 Split	100 Split
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	481	407	556	443	437	556
Flow North (MW)				448	377	306	322	293	207	173
Flow North + Mine (MW)				468	397	326	472	443	357	473
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				240	172	103	244	216	133	245
MW tripped for Level 2 (curve)				201	101	0	131	96	0	112
MW tripped for Level 3 (curve)				97	0	0	35	1	0	18
Empire-Forsyth Over load %	No mine load trip			Not Converged	125	110	105	81	80	60
Required lower PIPP (MW)	No mine load trip			400	400	400	530	556	556	556
Required MW reduction	No mine load trip			156	81	7	26	0	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	128	113	130	104	102	106
Required lower PIPP (MW)	50% mine load trip			390	390	390	450	450	446	530
Required MW reduction	50% mine load trip			166	91	17	106	0	0	26
Empire-Forsyth Over load %	100% mine load trip			Not Converged	131	117	Not Converged	127	126	Not Converged
Required lower PIPP (MW)	100% mine load trip			370	370	370	370	370	370	370
Required MW reduction	100% mine load trip			186	111	37	186	73	67	186
Worst Case % Loading Beyond RATS				118	125	116	117	<100	118	120
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2 -> 1 (10 MW)	2 -> 1 (37 MW)	2 -> 1 (55 MW)	2	2 -> 1 (67 MW)	2 -> 1 (74 MW)
		2PG / 2PP	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		1PG	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
	40 to 100%	3PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		2PG / 2PP	0	2	2	2 -> 1 (7 MW)	2	2	2	2
		1PG	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (59 MW)	3 -> 2 (81 MW)	3 -> 1 (7 MW)	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		open line	0	2	2	2 -> 1 (7 MW)	2	2	2	2

Table A.5 Thermal Loading of the Forsyth Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with High West to East Flow

	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	487	413	556	531	442	556
Flow North (MW)				442	377	306	316	292	208	168
Flow North + Mine (MW)				462	397	326	466	442	358	468
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				235	172	103	239	215	134	240
MW tripped for Level 2 (curve)				192	101	0	124	95	0	107
MW tripped for Level 3 (curve)				89	0	0	28	0	0	13
Empire-Forsyth Over load %	No mine load trip			Not Converged	134	113	112	106	82	68
Required lower PIPP (MW)	No mine load trip			365	360	360	490	490	490	556
Required MW reduction	No mine load trip			191	127	53	66	41	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	137	115	141	130	105	116
Required lower PIPP (MW)	50% mine load trip			350	350	350	400	400	400	490
Required MW reduction	50% mine load trip			206	137	63	156	131	42	66
Empire-Forsyth Over load %	100% mine load trip			Not Converged	141	119	Not Converged	157	127	Not Converged
Required lower PIPP (MW)	100% mine load trip			325	325	325	325	325	325	325
Required MW reduction	100% mine load trip			231	162	88	231	206	117	231
Worst Case % Loading Beyond RATS				130	139	127	127	128	130	132
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2 -> 1 (39 MW)	2 -> 1 (61 MW)	2 -> 1 (88 MW)	2 -> 1 (107 MW)	2 -> 1 (111 MW)	2 -> 1 (117 MW)	2 -> 1 (124 MW)
		2PG / 2PP	50	2 -> 1 (14 MW)	2 -> 1 (36 MW)	2 -> 1 (63 MW)	2 -> 1 (32 MW)	2 -> 1 (36 MW)	2 -> 1 (42 MW)	2
		1PG	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
		open line	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
	40 to 100%	3PG	50	2 -> 1 (14 MW)	2 -> 1 (36 MW)	2 -> 1 (63 MW)	2 -> 1 (32 MW)	2 -> 1 (36 MW)	2 -> 1 (42 MW)	2
		2PG / 2PP	0	2	2 -> 1 (26 MW)	2 -> 1 (53 MW)	2	2	2	2
		1PG	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
		open line	0	3 -> 2 (102 MW)	3 -> 1 (127 MW)	3 -> 1 (53 MW)	3 -> 2 (38 MW)	3 -> 2 (41 MW)	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2 -> 1 (14 MW)	2 -> 1 (36 MW)	2 -> 1 (63 MW)	2 -> 1 (32 MW)	2 -> 1 (36 MW)	2 -> 1 (42 MW)	2
		open line	0	2	2 -> 1 (26 MW)	2 -> 1 (53 MW)	2	2	2	2

Table A.6 Thermal Loading of the Forsyth Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with High West to East Flow and the System Split

	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Empire - Forsyth	195	202	201	229						
Season				100 W-E Split	100 W-E Split	100 W-E Split	100 W-E Split	100 W-E Split	100 W-E Split	100 W-E Split
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	479	407	556	524	437	556
Flow North (MW)				451	377	306	323	292	208	173
Flow North + Mine (MW)				471	397	326	473	442	358	473
MW tripped for Level 1 (curve)				243	172	103	245	215	134	245
MW tripped for Level 2 (curve)				205	101	0	132	95	0	112
MW tripped for Level 3 (curve)				101	0	0	36	0	0	18
Empire-Forsyth Over load %	No mine load trip			Not Converged	124	110	105	96	73	60
Required lower PIPP (MW)	No mine load trip			400	400	400	540	540	540	556
Required MW reduction	No mine load trip			156	79	7	16	0	0	0
Empire-Forsyth Over load %	50% mine load trip			Not Converged	128	113	130	121	95	106
Required lower PIPP (MW)	50% mine load trip			390	390	390	455	455	455	535
Required MW reduction	50% mine load trip			166	89	17	101	69	0	21
Empire-Forsyth Over load %	100% mine load trip			Not Converged	131	117	Not Converged	149	119	Not Converged
Required lower PIPP (MW)	100% mine load trip			380	380	380	380	380	380	380
Required MW reduction	100% mine load trip			176	99	27	176	144	57	176
Worst Case % Loading Beyond RATS				116	123	107	113	114	116	120
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2	2 -> 1 (27 MW)	2 -> 1 (44 MW)	2 -> 1 (49 MW)	2 -> 1 (57 MW)	2 -> 1 (64 MW)
		2PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		1PG	0	3 -> 2 (55 MW)	3 -> 2 (79 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (55 MW)	3 -> 2 (79 MW)	3 -> 1 (7 MW)	3	3	3	3
	40 to 100%	3PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		2PG	0	2	2	2 -> 1 (7 MW)	2	2	2	2
		1PG	0	3 -> 2 (55 MW)	3 -> 2 (79 MW)	3 -> 1 (7 MW)	3	3	3	3
		open line	0	3 -> 2 (55 MW)	3 -> 2 (79 MW)	3 -> 1 (7 MW)	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG	100	1	1	1	1	1	1	1
		1PG	50	2	2	2 -> 1 (17 MW)	2	2	2	2
		open line	0	2	2	2 -> 1 (7 MW)	2	2	2	2

Table A.7 Thermal Loading of the Perch Lake – Nordic 138 kV Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with High West to East Flow

Table	8I	Contingency: Dead River - Plains 345 kV									
Monitored line (ratings in MVA)	SN	SE	WN	WE							
Perch Lake - Nordic	160	191	191	191							
Season				100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	487	413	556	531	442	556
Flow North (MW)				442	377	306	316	292	208	168
Flow North + Mine (MW)				462	397	326	466	442	358	468
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				235	172	103	239	215	134	240
MW tripped for Level 2 (curve)				192	101	0	124	95	0	107
MW tripped for Level 3 (curve)				89	0	0	28	0	0	13
Perch-Nordic Overload %	No mine load trip			Not Converged	82	68	67	61	40	32
Required lower PIPP (MW)	No mine load trip			540	540	540	556	556	556	556
Required MW reduction	No mine load trip			16	0	0	0	0	0	0
Perch-Nordic Overload %	50% mine load trip			Not Converged	85	70	86	79	58	68
Required lower PIPP (MW)	50% mine load trip			535	535	535	556	556	556	556
Required MW reduction	50% mine load trip			21	0	0	0	0	0	0
Perch-Nordic Overload %	100% mine load trip			Not Converged	88	72	Not Converged	103	75	Not Converged
Required lower PIPP (MW)	100% mine load trip			520	520	520	520	520	520	520
Required MW reduction	100% mine load trip			36	0	0	36	11	0	36
Worst Case % Loading Beyond Existing RATS				<100	<100	<100	<100	<100	<100	<100
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2	2	2	2	2	2
		2PG / 2PP	50	2	2	2	2	2	2	2
		1PG	0	3	3	3	3	3	3	3
		open line	0	3	3	3	3	3	3	3
	40 to 100%	3PG	50	2	2	2	2	2	2	2
		2PG / 2PP	0	2	2	2	2	2	2	2
		1PG	0	3	3	3	3	3	3	3
		open line	0	3	3	3	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2	2	2	2	2	2
		open line	0	2	2	2	2	2	2	2

