Facility Study Update

40 MW Steam Turbine Generation
Ontonagon, Michigan

Prepared for Midwest ISO

March 12, 2004

American Transmission Company, LLC

Wenchun Zhu
Transmission Planning and Services

1. Executive Summary

This Facility Study Update is an extension of the System Impact and Facility Evaluation Study (dated December 29, 2003) regarding the 40MW steam-turbine generation in Ontonagon County, Michigan. The purpose of this Update is to modify the recommendations of the system upgrades as concluded in the original study report using a modified stability criterion applicable particular to the area relevant to this generation interconnection.

In the original System Impact and Facility Evaluation Study, it was required that the system stability performance must be satisfactory under three types of three-phase contingencies –

1. Fault cleared in primary time with an otherwise intact system.
2. Fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system.
3. Fault cleared in primary clearing time with a pre-existing outage of any other transmission element.

Later ATC determined that for this particular application, it is more appropriate to require satisfactory stability performance under single-phase breaker failure contingencies instead of three-phase breaker failure contingencies (as listed in item #2 above).

The stability performance of the area where the 40MW generation is to be connected is largely NOT satisfactory under three-phase breaker failure contingencies due to the nature of the power system facilities in the area. The generators that will produce the 40MW power are existing generators that were installed years ago and subsequently disconnected from the transmission system several years ago. Although ATC originally had intended to use the three-phase breaker failure criterion, it was determined later that it makes better engineering sense to first bring up the whole area to the single-phase breaker failure criterion instead of upgrading just a small portion of the area to the three-phase breaker failure criterion. ATC will pursue implementing the three-phase breaker failure criterion for the area through the regular planning process.

It should be noted that the single-phase breaker failure criterion is in compliance with the NERC planning standards.

The study results are summarized in Tables 1 through 3.

2. Introduction

The subjects of investigation are three existing steam-turbine generators, each rated at 20MW/22.2MVA. The 40MW generation investigated in this Study can be produced from either two or three existing generators.

The three existing generators are connected to the White Pine 69kV substation through two existing 13.8/69 kV transformers, one of which is currently out of service due to equipment failure. Both transformers have a maximum normal rating of 22.4MVA. The three generators are not in service during normal operation. Refer to Figure 1 for a one-line diagram of the generation facilities and the transmission system facilities in the vicinity. In this Study, it is assumed that the second transformer will be placed back in service upon connection of more than 20MW generation to the transmission system at the White Pine 69kV substation. Refer to Figure 2 for the one-line diagram of the system with 40MW generation connected to the White Pine 69kV substation.

This Update concludes the required system upgrades due to system stability and short-circuit impacts in the existing system and due to the 40MW generation.

The study results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the Generator data and/or ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this study is subject to re-evaluation. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to ATC prior to commercial operation.

3. Required Interconnection Facilities

The generators are connected through an existing substation. No additional interconnection facilities are required.

Both of the 69/13.8 kV transformers connected to the White Pine 69kV substation have a maximum normal rating of 22.4MVA. The Customer should make sure that these two transformers can operate at this maximum normal rating continuously before connecting the 40MW generation to the transmission system.

A backup relay associated with the breaker 839 is required to be consistent with the relay reliability standards of ATC. The customer is responsible for the cost of this backup relay. This requirement is listed in Table 1 and is the same as required in the original System Impact and Facility Evaluation Study report.

4. System Upgrades

The required system upgrades concluded in this study are a sub-set of the required system upgrades concluded in the original System Impact and Facility Evaluation Study (report dated December 29, 2003), due to the change in using the single-phase breaker failure stability criterion in this study from using the three-phase breaker failure stability criterion in the original study.

The required upgrades as discussed in the following and listed in Tables 1 through 3 in this report are the finalized requirements to address the stability and short-circuit breaker duty concerns for this generator interconnection request.

Existing System Upgrades - Stability Related

System upgrades required for the existing system in the context of system stability evaluation are listed in Table 1.

Note that the stability results as listed in Table A.2 in the Appendix A indicate that only a new carrier relay scheme at Victoria 69kV substation is required for the existing system. However, Table 1 also lists the required new carrier relay scheme at Mass 69kV substation. The reason is that carrier relay schemes involve communications between two ends of a line and they need to be installed at both ends in order for any scheme to work. The two required new carrier schemes as listed in Table 1 are at two ends of the 69kV line Victoria – Mass.

Existing System Upgrades - Short-Circuit Breaker-Duty Related

Short-circuit analysis found no unacceptable short-circuit system impact in the existing system.

With the 40MW Generation - Stability Related

The required system upgrades due to the 40MW generation in the context of system stability evaluation are listed in Table 3.

Note that the stability results as listed in Table A.4 in the Appendix A indicate the need for the carrier relay scheme at the Mass end on the 69kV line Mass – Winona. However, carrier relay schemes at both ends of the line must be installed in order for any scheme to work. Therefore, Table 3 includes required new carrier relay schemes at both substations Mass and Winona.

With the 40MW Generation - Short-Circuit Breaker-Duty Related

Short-circuit analysis found no unacceptable short-circuit system impact due to the 40MW generation.

Table 1 – System Upgrades Required for the Existing System

Locations	Facilities	Reasons
White Pine 69kV	New backup relay for breaker 839. Estimated Cost $30k.	Relay reliability
Victoria 69kV	New carrier scheme for breaker 795, to obtain 6.0c far end clearing on 69kV line Mass – Victoria. Estimated Cost $200k.	Stability
Mass 69kV	New carrier scheme For breaker 6540, to obtain 8.0c far end clearing on 69kV line Victoria – Mass. Estimated Cost $200k.	Stability

Note:
Total Estimated Cost to implement items at Victoria and Mass substations is $400,000.

Table 2 – Required Interconnection Facilities

Locations	Facilities
None	

Table 3 – Required System Upgrades due to the 40MW Generation
And the Associated Cost Estimates
Based on the System with the Completed Upgrades as Listed in Table 1

Locations	Facilities	Reasons	Cost Estimates
Mass 69kV	New carrier scheme For breaker 6550, to obtain 8.0c far end clearing on 69kV line Winona – Mass	Stability	$ 200,000
Winona 69kV	New carrier scheme For breaker 875, to obtain 8.0c far end clearing on 69kV line Mass – Winona	Stability	$ 200,000
Total Costs Estimate			$ 400,000