Table A.8 Thermal Loading of the Perch Lake – Nordic 138 kV Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with the System Split

Table	8J	Contingency: Dead River - Plains 345 kV								
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Perch Lake - Nordic	160	191	191	191						
Season				100 Split	100 Split	100 Split	100 Split	100 Split	100 Split	100 Split
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	481	407	556	443	437	556
Flow North (MW)				448	377	306	322	293	207	173
Flow North + Mine (MW)				468	397	326	472	443	357	473
Marquette Net Export (MW)				30	30	30	30	30	30	30
MW tripped for Level 1 (curve)				240	172	103	244	216	133	245
MW tripped for Level 2 (curve)				201	101	0	131	96	0	112
MW tripped for Level 3 (curve)				97	0	0	35	1	0	18
Perch-Nordic Overload %	No mine load trip			Not Converged	80	66	67	41	39	32
Required lower PIPP (MW)	No mine load trip			540	540	540	556	556	556	556
Required MW reduction	No mine load trip			16	0	0	0	0	0	0
Perch-Nordic Overload %	50% mine load trip			Not Converged	83	70	86	58	57	68
Required lower PIPP (MW)	50% mine load trip			535	535	535	556	556	556	556
Required MW reduction	50% mine load trip			21	0	0	0	0	0	0
Perch-Nordic Overload %	100% mine load trip			Not Converged	86	70	Not Converged	75	73	Not Converged
Required lower PIPP (MW)	100% mine load trip			520	520	520	520	520	520	520
Required MW reduction	100% mine load trip			36	0	0	36	0	0	36
Worst Case % Loading Beyond Existing RATS				<100	<100	<100	<100	<100	<100	<100
	Flt location	Flt type	% mine load trip	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level	Required Level
Dead River - Plains	0 to 40%	3PG	100	2	2	2	2	2	2	2
		2PG / 2PP	50	2	2	2	2	2	2	2
		1PG	0	3	3	3	3	3	3	3
		open line	0	3	3	3	3	3	3	3
	40 to 100%	3PG	50	2	2	2	2	2	2	2
		2PG / 2PP	0	2	2	2	2	2	2	2
		1PG	0	3	3	3	3	3	3	3
		open line	0	3	3	3	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG / 2PP	100	1	1	1	1	1	1	1
		1PG	50	2	2	2	2	2	2	2
		open line	0	2	2	2	2	2	2	2

Table A.9 Thermal Loading of the Forsyth – Arnold 138 kV Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with High West to East Flow

Table	8L	Dead River - Plains 345 kV								
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Forsyth - Arnold	**208**	**208**	287	287						
*Results calculated prior to an update of the local equipment ratings										
New Ratings:	**218**	**245**								
Season				100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E	100 Peak W to E
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	487	413	556	531	442	556
Flow North (MW)				442	377	306	316	292	208	168
Flow North + Mine (MW)				462	397	326	466	442	358	468
MW tripped for Level 1 (curve)				235	172	103	239	215	134	240
MW tripped for Level 2 (curve)				192	101	0	124	95	0	107
MW tripped for Level 3 (curve)				89	0	0	28	0	0	13
Forsyth-Arnold Overload %	No load trip			129	101	86	82	76	54	43
Required lower PIPP (MW)	No load trip			450	450	450	556	556	556	556
Required MW trip	No load trip			106	37	0	0	0	0	0
Forsyth-Arnold Overload %	50% load trip			132	104	90	104	97	75	83
Required lower PIPP (MW)	50% load trip			440	440	440	500	500	500	556
Required MW trip	50% load trip			116	47	0	56	31	0	0
Forsyth-Arnold Overload %	100% load trip			131	108	92	131	121	93	131
Required lower PIPP (MW)	100% load trip			435	435	435	435	435	435	435
Required MW trip	100% load trip			121	52	0	121	96	7	121
Worst Case Loading Beyond Existing RATS (Old Ratings)				103	109	<100	<100	101	102	104
Worst Case Loading Beyond Existing RATS (New Ratings)				**87**	**93**	**<85**	**<85**	**86**	**87**	**88**
	Flt location	Flt type	% load trip	Required LV	Required LV	Required LV	Required LV	Required LV	Required LV	Required LV
Dead River - Plains	0 to 40%	3PG	100	2	2	2	2	2 -> 1 (1 MW)	2 -> 1 (7 MW)	2 -> 1 (14 MW)
		2PG	50	2	2	2	2	2	2	2
		1PG	0	3 -> 2 (17 MW)	3 -> 2 (37 MW)	3	3	3	3	3
		open line	0	3 -> 2 (17 MW)	3 -> 2 (37 MW)	3	3	3	3	3
	40 to 100%	3PG	50	2	2	2	2	2	2	2
		2PG	0	2	2	2	2	2	2	2
		1PG	0	3 -> 2 (17 MW)	3 -> 2 (37 MW)	3	3	3	3	3
		open line	0	3 -> 2 (17 MW)	3 -> 2 (37 MW)	3	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG	100	1	1	1	1	1	1	1
		1PG	50	2	2	2	2	2	2	2
		open line	0	2	2	2	2	2	2	2

Table A.10 Thermal Loading of the Forsyth – Arnold 138 kV Line for the Loss of Plains – Dead River 345 kV, 100% Peak Load with the System Split

Table	8M	Dead River - Plains 345 kV								
Monitored line (ratings in MVA)	SN	SE	WN	WE						
Forsyth - Arnold	208	208	287	287						
Season				100 Split	100 Split	100 Split	100 Split	100 Split	100 Split	100 Split
Mine load (MW)				20	20	20	150	150	150	300
Presq. Output (MW)				556	481	407	556	443	437	556
Flow North (MW)				448	377	306	322	293	207	173
Flow North + Mine (MW)				468	397	326	472	443	357	473
MW tripped for Level 1 (curve)				240	172	103	244	216	133	245
MW tripped for Level 2 (curve)				201	101	0	131	96	0	112
MW tripped for Level 3 (curve)				97	0	0	35	1	0	18
Forsyth-Arnold Overload %	No load trip			124	99	83	82	56	53	43
Required lower PIPP (MW)	No load trip			485	485	485	556	556	556	556
Required MW trip	No load trip		0	71	0	0	0	0	0	0
Forsyth-Arnold Overload %	50% load trip			130	102	86	104	76	73	83
Required lower PIPP (MW)	50% load trip			470	470	470	540	540	540	556
Required MW trip	50% load trip		50	86	11	0	16	0	0	0
Forsyth-Arnold Overload %	100% load trip			124	105	89	124	96	93	124
Required lower PIPP (MW)	100% load trip			460	460	460	460	460	460	460
Required MW trip	100% load trip		100	96	21	0	96	0	0	96
Worst Case Loading Beyond Existing RATS				<100	<100	<100	<100	<100	<100	<100
	Flt location	Flt type	% load trip	Required LV	Required LV	Required LV	Required LV	Required LV	Required LV	Required LV
Dead River - Plains	0 to 40%	3PG	100	2	2	2	2	2	2	2
		2PG	50	2	2	2	2	2	2	2
		1PG	0	3	3	3	3	3	3	3
		open line	0	3	3	3	3	3	3	3
	40 to 100%	3PG	50	2	2	2	2	2	2	2
		2PG	0	2	2	2	2	2	2	2
		1PG	0	3	3	3	3	3	3	3
		open line	0	3	3	3	3	3	3	3
Presque Isle - Dead River	0 to 100%	3PG	100	1	1	1	1	1	1	1
		2PG	100	1	1	1	1	1	1	1
		1PG	50	2	2	2	2	2	2	2
		open line	0	2	2	2	2	2	2	2

Appendix B: 2007 Angular Stability Results

In the following tables the notation "A -> B" is used to show the existing trip level and the required trip level. If this notation is not used then the existing trip level setting is adequate to mitigate all thermal overloads for the particular condition. Highlighted cells indicate that the existing Presque Isle SPS trip level is more conservative than required for the given fault scenario.

Table B.1 Presque Isle – Perch Lake 138 kV Stability Results

Presque Isle to Perch Lake											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load (MW)			20	20	20	20	150	150	150	300				
Presque Isle (MW)			352	440	525	556	397	484	556	556				
Marquette Net Export (MW)			30	30	30	30	30	30	30	30				
Flow North (MW)			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-30%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	3	3
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
30-50%	3PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
50-100%	3PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	2PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	1PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.2 Presque Isle – Empire 138 kV Stability Results

Presque Isle to Empire											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-25%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	4	3
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
25-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.3 Presque Isle – National 138 kV Stability Results

Presque Isle to National											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-25%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	3	3
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	2 -> 4	2	3	4	3
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
25-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.4 Presque Isle – Cedar 138 kV Stability Results

Presque Isle to Cedar											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-35%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	3	3
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
35-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	75.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.5 Presque Isle – Freeman 138 kV Stability Results

Presque Isle to Freeman											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-35%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	3	3
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
35-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.6 Presque Isle – Empire 138 kV Stability Results

Presque Isle to Empire											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-25%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	3	3
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
25-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.7 Empire – Forsyth 138 kV Stability Results

Empire to Forsyth											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-70%	3PG	100.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	4	4	4
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
70-100%	3PG	75.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	25.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.8 Dead River – Plains 345 kV Stability Results

Dead River 345kV to Plains 34											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-40%	3PG	100.0%	2 -> 4	2	2 -> 3	2 -> 3	2 -> 4	2 -> 4	2 -> 3	2 -> 4	2	2	2	2
	2PG	50.0%	2 -> 4	2	2 -> 3	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	2	2	2
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	3	3
	0PG	0.0%	3 -> 4	3 -> 4	3	3	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	3	3
40-100%	3PG	50.0%	2 -> 4	2	2 -> 3	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	2	2	2
	2PG	0.0%	2 -> 4	2	2 -> 3	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	2	2	2
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	3	3
	0PG	0.0%	3 -> 4	3 -> 4	3	3	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	3	3

Table B.9 Cedar – National 138 kV Stability Results

Cedar to National											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.10 Freeman – Cedar 138 kV Stability Results

Freeman to Cedar											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	75.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.11 Cedar – Tilden 138 kV Stability Results

Cedar to Tilden											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.12 Tilden – National 138 kV Stability Results

Tilden to National											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.13 Empire – National 138 kV Stability Results

Empire to National											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	100.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.14 Presque Isle – Dead River 138 kV Stability Results

Presque Isle to Dead River 138												Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	100.0%	1	1	1 -> 2	1 -> 2	1	1	1	1	1	1	1	1
	2PG	100.0%	1	1	1 -> 2	1 -> 2	1 -> 4	1	1 -> 2	1	1	1	1	1
	1PG	50.0%	2 -> 4	2	2 -> 3	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	2	2	2
	0PG	0.0%	2 -> 4	2 -> 4	2 -> 3	2 -> 3	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	3	3	3

Table B.15 Plains – Nordic 138 kV Stability Results

Plains 138kV to Nordic											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	25.0%	4	4	4	4	4	4	4	4	4	4	4	4
	2PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	1PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.16 Plains – Morgan 345 kV Stability Results

Plains 345kV to Morgan 345kV											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	50.0%	3 -> 4	3 -> 4	3 -> 4	3	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	3	3
	2PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3
	0PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	3	4	3

Table B.17 Plains – Amberg 138 kV Stability Results

Plains 138kV to Amberg											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	25.0%	4	4	4	4	4	4	4	4	4	4	4	4
	2PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	1PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.18 White Clay – Morgan 138 kV Stability Results

White Clay to Morgan 138kV											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	2PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4

Table B.19 Plains – Arnold 138 kV Stability Results

Plains 138kV to Arnold											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	25.0%	4	4	4	4	4	4	4	4	4	4	4	4
	2PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	1PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4
	0PG	0.0%	4	4	4	4	4	4	4	4	4	4	4	4

Table B.20 Plains 345 kV – Plains 138 kV Stability Results

Plains 345kV to Plains 138kV											Existing RATS level	Required RATS Level	Required based on System Intact	Based on System Split
2007 light load (50% peak)			MW	MW	MW	MW	MW	MW	MW	MW				
Mine load			20	20	20	20	150	150	150	300				
Presque Isle			352	440	525	556	397	484	556	556				
Marquette Net Export			30	30	30	30	30	30	30	30				
Flow North			294	379	460	490	211	295	364	215				
Flow North + Mine (MW)			314	399	480	510	361	445	514	515				
MW tripped for Level 1 (Curve)			92	174	253	282	137	219	286	287				
MW tripped for Level 2 (Curve)			0	104	218	261	50	169	266	268				
MW tripped for Level 3 (Curve)			0	4	114	155	0	66	161	162				
Fault Location	Fault Type	Mine Load Tripped	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level	Trip level				
0-100%	3PG	50.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	4	4	4
	2PG	0.0%	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2 -> 4	2	4	4	4
	1PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4
	0PG	0.0%	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3 -> 4	3	4	4	4

Appendix C: 2010 Study Cases

All 2010 planning cases analyzed have a consistent file name structure. The first case listed in Table C.1 is used as an example in explaining the name structure.

- 2010S – The year and season of the case, year 2010 and summer peak.
- 050% – The ATC footprint load level is 50% of the non-coincident yearly peak load.
- FIRMXXX – The Firm transmission service scenario. The other possibilities are HE2W or HW2E followed by a three digit number representing the flow on the monitored element and SPLITXX meaning Firm transmission service with the system split at Indian Lake Substation.
- PI391 – PIPP is generating 391 MW.
- MI020 – The total mine load, Empire + Tilden = 20 MW.
- FN352 – The Flow North total line flow measured = 352 MVA.
- LV123_147_065_XXX – trip levels 1 and 2 are 147 MW and 65 MW respectively. While trip level 3 does not exist because the trip curve is not valid for the measured mine load and Flow North values.
- P0 – Prior Outage scenario “0” meaning that the system is intact.
- v1 – Version #1 of this planning case. As changes are made to all cases to adjust transmission or generation assumptions a new version number is assigned to all cases so that previous planning cases can be retained and the naming convention remains consistent.

Table C.1 Thermal Planning Cases (All 50% Cases Analyzed for Dynamic Stability)

2010S_050%_FIRMXXX_PI391_MI020_FN352_LV123_147_065_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI415_MI300_FN103_LV123_177_044_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI416_MI125_FN275_LV123_175_056_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI416_MI225_FN177_LV123_177_046_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI432_MI020_FN391_LV123_185_120_019_P0_v1.sav
2010S_050%_FIRMXXX_PI432_MI125_FN290_LV123_189_074_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI432_MI225_FN192_LV123_191_061_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI432_MI300_FN118_LV123_192_059_XXX_P0_v1.sav
2010S_050%_FIRMXXX_PI464_MI020_FN422_LV123_215_163_061_P0_v1.sav
2010S_050%_FIRMXXX_PI500_MI125_FN355_LV123_251_153_054_P0_v1.sav
2010S_050%_FIRMXXX_PI517_MI300_FN200_LV123_271_138_044_P0_v1.sav
2010S_050%_FIRMXXX_PI518_MI225_FN274_LV123_271_145_049_P0_v1.sav
2010S_050%_FIRMXXX_PI548_MI020_FN501_LV123_291_275_169_P0_v1.sav
2010S_050%_FIRMXXX_PI548_MI125_FN400_LV123_295_208_109_P0_v1.sav
2010S_050%_FIRMXXX_PI548_MI225_FN302_LV123_298_174_078_P0_v1.sav
2010S_050%_FIRMXXX_PI548_MI300_FN228_LV123_299_166_072_P0_v1.sav
2010S_050%_HE2W068_PI548_MI020_FN503_LV123_294_278_172_P0_v1.sav
2010S_050%_HE2W074_PI461_MI020_FN422_LV123_215_163_061_P0_v1.sav
2010S_050%_HE2W078_PI432_MI020_FN393_LV123_187_123_022_P0_v1.sav
2010S_050%_HE2W078_PI548_MI125_FN402_LV123_297_211_112_P0_v1.sav
2010S_050%_HE2W080_PI387_MI020_FN351_LV123_146_063_XXX_P0_v1.sav
2010S_050%_HE2W080_PI497_MI125_FN355_LV123_251_153_054_P0_v1.sav
2010S_050%_HE2W086_PI414_MI125_FN275_LV123_174_056_XXX_P0_v1.sav
2010S_050%_HE2W086_PI548_MI225_FN305_LV123_300_177_081_P0_v1.sav