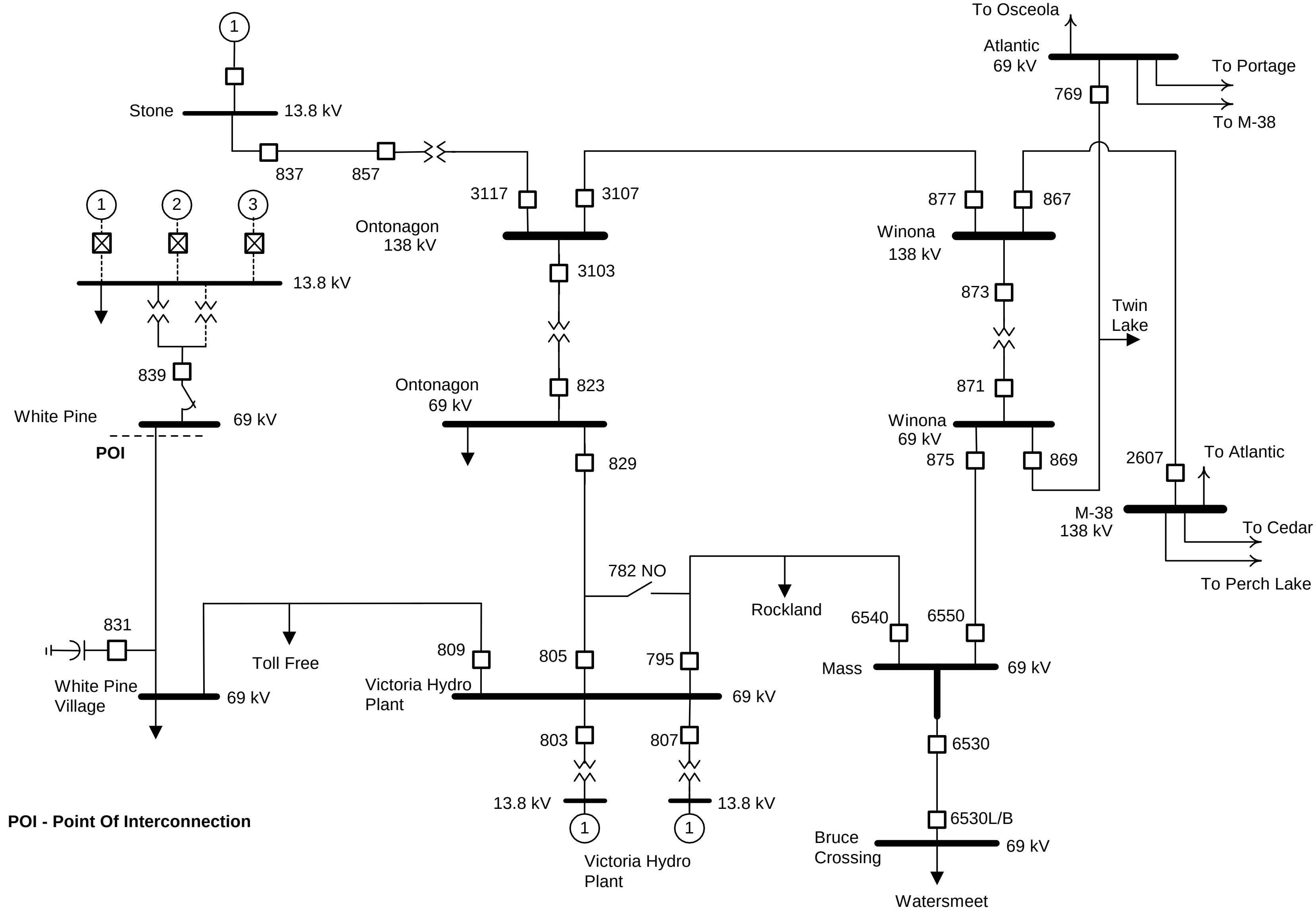

Figure 1 – One-Line Diagram of the Existing System

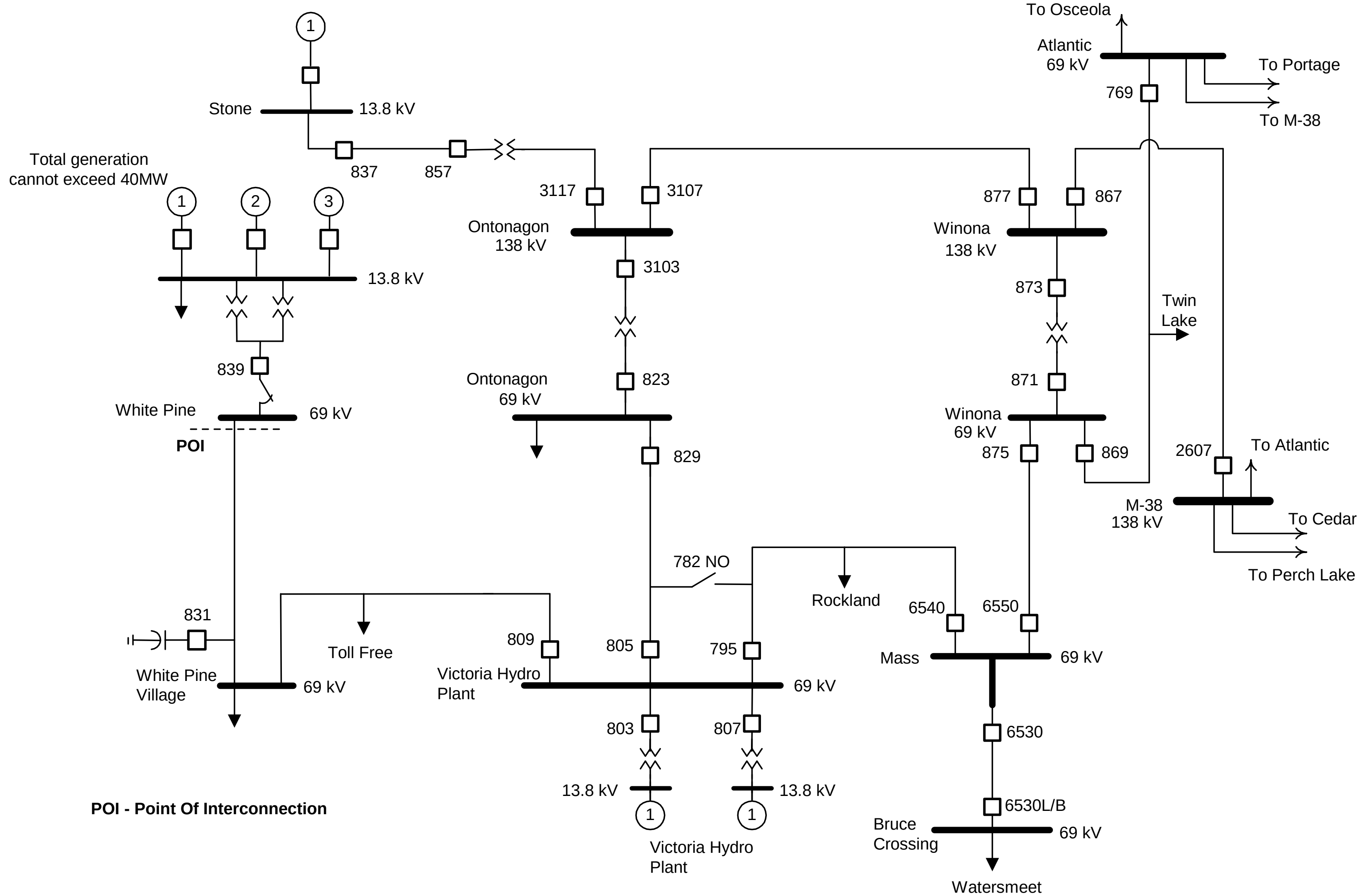

Figure 2 – One-Line Diagram of the System with 40MW Generation Connected to the White Pine 69kV Substation

Appendix A

Stability Analysis Results

Table A.1 – Stability Impacts for the Expected System in 2004
With No Generation Connected to the White Pine 69kV Substation
(Unacceptable stability performance is colored in red)

ID	Single-Phase Primary and Prior Outage Fault Three-Phase Breaker Failure Fault	Breaker #, Clearing Time	Conditions	Transient Performance W/ 0 units 0 MW export
Primary Faults				
F.1	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 809 – 23 c		Island formed; The rest of system is **Acceptable**
F.2	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c		Island formed; The rest of system is **Acceptable**
F.3	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c		**Acceptable**
F.4	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 805 – 8.0 c		**Acceptable**
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c		**Acceptable**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 795 – 23 c		**VIC 1&2 tripped; Transient voltage recovery unacceptable at WPV69, VIC69**

F.7	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 877 – 5.0 c		**Acceptable**
F.8	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3107 – 5.0 c		**Acceptable**
F.9	At Mass end on Mass – Iron River 69kV	MSS 6530 – 6.5 c IRR 6510 – 27 c		**Acceptable**
F.10	At Iron River end on Iron River – Mass 69kV	IRR 6510 – 4.5 c MSS 6530 – 29 c		**Acceptable**
F.11	At Winona end on Winona – Atlantic 69kV	WNA 869 – 4.5 c ATL 769 – 26 c		**Acceptable**
F.12	At Atlantic end on Atlantic – Winona 69kV	ATL 769 – 9.5 c WNA 869 – 3.0 c		**Acceptable**
F.13	At High side of Ontonagon xfmr	ONN 3103 – 6.0 c ONN 823 – 6.0 c		**Acceptable**
F.14	At Low side of Ontonagon xfmr	ONN 823 – 6.0 c ONN 3103 – 6.0 c		**Acceptable**
F.15	At High side of Winona xfmr	WNA 873 – 6.0 c WNA 871 – 6.0 c		**Acceptable**
F.16	At Low side of Winona xfmr	WNA 871 – 6.0 c WNA 873 – 6.0 c		**Acceptable**
F.17	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 875 – 33 c		**Acceptable**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6550 – 27 c		**Acceptable**

Faults Involving Breaker Failure				
F.19	At Mass end on Mass – Winona 69kV	MSS 6540 – 20 c MSS 6530 – 22 c WNA 875 – 33 c	Breaker failure at Mass 6550	**Acceptable**
F.20	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 871 – 91 c WNA 869 – 91 c	Breaker failure at Winona 875	**Acceptable**
F.21	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6540 – 42.5 c MSS 6530 – 44.5 c	Breaker failure At Mass 6550	**Acceptable**
F.22	At Winona end on Winona – Mass 69kV	MSS 6550 – 27 c WNA 871 – 62.5 c WNA 869 – 62.5 c	Breaker failure At Winona 875	**Acceptable**
F.23	At Victoria end on Victoria – White Pine 69kV	VIC 795 – 19.5 c VIC 805 – 19.5 c WPM 839 – 26 c	Breaker failure At Victoria 809	**Acceptable**
F.24	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 795 – 36 c VIC 805 – 36 c	Breaker failure at Victoria 809	**Acceptable**
F.25	At Ontonagon end on Ontonagon – Victoria 69kV	VIC 805 – 8 c ONN 823 – 86 c	Breaker failure at Ontonagon 829	**Acceptable**

F.26	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 809 – 20.5 c VIC 795 – 20.5 c	Breaker failure at Victoria 805	**Acceptable**
F.27	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 823 – 177 c	Breaker failure at Ontonagon 829	**Acceptable**
F.28	At Victoria end on Victoria – Ontonagon 69kV	VIC 795 – 19.5 c VIC 809 – 19.5 c ONN 829 – 27 c	Breaker failure at Victoria 805	**Acceptable**
F.29	At Mass end on Mass – Victoria 69kV	MSS 6550 – 20 c MSS 6530 – 22 c VIC 795 – 23 c	Breaker failure at Mass 6540	**Acceptable**
F.30	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 805 – 36 c VIC 809 – 36 c	Breaker failure at Victoria 795	**Acceptable**
F.31	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6550 – 42.5 c MSS 6530 – 44.5 c	Breaker failure at Mass 6540	**Acceptable**
F.32	At Victoria end on Victoria – Mass 69kV	VIC 805 – 19.5 c VIC 809 – 19.5 c MSS 6540 – 27 c	Breaker failure at Victoria 795	**Acceptable**