2010S_050%_HE2W087_PI432_MI125_FN292_LV123_191_076_XXX_P0_v1.sav
2010S_050%_HE2W087_PI515_MI225_FN274_LV123_270_145_049_P0_v1.sav
2010S_050%_HE2W092_PI548_MI300_FN231_LV123_301_168_074_P0_v1.sav
2010S_050%_HE2W093_PI514_MI300_FN199_LV123_271_138_044_P0_v1.sav
2010S_050%_HE2W094_PI414_MI225_FN178_LV123_177_046_XXX_P0_v1.sav
2010S_050%_HE2W095_PI432_MI225_FN195_LV123_193_063_XXX_P0_v1.sav
2010S_050%_HE2W100_PI413_MI300_FN103_LV123_177_044_XXX_P0_v1.sav
2010S_050%_HE2W100_PI432_MI300_FN120_LV123_194_061_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI391_MI020_FN353_LV123_148_066_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI415_MI300_FN102_LV123_177_044_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI416_MI125_FN275_LV123_175_056_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI416_MI225_FN177_LV123_177_045_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI432_MI020_FN391_LV123_185_120_019_P0_v1.sav
2010S_050%_SPLITXX_PI432_MI125_FN290_LV123_189_074_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI432_MI225_FN192_LV123_191_061_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI432_MI300_FN118_LV123_191_059_XXX_P0_v1.sav
2010S_050%_SPLITXX_PI464_MI020_FN422_LV123_215_164_061_P0_v1.sav
2010S_050%_SPLITXX_PI500_MI125_FN355_LV123_252_153_054_P0_v1.sav
2010S_050%_SPLITXX_PI517_MI300_FN199_LV123_271_138_044_P0_v1.sav
2010S_050%_SPLITXX_PI518_MI225_FN274_LV123_271_145_049_P0_v1.sav
2010S_050%_SPLITXX_PI548_MI020_FN501_LV123_292_275_169_P0_v1.sav
2010S_050%_SPLITXX_PI548_MI125_FN400_LV123_296_208_109_P0_v1.sav
2010S_050%_SPLITXX_PI548_MI225_FN302_LV123_298_174_079_P0_v1.sav
2010S_050%_SPLITXX_PI548_MI300_FN228_LV123_299_166_072_P0_v1.sav
2010S_080%_FIRMXXX_PI411_MI020_FN337_LV123_133_043_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI432_MI020_FN355_LV123_150_069_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI432_MI125_FN254_LV123_154_030_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI432_MI225_FN157_LV123_157_024_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI432_MI300_FN082_LV123_157_024_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI437_MI125_FN259_LV123_159_036_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI437_MI225_FN162_LV123_161_029_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI437_MI300_FN087_LV123_162_029_XXX_P0_v1.sav
2010S_080%_FIRMXXX_PI485_MI020_FN406_LV123_199_141_039_P0_v1.sav
2010S_080%_FIRMXXX_PI521_MI125_FN339_LV123_236_134_035_P0_v1.sav
2010S_080%_FIRMXXX_PI538_MI225_FN257_LV123_254_127_031_P0_v1.sav
2010S_080%_FIRMXXX_PI538_MI300_FN183_LV123_254_122_028_P0_v1.sav
2010S_080%_FIRMXXX_PI548_MI020_FN465_LV123_257_224_120_P0_v1.sav
2010S_080%_FIRMXXX_PI548_MI125_FN364_LV123_261_165_066_P0_v1.sav
2010S_080%_FIRMXXX_PI548_MI225_FN267_LV123_264_138_042_P0_v1.sav
2010S_080%_FIRMXXX_PI548_MI300_FN192_LV123_263_131_037_P0_v1.sav
2010S_080%_HE2W063_PI548_MI020_FN467_LV123_259_228_123_P0_v1.sav
2010S_080%_HE2W068_PI483_MI020_FN406_LV123_200_142_040_P0_v1.sav
2010S_080%_HE2W072_PI432_MI020_FN357_LV123_152_072_XXX_P0_v1.sav
2010S_080%_HE2W072_PI548_MI125_FN366_LV123_262_167_068_P0_v1.sav
2010S_080%_HE2W074_PI409_MI020_FN337_LV123_133_044_XXX_P0_v1.sav
2010S_080%_HE2W074_PI521_MI125_FN341_LV123_238_136_037_P0_v1.sav
2010S_080%_HE2W080_PI435_MI125_FN260_LV123_160_037_XXX_P0_v1.sav
2010S_080%_HE2W081_PI432_MI125_FN256_LV123_156_033_XXX_P0_v1.sav
2010S_080%_HE2W081_PI536_MI225_FN258_LV123_255_129_033_P0_v1.sav

2010S_080%_HE2W081_PI548_MI225_FN269_LV123_265_139_044_P0_v1.sav
2010S_080%_HE2W087_PI548_MI300_FN195_LV123_267_134_040_P0_v1.sav
2010S_080%_HE2W088_PI435_MI225_FN162_LV123_162_030_XXX_P0_v1.sav
2010S_080%_HE2W088_PI535_MI300_FN183_LV123_255_122_028_P0_v1.sav
2010S_080%_HE2W089_PI432_MI225_FN159_LV123_159_026_XXX_P0_v1.sav
2010S_080%_HE2W095_PI432_MI300_FN084_LV123_159_027_XXX_P0_v1.sav
2010S_080%_HE2W095_PI434_MI300_FN087_LV123_162_029_XXX_P0_v1.sav
2010S_080%_HW2E095_PI432_MI225_FN154_LV123_154_022_XXX_P0_v1.sav
2010S_080%_HW2E095_PI439_MI225_FN161_LV123_161_029_XXX_P0_v1.sav
2010S_080%_HW2E096_PI413_MI020_FN337_LV123_133_044_XXX_P0_v1.sav
2010S_080%_HW2E096_PI432_MI125_FN253_LV123_153_029_XXX_P0_v1.sav
2010S_080%_HW2E097_PI432_MI020_FN354_LV123_149_068_XXX_P0_v1.sav
2010S_080%_HW2E097_PI439_MI125_FN260_LV123_160_038_XXX_P0_v1.sav
2010S_080%_HW2E097_PI439_MI300_FN087_LV123_162_029_XXX_P0_v1.sav
2010S_080%_HW2E098_PI432_MI300_FN079_LV123_154_022_XXX_P0_v1.sav
2010S_080%_HW2E101_PI487_MI020_FN406_LV123_200_141_040_P0_v1.sav
2010S_080%_HW2E102_PI525_MI125_FN341_LV123_238_136_038_P0_v1.sav
2010S_080%_HW2E102_PI541_MI225_FN258_LV123_255_128_032_P0_v1.sav
2010S_080%_HW2E102_PI548_MI225_FN264_LV123_261_135_039_P0_v1.sav
2010S_080%_HW2E103_PI548_MI125_FN362_LV123_258_161_063_P0_v1.sav
2010S_080%_HW2E104_PI540_MI300_FN182_LV123_254_121_027_P0_v1.sav
2010S_080%_HW2E104_PI548_MI020_FN463_LV123_255_222_117_P0_v1.sav
2010S_080%_HW2E104_PI548_MI300_FN189_LV123_261_128_034_P0_v1.sav
2010S_100%_FIRMXXX_PI432_MI020_FN329_LV123_125_033_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI432_MI125_FN228_LV123_129_XXX_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI432_MI225_FN130_LV123_131_XXX_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI432_MI300_FN056_LV123_131_XXX_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI439_MI020_FN336_LV123_132_042_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI466_MI125_FN260_LV123_160_038_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI466_MI225_FN163_LV123_162_030_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI466_MI300_FN088_LV123_163_030_XXX_P0_v1.sav
2010S_100%_FIRMXXX_PI514_MI020_FN407_LV123_201_142_041_P0_v1.sav
2010S_100%_FIRMXXX_PI548_MI020_FN439_LV123_231_187_084_P0_v1.sav
2010S_100%_FIRMXXX_PI548_MI125_FN338_LV123_235_132_033_P0_v1.sav
2010S_100%_FIRMXXX_PI548_MI225_FN240_LV123_237_110_014_P0_v1.sav
2010S_100%_FIRMXXX_PI548_MI300_FN166_LV123_238_105_011_P0_v1.sav
2010S_100%_HE2W064_PI548_MI020_FN440_LV123_233_189_086_P0_v1.sav
2010S_100%_HE2W066_PI516_MI020_FN410_LV123_203_147_045_P0_v1.sav
2010S_100%_HE2W072_PI432_MI020_FN331_LV123_126_035_XXX_P0_v1.sav
2010S_100%_HE2W072_PI439_MI020_FN337_LV123_133_044_XXX_P0_v1.sav
2010S_100%_HE2W072_PI548_MI125_FN339_LV123_236_134_035_P0_v1.sav
2010S_100%_HE2W078_PI464_MI125_FN260_LV123_159_037_XXX_P0_v1.sav
2010S_100%_HE2W080_PI432_MI125_FN229_LV123_130_000_XXX_P0_v1.sav
2010S_100%_HE2W080_PI548_MI225_FN242_LV123_239_111_015_P0_v1.sav
2010S_100%_HE2W085_PI548_MI300_FN167_LV123_239_107_013_P0_v1.sav
2010S_100%_HE2W086_PI464_MI225_FN162_LV123_162_030_XXX_P0_v1.sav
2010S_100%_HE2W088_PI432_MI225_FN131_LV123_132_XXX_XXX_P0_v1.sav
2010S_100%_HE2W092_PI464_MI300_FN088_LV123_162_030_XXX_P0_v1.sav
2010S_100%_HE2W094_PI432_MI300_FN057_LV123_133_000_XXX_P0_v1.sav

2010S_100%_HW2E095_PI432_MI300_FN053_LV123_129_XXX_XXX_P0_v1.sav
2010S_100%_HW2E098_PI471_MI300_FN090_LV123_165_032_XXX_P0_v1.sav
2010S_100%_HW2E102_PI432_MI125_FN226_LV123_126_XXX_XXX_P0_v1.sav
2010S_100%_HW2E102_PI432_MI225_FN128_LV123_128_XXX_XXX_P0_v1.sav
2010S_100%_HW2E102_PI548_MI225_FN238_LV123_235_108_011_P0_v1.sav
2010S_100%_HW2E103_PI445_MI020_FN340_LV123_135_047_XXX_P0_v1.sav
2010S_100%_HW2E103_PI548_MI020_FN437_LV123_229_185_081_P0_v1.sav
2010S_100%_HW2E103_PI548_MI300_FN163_LV123_235_103_009_P0_v1.sav
2010S_100%_HW2E104_PI432_MI020_FN327_LV123_123_030_XXX_P0_v1.sav
2010S_100%_HW2E104_PI469_MI125_FN261_LV123_161_039_XXX_P0_v1.sav
2010S_100%_HW2E104_PI469_MI225_FN163_LV123_162_030_XXX_P0_v1.sav
2010S_100%_HW2E104_PI520_MI020_FN411_LV123_204_148_046_P0_v1.sav
2010S_100%_HW2E104_PI548_MI125_FN336_LV123_233_130_031_P0_v1.sav
2010S_100%_SPLITXX_PI548_MI020_FN440_LV123_232_189_086_P0_v1.sav
2010S_100%_SPLITXX_PI548_MI300_FN166_LV123_238_106_012_P0_v1.sav

Appendix D: 2010 Power Flow Study Results

Tables D.1 – D.5 shows the details of the planning case which results in the worst case loading for each monitored element that is found to be overloaded in the analysis of any of the 137 planning cases. It should be noted that most of the worst cases line loadings appear (to within 1% of the existing line rating) in multiple planning cases. However, the base case scenario is considered to be when mine loads sum to 225 MW, therefore if a case with mine loads equal to 225 MW resulted in the worst case line loading its attributes are listed.

Table D.1 Worst Case Loading of the Empire – Forsyth 138 kV Line in MVA (Same as Table 3.6.4.2)

Existing Rate B = 202 MVA Limited by: Conductor Summer Emergency Temperature Limit Conductor Characteristics: 605.0 kcmil ACSR 26/7 Squab (167° F) Uprate to 230° F increases the summer emergency rating to 278 MVA (1165 A) Uprate to 257° F increases the summer emergency rating to 302 MVA (1264 A) Uprate to 275° F increases the summer emergency rating to 318 MVA (1332 A) Uprate to 300° F increases the summer emergency rating to 337 MVA (1413 A) 300° F is the Maximum Emergency Temperature Rating per ATC Standards Contingency: Presque Isle – Dead River 138 kV Line or Dead River 345/138 kV Paralleled Transformers or Dead River – Plains 345 kV Line		
	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Stability Required Trip Level	Trip Level 3	No Trip Level
w/o sensitivities No Trip Level Trip Level 3 Trip Level 2 Trip Level 1	 307 MVA 287 237 < 200	 249 MVA 249 239 < 198
with sensitivities[1] No Trip Level Trip Level 3 Trip Level 2 Trip Level 1	 **340** MVA 317 259 190	 275 MVA 275 259 184
Worst Case Attributes Load Level Transfer PIPP Output Mine Load Flow North Trip Level 1 Trip Level 2 Trip Level 3	 80 % High West to East 547 MW 225 MW 264 MVA 261 MW 135 MW 39 MW	 80 % High West to East 431 MW 225 MW 154 MVA 154 MW 22 MW Does Not Exist

1. Worst case results are shown from studying each transmission sensitivity addition by itself and all transmission sensitivities together.

Table D.2 Worst Case Loading of the Presque Isle – Perch Lake 138 kV Line in MVA

Existing Rate B = 202 MVA
Limited by: Conductor Summer Emergency Temperature Limit

Conductor Characteristics: 605.0 kcmil ACSR 26/7 Squab (167° F)
Uprate to 230° F increases the summer emergency rating to 278 MVA (1165 A)
Uprate to 257° F increases the summer emergency rating to 302 MVA (1264 A)
Uprate to 275° F increases the summer emergency rating to 318 MVA (1332 A)
Uprate to 300° F increases the summer emergency rating to 337 MVA (1413 A)
300° F is the Maximum Emergency Temperature Rating per ATC Standards

Contingency: Presque Isle – Dead River 138 kV Line or
Dead River 345/138 kV Paralleled Transformers or
Dead River – Plains 345 kV Line

	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Stability Required Trip Level	Trip Level 3	No Trip Level
w/o sensitivities		
No Trip Level	220 MVA	176 MVA
Trip Level 3	188	176
Trip Level 2	< 188	< 176
Trip Level 1	< 188	< 176
with sensitivities[1]		
No Trip Level	222 MVA	180 MVA
Trip Level 3	189	180
Trip Level 2	< 189	< 180
Trip Level 1	< 189	< 180
Worst Case Attributes		
Load Level	50 %	50 %
Transfer	High East to West	High East to West
PIPP Output	547 MW	431 MW
Mine Load	225 MW	225 MW
Flow North	305 MVA	195 MVA
Trip Level 1	300 MW	193 MW
Trip Level 2	177 MW	63 MW
Trip Level 3	81 MW	Does Not Exist

1. Worst case results are shown from studying each transmission sensitivity addition by itself and all transmission sensitivities together.