F.33	At Ontonagon end on Ontonagon – Winona 138kV	WNA 877 – 5.0 c ONN 3117 – 62.5 c ONN 3103 – 62.5 c	Breaker failure at Ontonagon 3107	**Acceptable**
F.34	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 867 – 63 c WNA 873 – 63 c	Breaker failure at Winona 877	**Acceptable**
F.35	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3117 – 63 c ONN 3103 – 63 c	Breaker failure at Ontonagon 3107	**Acceptable**
F.36	At Winona end on Winona – Ontonagon 138kV	ONN 3107 – 5.0 c WNA 867 – 62.5 c WNA 873 – 62.5 c	Breaker failure at Winona 877	**Acceptable**
F.37	At Mass end on Mass – Iron River 69 kV	MSS 6550 – 20 c MSS 6540 – 20 c IRR 6510 – 27 c	Breaker failure at Mass 6530	**Acceptable**
F.38	At Mass end on Mass – Iron River 69 kV	MSS 6530 – 4.5 c IRR 6330 – 42.5 c IRR 6220 – 42.5 c IRR 6230 – 42.5 c	Breaker failure at Iron River 6510	**Acceptable**
F.39	At Iron River end on Iron River – Mass 69 kV	IRR 6510 – 4.5 c MSS 6550 – 42.5 c MSS 6540 – 42.5 c	Breaker failure at Mass 6530	**Acceptable**

F.40	At Iron River end on Iron River – Mass 69 kV	IRR 6330 – 20 c IRR 6220 – 20 c IRR 6230 – 20 c MSS 6530 – 27 c	Breaker failure at Iron River 6510	**Acceptable**
F.41	At Winona end on Winona – Atlantic 69kV	ATL 769 – 26 c WNA 875 – 62.5 c WNA 871 – 62.5 c	Breaker failure at Winona 869	**Acceptable**
F.42	At Atlantic end on Winona – Atlantic 69kV	ATL 769 – 9.5 c WNA 875 – 91 c WNA 871 – 91 c	Breaker failure at Winona 869	**Acceptable**
F.43	At High side of Ontonagon xfmr	ONN 823 – 6.0 c WNA 877 – 14 c ONN 3117 – 147 c	Breaker failure at Ontonagon 3103	**Acceptable**
F.44	At Low side of Ontonagon xfmr	ONN 3103 – 6.0 c VIC 805 – 23 c	Breaker failure at Ontonagon 823	**Acceptable**
F.45	At High side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 11 c M38 2607 – 48 c	Breaker failure at Winona 873	**Acceptable**
F.46	At High side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 20 c MSS 6550 – 63 c	Breaker failure at Winona 871	**Acceptable**
F.47	At Low side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 16 c M38 2607 – 30 c	Breaker failure at Winona 873	**Acceptable**
F.48	At Low side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 26 c MSS 6550 – 27 c	Breaker failure at Winona 871	**Acceptable**

Faults Involving Prior Outage				
F.49	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Ontonagon 69kV	Island formed; The rest of system is **Acceptable**
F.50	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Mass 69kV	Island formed; The rest of system is **Acceptable**
F.51	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Victoria – Ontonagon 69kV	Island formed; VIC 1&2 tripped; The rest of system is **Acceptable**
F.52	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Ontonagon – Winona 138kV	Island formed; Units in the island tripped; The rest of system is **Acceptable**
F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Winona 138/69 kV xfmr	**Acceptable**
F.54	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Victoria – Mass 69kV	Island formed; VIC 1&2 tripped; The rest of system is **Acceptable**
F.55	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Ontonagon – Winona 138kV	**Acceptable**
F.56	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Winona 138/69 kV xfmr	**Acceptable**

Table A.2 – Stability Impacts for the Expected System in 2004
Including Upgrades Required for the Existing System with No Generation Connected to the White Pine 69kV Substation
(Proposed system upgrades are colored in green)

ID	Single-Phase Primary and Prior Outage Fault Three-Phase Breaker Failure Fault	Breaker #, Clearing Time	Conditions	Transient Performance w/ 0 units 0 MW export
Primary Faults				
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c **VIC 795 – 8.0 c**		**Acceptable**
Faults Involving Breaker Failure				
No upgrades required since no system impacts were identified due to breaker failure contingencies				
Faults Involving Prior Outage				
No upgrades required since no system impacts were identified due to prior outage contingencies				

Table A.3 – Stability Impacts for the Expected System in 2004
With 40MW Generation Connected to the White Pine 69kV Substation, With No System Upgrades
(Unacceptable stability performance is colored in red)

ID	Single-Phase Primary and Prior Outage Fault Three-Phase Breaker Failure Fault	Breaker #, Clearing Time	Conditions	Transient Performance W/ 2 units 40 MW net export
Primary Faults				
F.1	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 809 – 23 c		Island formed; WPM 1 & 2 tripped; rest of system is **Acceptable**
F.2	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c		Island formed; WPM 1 & 2 tripped; rest of system is **Acceptable**
F.3	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c		**Acceptable**
F.4	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 805 – 8.0 c		**Acceptable**
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c		**WPM 1& 2, VIC 1&2 tripped; Unacceptable transient voltage recovery at VIC69, WPM69, ONN69, ONN138**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 795 – 23 c		**WPM 1 & 2, VIC 1&2 tripped; Unacceptable transient voltage recovery at VIC69, WPM69, ONN69**
F.7	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 877 – 5.0 c		**Acceptable**
F.8	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3107 – 5.0 c		**Acceptable**

F.9	At Mass end on Mass – Iron River 69kV	MSS 6530 – 6.5 c IRR 6510 – 27 c		**Acceptable**
F.10	At Iron River end on Iron River – Mass 69kV	IRR 6510 – 4.5 c MSS 6530 – 29 c		**Acceptable**
F.11	At Winona end on Winona – Atlantic 69kV	WNA 869 – 4.5 c ATL 769 – 26 c		**Acceptable**
F.12	At Atlantic end on Atlantic – Winona 69kV	ATL 769 – 9.5 c WNA 869 – 33.0 c		**Acceptable**
F.13	At High side of Ontonagon xfmr	ONN 3103 – 6.0 c ONN 823 – 6.0 c		**Acceptable**
F.14	At Low side of Ontonagon xfmr	ONN 823 – 6.0 c ONN 3103 – 6.0 c		**Acceptable**
F.15	At High side of Winona xfmr	WNA 873 – 6.0 c WNA 871 – 6.0 c		**Acceptable**
F.16	At Low side of Winona xfmr	WNA 871 – 6.0 c WNA 873 – 6.0 c		**Acceptable**
F.17	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 875 – 33 c		**Acceptable**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6550 – 27 c		**Unacceptable transient voltage recovery at VIC69, ONN69, MSS69**
Faults Involving Breaker Failure				
F.19	At Mass end on Mass – Winona 69kV	MSS 6540 – 20 c MSS 6530 – 22 c WNA 875 – 33 c	Breaker failure at Mass 6550	**Acceptable**
F.20	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 871 – 91 c WNA 869 – 91 c	Breaker failure at Winona 875	**Acceptable**
F.21	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6540 – 42.5 c MSS 6530 – 44.5 c	Breaker failure At Mass 6550	**Acceptable**

F.22	At Winona end on Winona – Mass 69kV	MSS 6550 – 27 c WNA 871 – 62.5 c WNA 869 – 62.5 c	Breaker failure At Winona 875	**Acceptable**
F.23	At Victoria end on Victoria – White Pine 69kV	VIC 795 – 19.5 c VIC 805 – 19.5 c WPM 839 – 26 c	Breaker failure At Victoria 809	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.24	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 795 – 36 c VIC 805 – 36 c	Breaker failure at Victoria 809	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.25	At Ontonagon end on Ontonagon – Victoria 69kV	VIC 805 – 8 c ONN 823 – 86 c	Breaker failure at Ontonagon 829	**Acceptable**
F.26	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 809 – 20.5 c VIC 795 – 20.5 c	Breaker failure at Victoria 805	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.27	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 823 – 177 c	Breaker failure at Ontonagon 829	**Acceptable**
F.28	At Victoria end on Victoria – Ontonagon 69kV	VIC 795 – 19.5 c VIC 809 – 19.5 c ONN 829 – 27 c	Breaker failure at Victoria 805	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.29	At Mass end on Mass – Victoria 69kV	MSS 6550 – 20 c MSS 6530 – 22 c VIC 795 – 23 c	Breaker failure at Mass 6540	**Acceptable**
F.30	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 805 – 36 c VIC 809 – 36 c	Breaker failure at Victoria 795	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.31	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6550 – 42.5 c MSS 6530 – 44.5 c	Breaker failure at Mass 6540	**Acceptable**
F.32	At Victoria end on Victoria – Mass 69kV	VIC 805 – 19.5 c VIC 809 – 19.5 c MSS 6540 – 27 c	Breaker failure at Victoria 795	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**

F.33	At Ontonagon end on Ontonagon – Winona 138kV	WNA 877 – 5.0 c ONN 3117 – 62.5 c ONN 3103 – 62.5 c	Breaker failure at Ontonagon 3107	**Acceptable**
F.34	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 867 – 63 c WNA 873 – 63 c	Breaker failure at Winona 877	**Acceptable**
F.35	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3117 – 63 c ONN 3103 – 63 c	Breaker failure at Ontonagon 3107	**Acceptable**
F.36	At Winona end on Winona – Ontonagon 138kV	ONN 3107 – 5.0 c WNA 867 – 62.5 c WNA 873 – 62.5 c	Breaker failure at Winona 877	**Acceptable**
F.37	At Mass end on Mass – Iron River 69 kV	MSS 6550 – 20 c MSS 6540 – 20 c IRR 6510 – 27 c	Breaker failure at Mass 6530	**Acceptable**
F.38	At Mass end on Mass – Iron River 69 kV	MSS 6530 – 4.5 c IRR 6330 – 42.5 c IRR 6220 – 42.5 c IRR 6230 – 42.5 c	Breaker failure at Iron River 6510	**Acceptable**
F.39	At Iron River end on Iron River – Mass 69 kV	IRR 6510 – 4.5 c MSS 6550 – 42.5 c MSS 6540 – 42.5 c	Breaker failure at Mass 6530	**Acceptable**
F.40	At Iron River end on Iron River – Mass 69 kV	IRR 6330 – 20 c IRR 6220 – 20 c IRR 6230 – 20 c MSS 6530 – 27 c	Breaker failure at Iron River 6510	**Acceptable**
F.41	At Winona end on Winona – Atlantic 69kV	ATL 769 – 26 c WNA 875 – 62.5 c WNA 871 – 62.5 c	Breaker failure at Winona 869	**Acceptable**
F.42	At Atlantic end on Winona – Atlantic 69kV	ATL 769 – 9.5 c WNA 875 – 91 c WNA 871 – 91 c	Breaker failure at Winona 869	**Acceptable**

F.43	At High side of Ontonagon xfmr	ONN 823 – 6.0 c WNA 877 – 14 c ONN 3117 – 147 c	Breaker failure at Ontonagon 3103	**Acceptable**
F.44	At Low side of Ontonagon xfmr	ONN 3103 – 6.0 c VIC 805 – 23 c	Breaker failure at Ontonagon 823	**Acceptable**
F.45	At High side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 11 c M38 2607 – 48 c	Breaker failure At Winona 873	**Acceptable**
F.46	At High side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 20 c MSS 6550 – 63 c	Breaker failure at Winona 871	**Acceptable**
F.47	At Low side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 16 c M38 2607 – 30 c	Breaker failure at Winona 873	**Acceptable**
F.48	At Low side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 26 c MSS 6550 – 27 c	Breaker failure at Winona 871	**Acceptable**
Faults Involving Prior Outage				
F.49	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Ontonagon 69kV	Island formed; WPM 1 & 2 tripped; rest of system is **Acceptable**
F.50	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Mass 69kV	Island formed; WPM 1 & 2 tripped; rest of system is **Acceptable**
F.51	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Victoria – Ontonagon 69kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.52	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Ontonagon – Winona 138kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**

F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Winona 138/69 kV xfmr	**WPM 1 & 2, VIC 1&2 tripped; Transient voltage recovery unacceptable at VIC69, ONN69**
F.54	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Victoria – Mass 69kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Acceptable**
F.55	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Ontonagon – Winona 138kV	**Acceptable**
F.56	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Winona 138/69 kV xfmr	**Acceptable**

Table A.4 – Stability Impacts for the Expected System in 2004
With 40MW Generation Connected to the White Pine 69kV Substation and with Upgrades
(Proposed system upgrades are colored in green)

ID	Single-Phase Primary and Prior Outage Fault Three-Phase Breaker Failure Fault	Breaker #, Clearing Time	Conditions	Transient Performance W/ 2 units 40 MW net export
Primary Faults				
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c **MSS 6540 – 8.0 c**		**Acceptable**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c **VIC 795 – 6.0 c**		**Acceptable**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c **MSS 6550 – 8.0 c**		**Acceptable**
Faults Involving Breaker Failure				
No upgrades required since no system impacts were identified due to breaker failure contingencies				
Faults Involving Prior Outage				
F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c **MSS 6540 – 8.0 c**	Prior outage Winona 138/69 kV xfmr	**Acceptable**

System Impact and Facility Evaluation Study Report

40 MW Steam Turbine Generation
Ontonagon, Michigan

October 16, 2003

American Transmission Company, LLC

Wenchun Zhu, Joel Berry, Richard Berg
Transmission Planning and Services

Jennifer Stroud, Joe Riederer
System Protection and Control

David Leary, Michael Hueppchen, Andy Dolan, Mathew Westrich
Engineering, Maintenance and Construction

This page intentionally left blank.

Executive Summary

This report contains the System Impact and Facility Evaluation Study regarding the 40MW steam-turbine generation in Ontonagon County, Michigan. The purpose of this Study is to evaluate the system impact due to the 40MW steam-turbine generation. This Study also investigates whether specific system upgrades will address all the identified system impacts. Cost estimates of the required system upgrades are also provided in this report.

The subjects of investigation are three existing steam-turbine generators, each rated at 20MW/22.2MVA. The 40MW generation investigated in this Study can be produced from either two or three existing generators.

The three existing generators are connected to the White Pine 69kV substation through two existing 13.8/69 kV transformers, one of which is currently out of service due to equipment failure. Both transformers have a maximum normal rating of 22.4MVA. The three generators are not in service during normal operation. Refer to Figure 1.1 for a one-line diagram of the generation facilities and the transmission system facilities in the vicinity. In this Study, it is assumed that the second transformer will be placed back in service upon connection of more than 20MW generation to the transmission system at the White Pine 69kV substation. Refer to Figure 1.2 for the one-line diagram of the system with 40MW generation connected to the White Pine 69kV substation.

This study is to identify whether any stability, short circuit, or thermal limits may be violated on the ATC transmission system by the 40MW generation. If any stability, short circuit, or thermal problems are found, then possible solutions that might address these problems are suggested, and the cost estimates for the proposed system upgrades are provided.

The study results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the Generator data and/or ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this study may be subject to re-evaluation. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to ATC prior to commercial operation.

System Impacts and Required/Optional System Upgrades

Required Interconnection Equipment

Both of the 69/13.8 kV transformers connected to the White Pine 69kV substation have a maximum normal rating of 22.4MVA. The Customer should make sure that these two transformers can operate at this maximum normal rating continuously before connecting the 40MW generation to the transmission system.

Also, a backup relay associated with the breaker 839 is required to be consistent with the relay reliability standards of ATC. The customer is responsible for the cost of this backup relay.

<u>Stability Impact and Required Upgrades</u>

With no generation connected to the White Pine 69kV substation

The Study identified a number of primary and breaker failure faults that caused unacceptable stability system impacts in the system with no generation connected to the White Pine 69kV substation. The Study also identified breakers/relays upgrades that could eliminate all the identified unacceptable stability impacts. Refer to Table 1.1 for details of these required system upgrades.

With 40MW generation connected to the White Pine 69kV substation

Stability impact was evaluated for the system with 40MW generation connected to the White Pine 69kV substation. It is assumed that the two 69/13.8 kV transformers connected to the White Pine 69kV substation are both placed in service. Refer to Figure 1.2 for the system configuration.

The Study identified a number of primary, breaker failure and prior outage contingencies that caused unacceptable stability impacts in this system. The Study also identified breakers/relays upgrades that could eliminate all identified unacceptable stability impacts in the system, except those involving loss of the 69kV line White Pine - Victoria. Refer to Table 1.2 for details of these required system upgrades and the associated costs estimates.

The Study found that all those studied primary, breaker failure and prior outage contingencies involving the loss of the 69kV line White Pine – Victoria pose unacceptable stability impact on the generators connected to the White Pine 69kV substation, due to the radial interconnection of the generators. However, the Study also found that with the identified breakers/relays upgrades as listed in Table 1.2, the unacceptable stability impact caused by the loss of the 69kV line White Pine – Victoria does not extend to any other generators in the rest of the system for any studied contingency. Therefore, the identified upgrades as listed in Table 1.2 are deemed satisfactory for bringing on line the 40MW generation. The upgraded system condition is determined to be in compliance with the NERC Planning Standards. The generators connected to the White Pine 69kV substation should be equipped with adequate relays to trip off the generators once they go out of synchronism, in order to protect the generators and auxiliary equipment.

<u>Short Circuit Impact and Required Upgrades</u>

Short-circuit analysis found no unacceptable short-circuit system impact due to the 40MW generation.

<u>Thermal Impact and Optional Upgrades</u>

Optional System Upgrades are not required to establish generation interconnection. Therefore, any optional facilities identified do not have to be implemented prior to the commercial operation of the 40MW generation. System upgrades due to thermal constraints identified in this Study are optional. The thermal overloading impacts associated with the 40MW generation may be significantly affected by the delivery of specific transmission service requests. Therefore, the thermal overloads identified in this study may not be the same as the thermal overloads identified via a specific Transmission Service Request (TSR). Any Required System Upgrades due to thermal constraints would be identified in the relevant TSRs. Nevertheless, the thermal limit violations identified in this study are local to the generators connected to the White Pine 69kV substation and are likely to be a reasonable indication of some of the facilities that might need upgrading when power delivery service is requested.

Thermal overloading was analyzed for the expected 2004 summer peak system. The Study identified no thermal overloads in the system without any generation connected to the White Pine 69kV substation. The Study found a number of thermal overloads in the system with 40MW generation connected to the White Pine. Refer to Table 3.2 in section 3.3 (Thermal Overloading Analysis Results) for details of the identified thermal overloads.