Table D.3 Worst Case Loading of the Perch Lake – Nordic 138 kV Line in MVA

Existing Rate B = 191 MVA Limited by: Conductor Summer Emergency Temperature Limit – Determined from UPPCO line data books Conductor Characteristics: 605.0 kcmil ACSR 26/7 Squab (Unknown ° F) Uprate to 230° F increases the summer emergency rating to 278 MVA (1165 A) Uprate to 257° F increases the summer emergency rating to 302 MVA (1264 A) Uprate to 275° F increases the summer emergency rating to 318 MVA (1332 A) Uprate to 300° F increases the summer emergency rating to 337 MVA (1413 A) 300° F is the Maximum Emergency Temperature Rating per ATC Standards Contingency: Presque Isle – Dead River 138 kV Line or Dead River 345/138 kV Paralleled Transformers or Dead River – Plains 345 kV Line		
	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Stability Required Trip Level	Trip Level 3	No Trip Level
w/o sensitivities No Trip Level Trip Level 3 Trip Level 2 Trip Level 1	 222 MVA 197 < 163 < 163	 184 MVA 184 < 184 < 184
with sensitivities[1] No Trip Level Trip Level 3 Trip Level 2 Trip Level 1	 226 MVA 200 165 < 165	 188 MVA 188 < 188 < 188
Worst Case Attributes Load Level Transfer PIPP Output Mine Load Flow North Trip Level 1 Trip Level 2 Trip Level 3	 50 % High East to West 547 MW 225 MW 305 MVA 300 MW 177 MW 81 MW	 50 % High East to West 431 MW 225 MW 195 MVA 193 MW 63 MW Does Not Exist

1. Worst case results are shown from studying each transmission sensitivity addition by itself and all transmission sensitivities together.

Table D.4 Worst Case Loading of the Forsyth – Arnold 138 kV Line in MVA

Existing Rate B = 245 MVA
Limited by: Conductor Summer Emergency Temperature Limit

Conductor Characteristics: 605.0 kcmil ACSR 26/7 Squab (200° F)
Uprate to 230° F increases the summer emergency rating to 278 MVA (1165 A)
Uprate to 257° F increases the summer emergency rating to 302 MVA (1264 A)
Uprate to 275° F increases the summer emergency rating to 318 MVA (1332 A)
Uprate to 300° F increases the summer emergency rating to 337 MVA (1413 A)
300° F is the Maximum Emergency Temperature Rating per ATC Standards

Contingency: Presque Isle – Dead River 138 kV Line or
Dead River 345/138 kV Paralleled Transformers or
Dead River – Plains 345 kV Line

	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Stability Required Trip Level	Trip Level 3	No Trip Level
w/o sensitivities		
No Trip Level	258 MVA	211 MVA
Trip Level 3	226	211
Trip Level 2	< 226	< 211
Trip Level 1	< 226	< 211
with sensitivities[1]		
No Trip Level	266 MVA	216 MVA
Trip Level 3	234	216
Trip Level 2	< 234	< 216
Trip Level 1	< 234	< 216
Worst Case Attributes		
Load Level	50 %	50 %
Transfer	Firm Transmission Service	Firm Transmission Service
PIPP Output	547 MW	431 MW
Mine Load	225 MW	225 MW
Flow North	302 MVA	192 MVA
Trip Level 1	298 MW	191 MW
Trip Level 2	174 MW	61 MW
Trip Level 3	78 MW	Does Not Exist

1. Worst case results are shown from studying each transmission sensitivity addition by itself and all transmission sensitivities together.

Table D.5 Worst Case Loading of the Arnold – Plains 138 kV Line in MVA

Existing Rate B = 202 MVA Limited by: Conductor Summer Emergency Temperature Limit Conductor Characteristics: 605.0 kcmil ACSR 26/7 Squab (167° F) Uprate to 230° F increases the summer emergency rating to 278 MVA (1165 A) Uprate to 257° F increases the summer emergency rating to 302 MVA (1264 A) Uprate to 275° F increases the summer emergency rating to 318 MVA (1332 A) Uprate to 300° F increases the summer emergency rating to 337 MVA (1413 A) 300° F is the Maximum Emergency Temperature Rating per ATC Standards Contingency: Presque Isle – Dead River 138 kV Line or Dead River 345/138 kV Paralleled Transformers or Dead River – Plains 345 kV Line		
	Presque Isle Output > 431 MW	Presque Isle 3 & 4 Retired
Stability Required Trip Level	Trip Level 3	No Trip Level
w/o sensitivities		
No Trip Level	223 MVA	188 MVA
Trip Level 3	200	188
Trip Level 2	< 200	< 188
Trip Level 1	< 200	< 188
with sensitivities[1]		
No Trip Level	237 MVA	203 MVA
Trip Level 3	214	203
Trip Level 2	182	186
Trip Level 1	< 182	< 186
Worst Case Attributes		
Load Level	50 %	50 %
Transfer	High East to West	High East to West
PIPP Output	547 MW	431 MW
Mine Load	225 MW	225 MW
Flow North	305 MVA	195 MVA
Trip Level 1	300 MW	193 MW
Trip Level 2	177 MW	63 MW
Trip Level 3	81 MW	Does Not Exist

1. Worst case results are shown from studying each transmission sensitivity addition by itself and all transmission sensitivities together.

Appendix E: Plains Substation Special Protection System

The SPS at the Plains Substation is designed to isolate a portion of the Upper Peninsula of Michigan from the rest of the ATC system for angular instabilities that originate from the PIPP. The existing Plains Substation SPS is described in Reference [3]. The Plains Substation SPS design is scheduled to be reviewed in 2008 to take into account system changes since the initial design in the early 1990s. Any changes required as a result of this review are currently scheduled for implementation in 2009. Figure E.1 shows the separated area in RED. The separation is achieved by opening:

1. Nordic – Perch Lake 138 kV line
2. Plains – Dead River 345 kV line
3. Arnold – Forsyth 138 kV line
4. Conover – Land O Lakes 69 kV line
5. Chandler – Forsyth 69 kV line

Preliminary power flow analysis performed using the summer 2011 peak load case including the Eastern U.P. capacitor banks at Perkins 138 kV (1x24.5 + 1x16.33 MVAR), Indian Lake 138 kV (16.33 MVAR) and Hiawatha 138 kV (16.33 MVAR) Substations shows that the separated areas achieve acceptable steady state solutions for the following three system conditions. The three system conditions are analyzed to consider various stages in the construction of major projects potentially affecting the operation of the Plains Substation SPS.

1. Intact System
2. Removing Iron Grove – Brule – Plains 138 kV and restore Plains – Brule – Iron Grove to 69 kV from the intact system
3. Removing Highway 22 345 kV bus, which removes the 345 kV lines from Highway 22 to Gardner Park, Morgan, and Werner West from the system described in item 2 above

The total separated load shown in the RED area is less than 800 MW in 2007.