Table 1.1 – Required Upgrades in the System with No Generation Connected to the White Pine 69kV Substation

Locations	Facilities	Who Pays
White Pine 69kV	New backup relay for breaker 839. Estimated Cost $30k	White Pine Refinery
Victoria 69kV	New carrier scheme for breaker 795, to obtain 8.0c far end clearing on 69kV line Mass – Victoria. Estimated Cost $200k	ATC
Mass 69kV	New carrier scheme, modify BF scheme & change 6550 to be two-cycle device To obtain 8.0c far end clearing on 69kV line Winona – Mass; and 15.5c close-in end fault backup clearing and 16.0c far end fault backup clearing. Estimated Cost $350k. New two-cycle breaker 6540. Estimated Cost $150k Sub-Total Cost Estimate $500k	ATC
Winona 69kV	New breaker failure relay, plus change three (3) breakers to be two-cycle device To obtain 15.5c close-in end fault backup clearing and 16.0c far end fault backup clearing. Estimated Cost $650k	ATC
Winona 138kV	Change three (3) breakers to be two-cycle device and revise breaker failure scheme To obtain 15.5c close-in end fault backup clearing and 16.0c far end fault backup clearing. Estimated Cost $700k	ATC

Total Estimated Cost to implement items listed in Table 1.1 is $2.08 million.

Table 1.2 – Required System Upgrades due to the 40MW Generation
And the Associated Cost Estimates
Based on the System with the Completed Upgrades as Listed in Table 1.1

Locations	With 40MW generation	
	Facilities	**Cost Estimates**
Victoria 69kV	Reset relay scheme for breaker 795, 6.0c far end clearing, 69kV line Mass – Victoria	$ 0.0
Mass 69kV	Reset carrier scheme for breaker 6540, 8.0c far end clearing, 69kV line Victoria – Mass Reset breaker failure scheme, 10.0c close-in end fault backup clearing, 10.0c far end fault backup clearing	$ 0.0
Winona 69kV	New carrier scheme for breaker 875, 8.0c far end clearing, 69kV line Mass – Winona Reset breaker failure scheme, 12.0c close-in end fault backup clearing, 12.0c far end fault backup clearing	$ 200,000
Winona 138kV	Reset breaker failure scheme, 12.0c close-in end fault backup clearing, 12.0c far end fault backup clearing	$ 0.0
Total Costs Estimate		$ 200,000

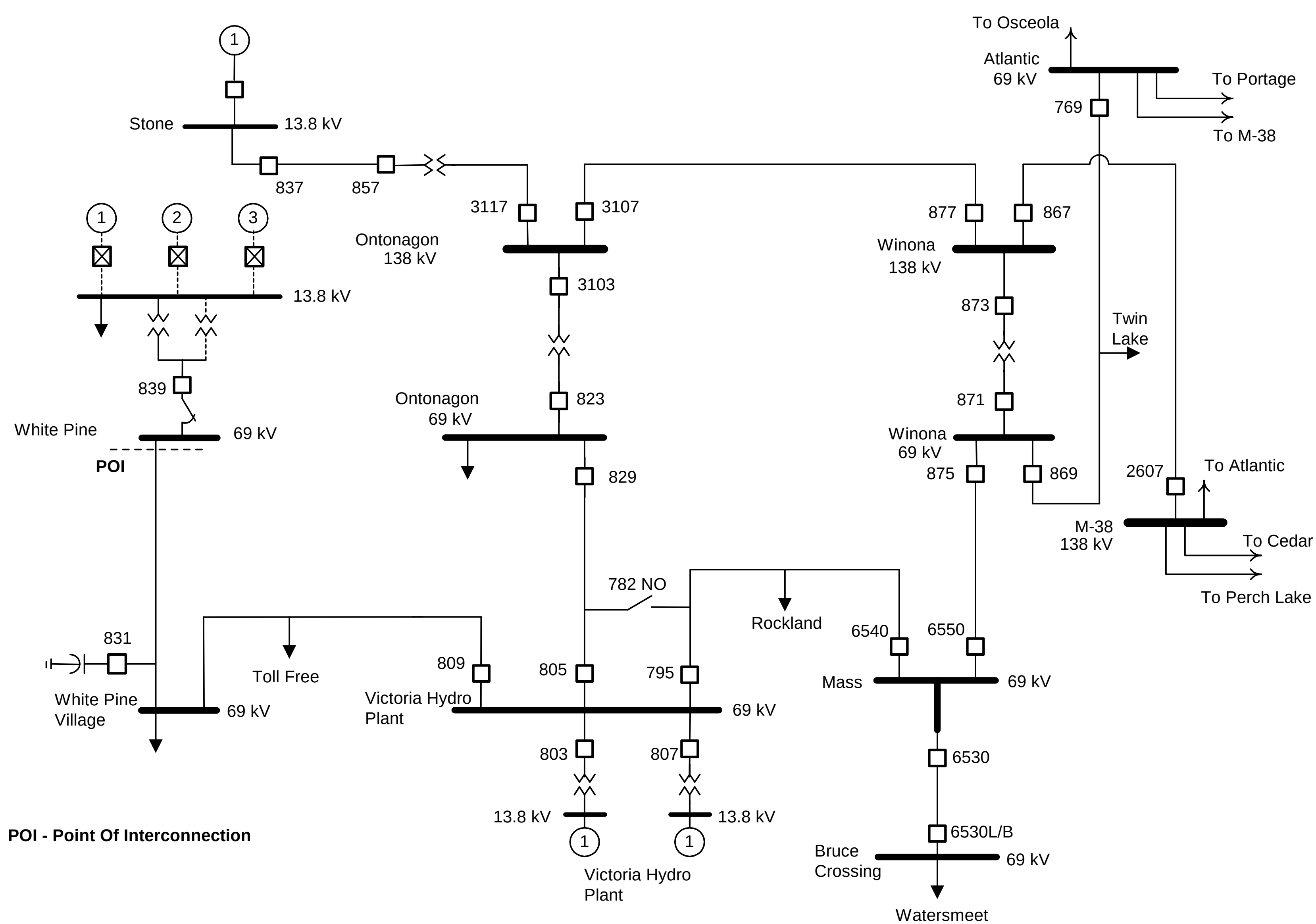

Figure 1.1 – One-Line Diagram of the Existing System with No Generation Connected to the White Pine 69kV Substation

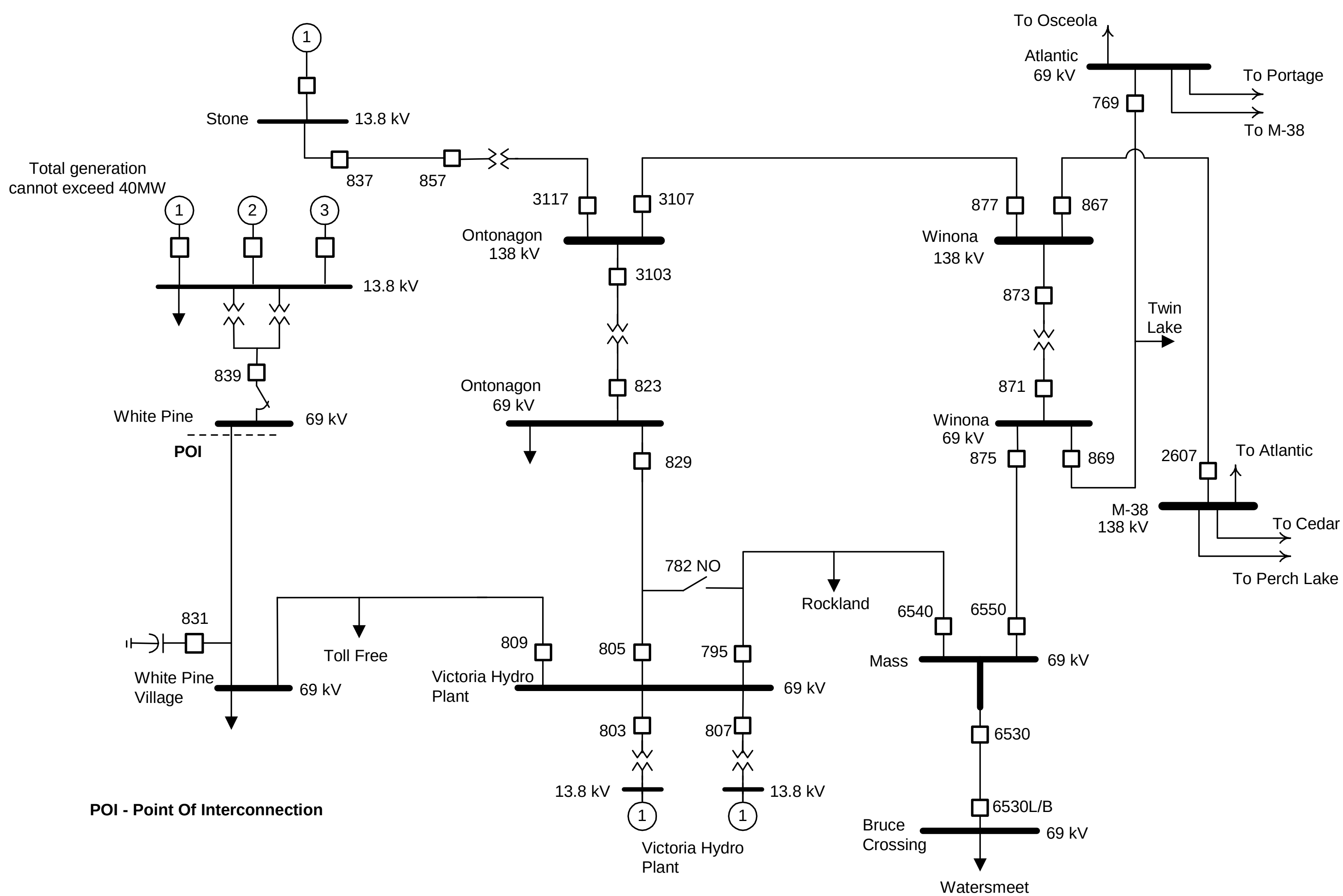

Figure 1.2 – One-Line Diagram of the System with 40MW Generation Connected to the White Pine 69kV Substation

1. Introduction and Project Description

This report contains the System Impact and Facility Evaluation Study regarding the 40MW steam-turbine generation in Ontonagon County, Michigan. The purpose of this Study is to evaluate the system impact due to the 40MW steam-turbine generation. This Study also investigates whether specific system upgrades will address all the identified system impacts. Cost estimates of the required system upgrades are also provided in this report.