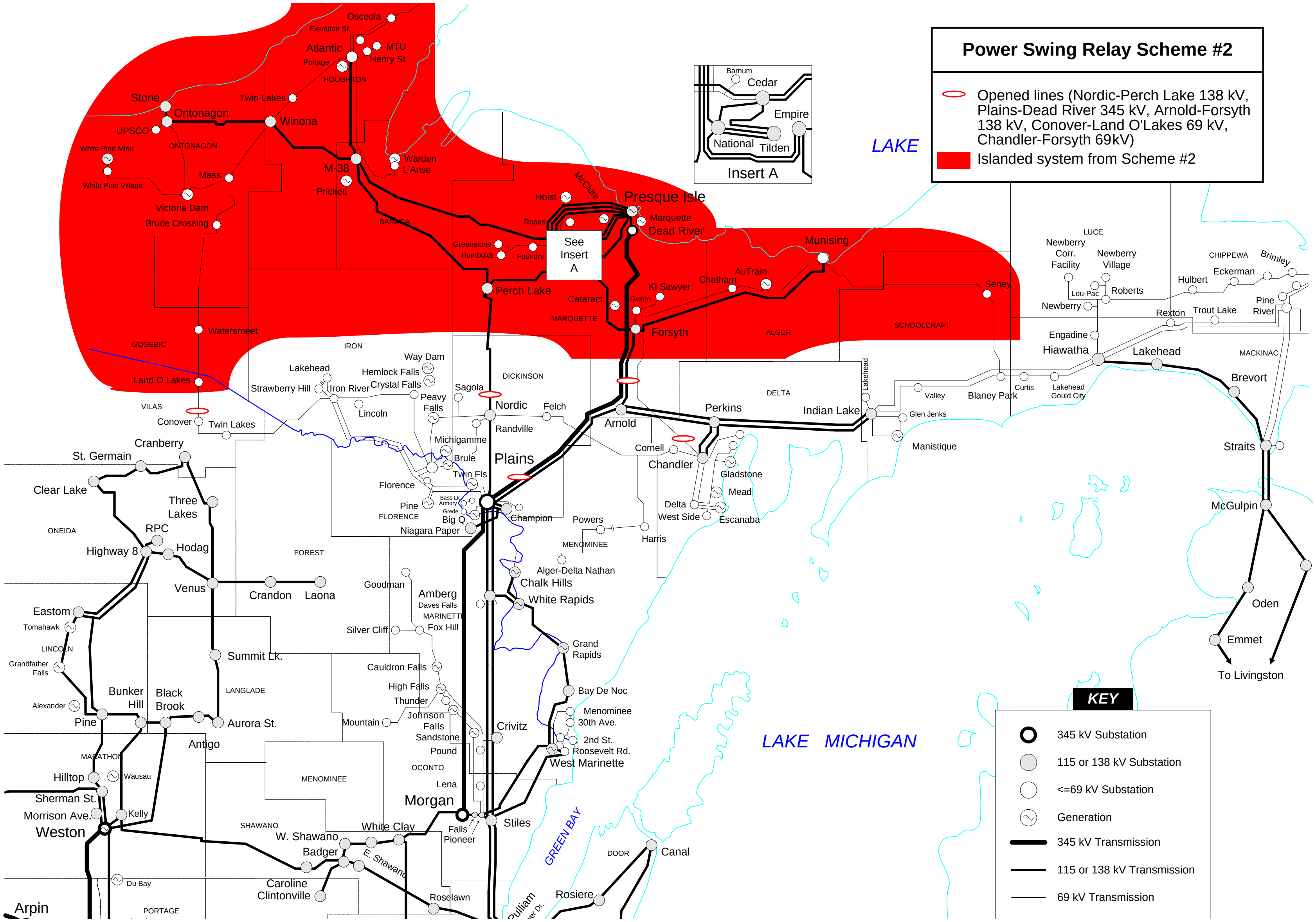

Figure E.1 Plains SPS Proposed Design

Appendix F: Terminology

ACSR	Aluminum Conductor Steel Reinforced
ATC	American Transmission Company
ATCLLC	American Transmission Company LLC
BES	Bulk Electric System (≥ 100 kV)
BK	Circuit Breaker
CB	Circuit Breaker
CCT	Critical Clearing Time
EMS	Energy Management System
IEEE	Institute of Electrical and Electronic Engineers
kV	Kilovolt
LDC	Load Distribution Company
MAIN	Mid-American Interconnected Network
MI	Mine Load
MRO	Midwest Reliability Organization
MVA	Megavolt-amps
MW	Megawatt
NERC	North American Electric Reliability Corporation
PG	Phase-to-Ground (Fault)
PIPP	Presque Isle Power Plant
PP	Phase-to-Phase (Fault)
PTI	Power Technologies Incorporated
p.u.	per unit
RATS	Remedial Action Tripping Scheme (this term is now obsolete)
RFC	Reliability First Corporation
RTCA	Real Time Contingency Analyzer
SE	Summer Emergency (Rating)
SEL	Schweitzer Engineering Laboratories
SPS	Special Protection System
TBD	To Be Determined
TPL-001-0	NERC Transmission Planning Standard 001: “System Performance Under Normal Conditions”
TPL-002-0	NERC Transmission Planning Standard 002: “System Performance Following Loss of a Single BES Element”

TPL-003-0	NERC Transmission Planning Standard 003: "System Performance Following Loss of Two or More BES Element"
UPPCO	Upper Peninsula Power Company

Substation Identifiers

AMB	Amberg Substation
ARN	Arnold Substation
BRU	Bruce Crossing Substation
CDR	Cedar Substation
CHD	Chandler Substation
CNTU	Cornell (UPPCO) Tap
DRV	Dead River Substation
EMP	Empire Substation
FRE	Freeman Substation
FRY	Forsyth Substation
M38	M38 Substation
MGN	Morgan Substation
MSS	Mass Substation
NAT	National Substation
NLK	North Lake Substation
NRD	Nordic Substation
PLA	Plains Substation
PLK	Perch Lake Substation
PRI	Presque Isle Substation
TLD	Tilden Substation
WCL	White Clay Substation
WSNT	Watson Tap

Transmission Line Identifiers

Cedar Line	Cedar – M38 138 kV (2007) becomes North Lake – M38 138 kV (2010)
Flow North	The sum of real power flow on the following three lines: Dead River – Plains 345 kV Forsyth – Arnold 138 kV Perch Lake – Nordic 138 kV

Forsyth Line	Empire – Forsyth 138 kV
Freeman605	Freeman – Cedar 138 kV (2007) becomes a section of Freeman – Tilden 138 kV (2010)
Goose Lake	Presque Isle (Bus 3) – Empire (Bus 6) 138 kV
MBLP	Presque Isle – Marquette Diesel 69 kV
M38 Line	Perch Lake – M38 138 kV
PI336	Presque Isle – Cedar 138 kV (2007) becomes a section of Presque Isle – National 138 kV circuit 2 (2010)
PI605	Presque Isle – Freeman 138 kV
16342	Empire – National 138 kV
16343	Tilden – National 138 kV circuit 1
16344	Tilden – National 138 kV circuit 2
16353	Cedar – National 138 kV (2007) becomes a section of Presque Isle – National 138 kV circuit 2 (2010)
26641	Cedar – Tilden 138 kV (2007) becomes a section of Freeman – Tilden 138 kV (2010)
29061	Forsyth – Arnold 138 kV
31253	Perch Lake – Nordic 138 kV
35321	Plains – Morgan 345 kV
446	Presque Isle – National 138 kV circuit 1
457	Presque Isle (Bus 5) – Empire (Bus 2) 138 kV (2007) becomes Presque Isle – North Lake 138 kV and North Lake – Empire 138 kV (2010)
468	Presque Isle – Perch Lake 138 kV
481	Presque Isle – Dead River 138 kV
78661	Nordic – Plains 138 kV
85601	Dead River – Plains 345 kV

Appendix G: Presque Isle SPS Trip Level Settings

The Presque Isle SPS relay trip level settings for the Immediate, Interim, and Permanent Solutions are described in Tables G.1 and G.2. The Immediate Solution trip level settings are the same as the existing 2007 trip level settings. The existing SPS has a voltage relay on the 138 kV Bus Section #5 at the Presque Isle Substation which supervises the SPS trips for faults on the lines that emanate from the PIPP and for faults on the Forsyth line. For these faults, the voltage would also have to drop below a threshold value before generation is tripped at the PIPP. The threshold value for the existing SPS is being checked as of the date of this report. The recommended voltage threshold is 0.90 p.u. for both the Interim Solution and the Permanent Solution.

The breaker open conditions are described in Table G.2.