The subjects of investigation are three existing steam-turbine generators, each rated at 20MW/22.2MVA. The 40MW generation investigated in this Study can be produced from either two or three existing generators.

The three existing generators are connected to the White Pine 69kV substation through two existing 13.8/69 kV transformers, one of which is currently out of service due to equipment failure. Both transformers have a maximum normal rating of 22.4MVA. The three generators are not in service during normal operation. Refer to Figure 1.1 for a one-line diagram of the generation facilities and the transmission system facilities in the vicinity. In this Study, it is assumed that the second transformer will be placed back in service upon connection of more than 20MW generation to the transmission system at the White Pine 69kV substation. Refer to Figure 1.2 for the one-line diagram of the system with 40MW generation connected to the White Pine 69kV substation.

This study is to identify whether any stability, short circuit, or thermal limits may be violated on the ATC transmission system by the 40MW generation. If any stability, short circuit, or thermal problems are found, then possible solutions that might address these problems are suggested, and the cost estimates for the proposed system upgrades are provided.

The study results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the Generator data and/or ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this study may be subject to re-evaluation. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to ATC prior to commercial operation.

2. Criteria and Methodology

2.1 Study Criteria

All relevant MISO-adopted NERC Reliability Criteria and the ATC contingency criteria are to be met for both the stability analysis and the thermal overloading analysis. Details of the stability and steady-state analysis criteria applied in this study can be found in Appendix D.

2.2 Study Methodology

2.2.1 Before and After Comparison

To identify what impacts should be attributed to the 40MW generation, two system conditions were examined - “Before” and “After” the 40MW generation interconnection. Any additional problems identified in the “After” state as compared to the “Before” state are to be attributed to the 40 MW generation.

2.2.2 Base Case Development

The 2004 Summer Peak base case from the Multi-Regional Modeling Working Group (MMWG) 2002 series was used as the starting point for the development of the base cases used in the power flow analysis and stability analysis.

The thermal overloading analysis was performed using the full 100% peak load base case because this should yield the most conservative results.

The stability analysis used a light load condition (70% of 2004 summer peak load in the Upper Michigan area and 50% of 2004 summer peak load in the rest of the system). It is assumed that the 40MW generation was from two units generating at their full capacity. It is also assumed that a number of the power plants local to the White Pine 69kV substation are fully generating. These assumptions result in a worse case representation for the stability analysis. The conservative conclusions based on this representation aim at protecting the system in all seasons.

In the base cases for both the power flow and stability analysis, the generation connected to the White Pine 69kV substation was assumed to be exported outside the Upper Michigan area to the rest of the ATC system.

3. Analysis Results

3.1 Stability Analysis Results

The stability analysis was performed using the Dynamics Simulation and Power Flow modules of the Power System Simulation/Engineering-28 (PSS/E, Version 28) program from Power Technologies, Inc (PTI). This program is accepted industry-wide for dynamic stability analysis.

Two base scenarios were evaluated in the stability analysis, as illustrated in Table 3.1.

Table 3.1 – Two base scenarios evaluated in the stability analysis

Base scenario #1	With no generation connected to the White Pine 69kV substation
Base scenario #2	With 40MW generation connected to the White Pine 69kV substation

For each studied base scenario, a number of contingencies were evaluated, which can be categorized into three classes – primary faults, prior outage faults and breaker failure faults. For each studied contingency, system stability performance was evaluated in four aspects – transient stability, dynamic damping, transient and dynamic voltage recovery and post-contingency voltage. Details of the stability analysis results are included in Tables A.1 through A.4 in the Appendix A.

With no generation connected to the White Pine 69kV substation

Stability analysis identified a number of primary and breaker failure contingencies that caused unacceptable system stability performance in the system with no generation connected to the White Pine 69kV substation, details of which are documented in Table A.1 in the Appendix A.

Stability analysis also identified breakers/relays upgrades that could eliminate all the identified unacceptable stability impacts. Detailed results are documented in Table A.2 in the Appendix A.

In summary, carrier relay schemes (which enable faster far end clearing) and/or breaker failure relay schemes (which enable faster breaker failure backup clearing) are required at Victoria 69kV, Mass 69kV, Winona 69kV and Winona 138kV substations. These upgrades are listed in Table 1.1 in the Executive Summary section.

With 40MW generation connected to the White Pine 69kV substation

Stability analysis identified a number of primary, breaker failure and prior outage faults that caused unacceptable system stability performance due to the 40MW generation connected to the White Pine 69kV substation. Refer to Table A.3 in the Appendix A for details.

Stability analysis also identified breakers/relays upgrades that could eliminate all identified unacceptable stability impacts in the system with the 40MW generation, except those involving loss of the 69kV line White Pine - Victoria. Refer to Table A.4 in the Appendix A for details.

Stability analysis found that all those studied primary, breaker failure and prior outage contingencies involving the loss of the 69kV line White Pine – Victoria pose unacceptable stability impact on the generators connected to the White Pine 69kV substation, due to the radial interconnection of the generators. However, the analysis also found that with the identified breakers/relays upgrades, the unacceptable stability impact caused by the loss of the 69kV line White Pine – Victoria does not extend to any other generators in the rest of the system for any studied contingency. Therefore, the identified upgrades are deemed satisfactory for bringing on line the 40MW generation. The upgraded system condition is determined to be in compliance with the NERC Planning Standards. The generators connected to the White Pine 69kV substation should be equipped with adequate relays to trip off the generators once they go out of synchronism, in order to protect the generators and auxiliary equipment.

In summary, due to the 40MW generation, additional breakers/relays upgrades are required at Victoria 69kV, Mass 69kV, Winona 69kV and Winona 138kV substations, in addition to the upgrades required for the existing system. These upgrades are summarized in Table 1.2 in the Executive Summary section.

3.2 Short-Circuit Analysis Results

The short circuit analysis was performed using the Computer Assisted Protection Engineering (CAPE) program (Build Date May 6, 2002). This program is accepted industry-wide for short circuit analysis.

The purpose of the short-circuit analysis was to identify circuit breakers that likely need to be replaced due to inadequate fault interrupting capabilities caused by the 40MW generation.

Short-circuit analysis found no unacceptable short-circuit system impact due to the 40MW generation. The calculated maximum short-circuit current for any evaluated breaker is less than 6000Amp, which is much smaller than the interrupting capability of any evaluated breaker in the region local to the White Pine 69kV substation.

The Study concluded that no system upgrades are required in the context of short-circuit analysis.

3.3 Thermal Overloading Analysis Results

The purpose of the thermal overloading analysis was to identify the impact of the 40MW generation on branch thermal loadings. PTI MUST AC Transfer Analysis module was used for the thermal analysis. PTI MUST program is accepted industry-wide for this type of analysis.

The Study found no thermal overloads in the system without any generation connected to the White Pine 69kV substation. The Study found a number of thermal overloads in the system with the 40MW generation. These thermal overloads are summarized in Tables 3.2 in the following.

Table 3.2 - Thermal overloads due to the 40MW generation connected to the White Pine 69kV substation

Overloaded Element	**Emergency/Normal Rating, MVA**	**Worst Cont. MVA flow, "After"[1]**	**Worst Cont. Loading (%), "After"[1]**	**Loading (%), "Before"[1]**	**Worst Contingency**
Ontonagon 69 kV – Victoria 69 kV	25.0	48.7	194.7	30.4	Victoria 69 kV – Mass 69 kV
Ontonagon 69 kV – Ontonagon 138 kV	25.0	41.0	164.0	16.4	Victoria 69 kV – Mass 69 kV
Victoria 69 kV – Mass 69 kV	25.0	31.9	127.6	28.2	*Normal condition*
Victoria 69 kV – Mass 69 kV	25.0	45.2	181.0	27.0	Ontonagon 69 kV – Victoria 69 kV
Victoria 69 kV – White Pine Village 69 kV	29.0	39.0	134.5	13.0	***Normal condition***
White Pine 69 kV – White Pine Village 69 kV	36.0	40.0	111.1	8.3	***Normal condition***
Winona 69 kV – Mass 69 kV	25.0	26.4	105.6	20.0	Ontonagon 69 kV – Victoria 69 kV

[1] **"After"** – with the 40MW generation
"Before" – with no generation

Appendix A

Stability Analysis Results

Table A.1 – Stability Impacts for the Expected System in 2004
With No Generation Connected to the White Pine 69kV Substation
(Unacceptable stability performance is colored in red)

ID	3-Phase Fault	Breaker #, Clearing Time	Conditions	Transient Performance
				W/ 0 units 0 MW export
Primary Faults				
F.1	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 809 – 23 c		Island formed; The rest of system is **Good**
F.2	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c		Island formed; The rest of system is **Good**
F.3	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c		**Good**
F.4	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 805 – 8.0 c		**Good**
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c		**Good**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 795 – 23 c		**VIC 1&2 tripped; Transient voltage recovery unacceptable at WPV69, VIC69**

F.7	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 877 – 5.0 c		**Good**
F.8	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3107 – 5.0 c		**Good**
F.9	At Mass end on Mass – Iron River 69kV	MSS 6530 – 6.5 c IRR 6510 – 27 c		**Good**
F.10	At Iron River end on Iron River – Mass 69kV	IRR 6510 – 4.5 c MSS 6530 – 29 c		**Good**
F.11	At Winona end on Winona – Atlantic 69kV	WNA 869 – 4.5 c ATL 769 – 26 c		**Good**
F.12	At Atlantic end on Atlantic – Winona 69kV	ATL 769 – 9.5 c WNA 869 – 3.0 c		**Good**
F.13	At High side of Ontonagon xfmr	ONN 3103 – 6.0 c ONN 823 – 6.0 c		**Good**
F.14	At Low side of Ontonagon xfmr	ONN 823 – 6.0 c ONN 3103 – 6.0 c		**Good**
F.15	At High side of Winona xfmr	WNA 873 – 6.0 c WNA 871 – 6.0 c		**Good**
F.16	At Low side of Winona xfmr	WNA 871 – 6.0 c WNA 873 – 6.0 c		**Good**
F.17	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 875 – 33 c		**Good**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6550 – 27 c		**Good**

Faults Involving Breaker Failure				
F.19	At Mass end on Mass – Winona 69kV	MSS 6540 – 20 c MSS 6530 – 22 c WNA 875 – 33 c	Breaker failure at Mass 6550	**VIC 1&2 tripped;** The rest of system is acceptable
F.20	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 871 – 91 c WNA 869 – 91 c	Breaker failure at Winona 875	**Good**
F.21	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6540 – 42.5 c MSS 6530 – 44.5 c	Breaker failure At Mass 6550	**Good**
F.22	At Winona end on Winona – Mass 69kV	MSS 6550 – 27 c WNA 871 – 62.5 c WNA 869 – 62.5 c	Breaker failure At Winona 875	**VIC 1&2 tripped;** The rest of system is acceptable
F.23	At Victoria end on Victoria – White Pine 69kV	VIC 795 – 19.5 c VIC 805 – 19.5 c WPM 839 – 26 c	Breaker failure At Victoria 809	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.24	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 795 – 36 c VIC 805 – 36 c	Breaker failure at Victoria 809	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.25	At Ontonagon end on Ontonagon – Victoria 69kV	VIC 805 – 8 c ONN 823 – 86 c	Breaker failure at Ontonagon 829	**Good**

F.26	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 809 – 20.5 c VIC 795 – 20.5 c	Breaker failure at Victoria 805	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.27	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 823 – 177 c	Breaker failure at Ontonagon 829	**Good**
F.28	At Victoria end on Victoria – Ontonagon 69kV	VIC 795 – 19.5 c VIC 809 – 19.5 c ONN 829 – 27 c	Breaker failure at Victoria 805	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.29	At Mass end on Mass – Victoria 69kV	MSS 6550 – 20 c MSS 6530 – 22 c VIC 795 – 23 c	Breaker failure at Mass 6540	**VIC 1&2 tripped; Transient voltage recovery unacceptable at WPV69, WPM69, VIC69, ONN69**
F.30	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 805 – 36 c VIC 809 – 36 c	Breaker failure at Victoria 795	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.31	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6550 – 42.5 c MSS 6530 – 44.5 c	Breaker failure at Mass 6540	**Good**
F.32	At Victoria end on Victoria – Mass 69kV	VIC 805 – 19.5 c VIC 809 – 19.5 c MSS 6540 – 27 c	Breaker failure at Victoria 795	Island formed; VIC 1&2 tripped; The rest of system is **Good**

F.33	At Ontonagon end on Ontonagon – Winona 138kV	WNA 877 – 5.0 c ONN 3117 – 62.5 c ONN 3103 – 62.5 c	Breaker failure at Ontonagon 3107	**Good**
F.34	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 867 – 63 c WNA 873 – 63 c	Breaker failure at Winona 877	**Good**
F.35	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3117 – 63 c ONN 3103 – 63 c	Breaker failure at Ontonagon 3107	**Good**
F.36	At Winona end on Winona – Ontonagon 138kV	ONN 3107 – 5.0 c WNA 867 – 62.5 c WNA 873 – 62.5 c	Breaker failure at Winona 877	**VIC 1&2, Warden 1, Portage 1 tripped; Transient voltage recovery unacceptable at many buses**
F.37	At Mass end on Mass – Iron River 69 kV	MSS 6550 – 20 c MSS 6540 – 20 c IRR 6510 – 27 c	Breaker failure at Mass 6530	**VIC 2 tripped; Transient voltage recovery unacceptable at WPV69, WPM69, VIC69, ONN69**
F.38	At Mass end on Mass – Iron River 69 kV	MSS 6530 – 4.5 c IRR 6330 – 42.5 c IRR 6220 – 42.5 c IRR 6230 – 42.5 c	Breaker failure at Iron River 6510	**Good**
F.39	At Iron River end on Iron River – Mass 69 kV	IRR 6510 – 4.5 c MSS 6550 – 42.5 c MSS 6540 – 42.5 c	Breaker failure at Mass 6530	**Good**

F.40	At Iron River end on Iron River – Mass 69 kV	IRR 6330 – 20 c IRR 6220 – 20 c IRR 6230 – 20 c MSS 6530 – 27 c	Breaker failure at Iron River 6510	**Good**
F.41	At Winona end on Winona – Atlantic 69kV	ATL 769 – 26 c WNA 875 – 62.5 c WNA 871 – 62.5 c	Breaker failure at Winona 869	**VIC 1&2 tripped;** The rest of system is acceptable
F.42	At Atlantic end on Winona – Atlantic 69kV	ATL 769 – 9.5 c WNA 875 – 91 c WNA 871 – 91 c	Breaker failure at Winona 869	**Good**
F.43	At High side of Ontonagon xfmr	ONN 823 – 6.0 c WNA 877 – 14 c ONN 3117 – 147 c	Breaker failure at Ontonagon 3103	**Good**
F.44	At Low side of Ontonagon xfmr	ONN 3103 – 6.0 c VIC 805 – 23 c	Breaker failure at Ontonagon 823	**Good**
F.45	At High side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 11 c M38 2607 – 48 c	Breaker failure at Winona 873	**Good**
F.46	At High side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 20 c MSS 6550 – 63 c	Breaker failure at Winona 871	**Good**
F.47	At Low side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 16 c M38 2607 – 30 c	Breaker failure at Winona 873	**Good**
F.48	At Low side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 26 c MSS 6550 – 27 c	Breaker failure at Winona 871	**Good**

Faults Involving Prior Outage				
F.49	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Ontonagon 69kV	Island formed; The rest of system is **Good**
F.50	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Mass 69kV	Island formed; The rest of system is **Good**
F.51	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Victoria – Ontonagon 69kV	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.52	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Ontonagon – Winona 138kV	Island formed; Units in the island tripped; The rest of system is **Good**
F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Winona 138/69 kV xfmr	**Good**
F.54	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Victoria – Mass 69kV	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.55	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Ontonagon – Winona 138kV	**Good**
F.56	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Winona 138/69 kV xfmr	**Good**

Table A.2 – Stability Impacts for the Expected System in 2004

Including Upgrades for the System with No Generation Connected to the White Pine 69kV Substation (Proposed system upgrades are colored in green)

ID	3-Phase Fault	Breaker #, Clearing Time	Conditions	Transient Performance
				w/ 0 units 0 MW export
Primary Faults				
F.1	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 809 – 23 c		Island formed; The rest of system is **Good**
F.2	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c		Island formed; The rest of system is **Good**
F.3	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c		**Good**
F.4	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 805 – 8.0 c		**Good**
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c		**Good**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c **VIC 795 – 8.0 c**		**Good**

F.7	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 877 – 5.0 c		**Good**
F.8	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3107 – 5.0 c		**Good**
F.9	At Mass end on Mass – Iron River 69kV	MSS 6530 – 6.5 c IRR 6510 – 27 c		**Good**
F.10	At Iron River end on Iron River – Mass 69kV	IRR 6510 – 4.5 c MSS 6530 – 29 c		**Good**
F.11	At Winona end on Winona – Atlantic 69kV	WNA 869 – 4.5 c ATL 769 – 26 c		**Good**
F.12	At Atlantic end on Atlantic – Winona 69kV	ATL 769 – 9.5 c WNA 869 – 3.0 c		**Good**
F.13	At High side of Ontonagon xfmr	ONN 3103 – 6.0 c ONN 823 – 6.0 c		**Good**
F.14	At Low side of Ontonagon xfmr	ONN 823 – 6.0 c ONN 3103 – 6.0 c		**Good**
F.15	At High side of Winona xfmr	WNA 873 – 6.0 c WNA 871 – 6.0 c		**Good**
F.16	At Low side of Winona xfmr	WNA 871 – 6.0 c WNA 873 – 6.0 c		**Good**
F.17	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 875 – 33 c		**Good**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6550 – 27 c		**Good**