Table G.1 Relay Trip Level Settings for the Immediate, Interim and Permanent Solutions
Highlighted cells indicate settings which differ between the Interim Solution and the Permanent Solution

<table>
<tr><th>Relay Name</th><th>Relay at</th><th>Relay sees</th><th>Fault type</th><th colspan="2">Fault Location</th><th>Immediate Solution (Existing SPS)</th><th>Interim Solution</th><th>Permanent Solution</th></tr>
<tr><td rowspan="4">SEL-311C[1]</td><td rowspan="4">DRV 345</td><td rowspan="4">Line 85601 and PLA 345/138[2]</td><td>3PG</td><td>Anywhere</td><td></td><td>2</td><td>1[3]</td><td>2</td></tr>
<tr><td>2PG/2PP</td><td>0 to 40%</td><td>line 85601</td><td>2</td><td>1[3]</td><td>2</td></tr>
<tr><td>2PG/2PP</td><td>40 to 100%</td><td>line 85601</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td>1PG</td><td>Anywhere</td><td></td><td>3</td><td>3</td><td>3</td></tr>
<tr><td rowspan="2">SEL-311C[1]</td><td rowspan="2">PRI 138</td><td rowspan="2">Line 481 and both DRV 345/138</td><td>3PG/2PG/2PP</td><td>Anywhere</td><td></td><td>1</td><td>1 [3]</td><td>1</td></tr>
<tr><td>1PG</td><td>Anywhere</td><td></td><td>2</td><td>1[3]</td><td>2</td></tr>
<tr><td rowspan="7">SEL-321</td><td rowspan="7">PRI 138</td><td rowspan="7">Line 468</td><td>3PG</td><td>0 to 30%</td><td>Line 468</td><td>2</td><td colspan="2">3</td></tr>
<tr><td>3PG</td><td>30 to 50%</td><td>Line 468</td><td>3</td><td colspan="2">No trip</td></tr>
<tr><td>3PG</td><td>50 to 100%</td><td>Line 468</td><td>No trip</td><td colspan="2">No trip</td></tr>
<tr><td>2PG/2PP</td><td>0 to 30%</td><td>Line 468</td><td>3</td><td colspan="2">3</td></tr>
<tr><td>2PG/2PP</td><td>30 to 50%</td><td>Line 468</td><td>3</td><td colspan="2">No trip</td></tr>
<tr><td>2PG/2PP</td><td>50 to 100%</td><td>Line 468</td><td>No trip</td><td colspan="2">No trip</td></tr>
<tr><td>1PG</td><td>Anywhere</td><td></td><td>No trip</td><td colspan="2">No trip</td></tr>
<tr><td rowspan="5">SEL-321</td><td rowspan="5">EMP 138</td><td rowspan="5">Forsyth Line</td><td>3PG</td><td>0 to 70%</td><td>Forsyth Line</td><td>2</td><td colspan="2">No trip</td></tr>
<tr><td>3PG</td><td>70 to 100%</td><td>Forsyth Line</td><td>3</td><td colspan="2">No trip</td></tr>
<tr><td>2PG/2PP</td><td>0 to 70%</td><td>Forsyth Line</td><td>3</td><td colspan="2">No trip</td></tr>
<tr><td>2PG/2PP</td><td>70 to 100%</td><td>Forsyth Line</td><td>3</td><td colspan="2">No trip</td></tr>
<tr><td>1PG</td><td>Anywhere</td><td></td><td>No trip</td><td colspan="2">No trip</td></tr>
</table>

Relay Name	Relay at	Relay sees	Fault type	Fault Location	Immediate Solution (Existing SPS)	Interim Solution	Permanent Solution
SEL-321	PRI 138	Line 457	3PG	0 to 25% Line 457	2	3	
			3PG	25 to 100% Line 457	3	No trip	
			2PG/2PP	0 to 25% Line 457	3	3	
			2PG/2PP	25 to 100% Line 457	3	No trip	
			1PG	Anywhere	No trip	No trip	
SEL-321	PRI 138	Goose Lake Line and Line 16342	3PG	0 to 25% Goose Lake Line	2	3	
			3PG	25 to 100% Goose Lake Line	3	No trip	
			3PG	0 to 100% Line 16342	3	No trip	
			2PG/2PP	0 to 25% Goose Lake Line	3	3	
			2PG/2PP	25 to 100% Goose Lake Line	3	No trip	
			2PG/2PP	0 to 100% Line 16342	3	No trip	
			1PG	Anywhere	No trip	No trip	
SEL-321	PRI 138	Line 446	3PG	0 to 25% Line 446	2	3	
			3PG	25 to 100% Line 446	3	No trip	
			2PG/2PP	0 to 25% Line 446	3	3	
			2PG/2PP	25 to 100% Line 446	3	No trip	
			1PG	Anywhere	No trip	No trip	
SEL-321	PRI 138	Lines PI605, Freeman605, 26641, 16343, and 16344	3PG	0 to 35% Line PI605	2	3	
			3PG	35 to 100% Line PI605	3	No trip	
			3PG	0 to 100% Freeman605	3	No trip	
			3PG	0 to 100% Line 26641	3	No trip	
			3PG	0 to 100% Line 16343	3	No trip	
			3PG	0 to 100% Line 16344	3	No trip	
			2PG/2PP	0 to 35% Line PI605	3	3	
			2PG/2PP	35 to 100% Line PI605	3	No trip	
			2PG/2PP	0 to 100% Freeman605	3	No trip	
			2PG/2PP	0 to 100% Line 26641	3	No trip	
			2PG/2PP	0 to 100% Line 16343	3	No trip	
			2PG/2PP	0 to 100% Line 16344	3	No trip	
			1PG	Anywhere	No trip	No trip	

Relay Name	Relay at	Relay sees	Fault type	Fault Location		Immediate Solution (Existing SPS)	Interim Solution	Permanent Solution
SEL-321	PRI 138	Line PI336 and 16353	3PG	0 to 35%	Line PI336	2	3	
			3PG	35 to 100%	Line PI336	3	No trip	
			3PG	0 to 100%	Line 16353	3	No trip	
			2PG/2PP	0 to 35%	Line PI336	3	3	
			2PG/2PP	35 to 100%	Line PI336	3	No trip	
			2PG/2PP	0 to 100%	Line 16353	3	No trip	
			1PG	Anywhere		No trip	No trip	

1. The SEL-321 relay provides a redundant trip signal.
2. The Interim and the Permanent Solution need to be modified to see only through line 85601
3. These faults could result in mine load to trip off line and also the loss of the faulted line. This leads to potential generation instabilities and also the potential overload of the Forsyth line. Potential instabilities and thermal overloads are addressed by a trip level 1 as shown. Uprating the Forsyth line resolves potential thermal overloads and the trip signal severity could be dropped to a trip level 2.

Table G.2 Breaker Open Trip Level Settings for the Immediate, Interim and Permanent Solutions

Substation	Breaker(s) opened[1]	Immediate Solution or Existing SPS	Interim Solution	Permanent Solution
PRI 138	BS18 and BS78	3	3	
PLA 345	BS23 and BS16	3	No trip	
PLA 345	BS12 and BS23	3	3	
DRV 138	481	3	3	
DRV 345	BS12	3	3	
MGN 138	BS56 and BS67	3	No trip	
MGN 345	BS12	3	No trip	

1. There is no voltage supervision for the breaker open signals.

Appendix H: Limiting Elements

All limiting elements of thermally overloaded facilities identified in this report are listed in Table H.1.

Table H.1 Thermally Limited Facilities and Specific Equipment Limitations

	Most Limiting		2nd Most Limiting		
Transmission Facility	Element	Rating (MVA)	Element	Rating (MVA)	Line Length (miles)
FRY 138/69	Under Review	48			-
NRD 138/69	Power Transformer	56	Meter at NRD 138	108	-
PLK 138 – NRD 138	Line Conductor Clearance Meter at PLK 138 CT at PLK 138	191	Switch at PLK 138	199	29.6
EMP 138 – FRY 138	Line Conductor Clearance Line Conductor Clearance[1]	202 302	Line Trap at EMP 138 TBD[2]	214 TBD[2]	17.6
CDR 138 – M38 138 (2007) NLK 138 – M38 138 (2010)	Under Review	96			
FRY 138 – ARN 138	Line Conductor Clearance	245	Jumper at FRY 138 Jumper at ARN 138	278	16.6
PRI 138 – EMP 138 Line 457	Switch at PRI 138	191	Line Conductor Clearance	201	32.4
EMP 138 – NAT 138	Line Conductor Clearance	202	Line Trap at EMP 138 Line Trap at NAT 138	214	9.2
MSS 69 – BRU 69	Relay Setting at MSS 69	34	Line Conductor Clearance	43	18.6
PRI 138 – PLK 138	Line Conductor Clearance	202	Line Trap at PRI 138 Line Trap at PLK 138	214	36.7
PRI 138 – EMP 138 Line GooseLake	Line Conductor Clearance	166	2 Switches at PRI 138	199	17.8
EMP BS 1-2	Non-Directional Thermal Relay	185	Bus conductor	217	Not applicable-

1. Limiting element after the proposed line uprate and substation equipment replacement is completed.
2. TBD – To Be Determined upon implementation of the proposed line uprate and substation equipment replacement is completed.