Faults Involving Breaker Failure				
F.19	At Mass end on Mass – Winona 69kV	**MSS 6540 – 15.5 c** **MSS 6530 – 15.5c** WNA 875 – 33 c	Breaker failure at Mass 6550	**Good**
F.20	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 871 – 91 c WNA 869 – 91 c	Breaker failure at Winona 875	**Good**
F.21	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c **MSS 6540 – 16 c** **MSS 6530 – 16 c**	Breaker failure at Mass 6550	**Good**
F.22	At Winona end on Winona – Mass 69kV	**MSS 6550 – 8.0 c** **WNA 871 – 15.5 c** **WNA 869 – 15.5 c**	Breaker failure at Winona 875	**Good**
F.23	At Victoria end on Victoria – White Pine 69kV	VIC 795 – 19.5 c VIC 805 – 19.5 c WPM 839 – 26 c	Breaker failure at Victoria 809	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.24	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 795 – 36 c VIC 805 – 36 c	Breaker failure at Victoria 809	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.25	At Ontonagon end on Ontonagon – Victoria 69kV	VIC 805 – 8 c ONN 823 – 86 c	Breaker failure at Ontonagon 829	**Good**

F.26	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 809 – 20.5 c VIC 795 – 20.5 c	Breaker failure at Victoria 805	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.27	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 823 – 177 c	Breaker failure at Ontonagon 829	**Good**
F.28	At Victoria end on Victoria – Ontonagon 69kV	VIC 795 – 19.5 c VIC 809 – 19.5 c ONN 829 – 27 c	Breaker failure at Victoria 805	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.29	At Mass end on Mass – Victoria 69kV	**MSS 6550 – 15.5 c** **MSS 6530 – 15.5 c** **VIC 795 – 8.0 c**	Breaker failure at Mass 6540	**Good**
F.30	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 805 – 36 c VIC 809 – 36 c	Breaker failure at Victoria 795	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.31	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6550 – 42.5 c MSS 6530 – 44.5 c	Breaker failure at Mass 6540	**Good**
F.32	At Victoria end on Victoria – Mass 69kV	VIC 805 – 19.5 c VIC 809 – 19.5 c MSS 6540 – 27 c	Breaker failure at Victoria 795	Island formed; VIC 1&2 tripped; The rest of system is **Good**

F.33	At Ontonagon end on Ontonagon – Winona 138kV	WNA 877 – 5.0 c ONN 3117 – 62.5 c ONN 3103 – 62.5 c	Breaker failure at Ontonagon 3107	**Good**
F.34	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 867 – 63 c WNA 873 – 63 c	Breaker failure at Winona 877	**Good**
F.35	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3117 – 63 c ONN 3103 – 63 c	Breaker failure at Ontonagon 3107	**Good**
F.36	At Winona end on Winona – Ontonagon 138kV	ONN 3107 – 5.0 c **WNA 867 – 15.5 c** **WNA 873 – 15.5 c**	Breaker failure at Winona 877	**Good**
F.37	At Mass end on Mass – Iron River 69 kV	**MSS 6550 – 15.5 c** **MSS 6540 – 15.5 c** IRR 6510 – 27 c	Breaker failure at Mass 6530	**Good**
F.38	At Mass end on Mass – Iron River 69 kV	MSS 6530 – 4.5 c IRR 6330 – 42.5 c IRR 6220 – 42.5 c IRR 6230 – 42.5 c	Breaker failure at Iron River 6510	**Good**
F.39	At Iron River end on Iron River – Mass 69 kV	IRR 6510 – 4.5 c MSS 6550 – 42.5 c MSS 6540 – 42.5 c	Breaker failure at Mass 6530	**Good**

F.40	At Iron River end on Iron River – Mass 69 kV	IRR 6330 – 20 c IRR 6220 – 20 c IRR 6230 – 20 c MSS 6530 – 27 c	Breaker failure at Iron River 6510	**Good**
F.41	At Winona end on Winona – Atlantic 69kV	ATL 769 – 26 c **WNA 875 – 15.5 c** **WNA 871 – 15.5 c**	Breaker failure at Winona 869	**Good**
F.42	At Atlantic end on Winona – Atlantic 69kV	ATL 769 – 9.5 c WNA 875 – 91 c WNA 871 – 91 c	Breaker failure at Winona 869	**Good**
F.43	At High side of Ontonagon xfmr	ONN 823 – 6.0 c WNA 877 – 14 c ONN 3117 – 147 c	Breaker failure at Ontonagon 3103	**Good**
F.44	At Low side of Ontonagon xfmr	ONN 3103 – 6.0 c VIC 805 – 23 c	Breaker failure at Ontonagon 823	**Good**
F.45	At High side of Winona xfmr	WNA 871 – 6.0 c **WNA 877 – 15.5 c** **WNA 867 – 15.5 c**	Breaker failure at Winona 873	**Good**
F.46	At High side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 20 c MSS 6550 – 63 c	Breaker failure at Winona 871	**Good**
F.47	At Low side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 16 c M38 2607 – 30 c	Breaker failure at Winona 873	**Good**
F.48	At Low side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 26 c MSS 6550 – 27 c	Breaker failure at Winona 871	**Good**

Faults Involving Prior Outage				
F.49	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Ontonagon 69kV	Island formed; The rest of system is **Good**
F.50	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Mass 69kV	Island formed; The rest of system is **Good**
F.51	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Victoria – Ontonagon 69kV	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.52	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Ontonagon – Winona 138kV	Island formed; Units in the island tripped; The rest of system is **Good**
F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Winona 138/69 kV xfmr	**Good**
F.54	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Victoria – Mass 69kV	Island formed; VIC 1&2 tripped; The rest of system is **Good**
F.55	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Ontonagon – Winona 138kV	**Good**
F.56	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Winona 138/69 kV xfmr	**Good**

Table A.3 – Stability Impacts for the Expected System in 2004

With 40MW Generation Connected to the White Pine 69kV Substation, With No System Upgrades (Unacceptable stability performance is colored in red)

ID	3-Phase Fault	Breaker #, Clearing Time	Conditions	Transient Performance
				W/ 2 units 40 MW net export
Primary Faults				
F.1	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 809 – 23 c		Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.2	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c		Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.3	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c		**Good**
F.4	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 805 – 8.0 c		**Good**
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c		**Unacceptable transient voltage recovery at VIC69, WPM69, ONN69, ONN138**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 795 – 23 c		**Unacceptable transient voltage recovery at VIC69, WPM69, ONN69**
F.7	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 877 – 5.0 c		**Good**
F.8	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3107 – 5.0 c		**Good**
F.9	At Mass end on Mass – Iron River 69kV	MSS 6530 – 6.5 c IRR 6510 – 27 c		**Good**
F.10	At Iron River end on Iron River – Mass 69kV	IRR 6510 – 4.5 c MSS 6530 – 29 c		**Good**

F.11	At Winona end on Winona – Atlantic 69kV	WNA 869 – 4.5 c ATL 769 – 26 c		**Good**
F.12	At Atlantic end on Atlantic – Winona 69kV	ATL 769 – 9.5 c WNA 869 – 33.0 c		**Good**
F.13	At High side of Ontonagon xfmr	ONN 3103 – 6.0 c ONN 823 – 6.0 c		**Good**
F.14	At Low side of Ontonagon xfmr	ONN 823 – 6.0 c ONN 3103 – 6.0 c		**Good**
F.15	At High side of Winona xfmr	WNA 873 – 6.0 c WNA 871 – 6.0 c		**Good**
F.16	At Low side of Winona xfmr	WNA 871 – 6.0 c WNA 873 – 6.0 c		**Good**
F.17	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 875 – 33 c		**Good**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6550 – 27 c		**Unacceptable transient voltage recovery at VIC69, ONN69, MSS69**
Faults Involving Breaker Failure				
F.19	At Mass end on Mass – Winona 69kV	MSS 6540 – 20 c MSS 6530 – 22 c WNA 875 – 33 c	Breaker failure at Mass 6550	**Unacceptable transient voltage recovery at VIC69, WPM69, ONN69, ONN138**
F.20	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 871 – 91 c WNA 869 – 91 c	Breaker failure at Winona 875	**Good**
F.21	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c MSS 6540 – 42.5 c MSS 6530 – 44.5 c	Breaker failure At Mass 6550	**WPM 1 & 2, VIC 1 & 2 tripped; Unacceptable transient voltage recovery at VIC69, WPM69, ONN69, ONN138**
F.22	At Winona end on Winona – Mass 69kV	MSS 6550 – 27 c WNA 871 – 62.5 c WNA 869 – 62.5 c	Breaker failure At Winona 875	**WPM 1 & 2, VIC 1 & 2 tripped;** rest of system is **Good**

F.23	At Victoria end on Victoria – White Pine 69kV	VIC 795 – 19.5 c VIC 805 – 19.5 c WPM 839 – 26 c	Breaker failure At Victoria 809	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**

F.24	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 795 – 36 c VIC 805 – 36 c	Breaker failure at Victoria 809	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.25	At Ontonagon end on Ontonagon – Victoria 69kV	VIC 805 – 8 c ONN 823 – 86 c	Breaker failure at Ontonagon 829	**Good**
F.26	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 809 – 20.5 c VIC 795 – 20.5 c	Breaker failure at Victoria 805	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.27	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 823 – 177 c	Breaker failure at Ontonagon 829	**Good**
F.28	At Victoria end on Victoria – Ontonagon 69kV	VIC 795 – 19.5 c VIC 809 – 19.5 c ONN 829 – 27 c	Breaker failure at Victoria 805	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.29	At Mass end on Mass – Victoria 69kV	MSS 6550 – 20 c MSS 6530 – 22 c VIC 795 – 23 c	Breaker failure at Mass 6540	**WPM 1 & 2, VIC 1 & 2 tripped; Unacceptable transient voltage recovery at VIC69, WPM69, ONN69**
F.30	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 805 – 36 c VIC 809 – 36 c	Breaker failure at Victoria 795	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.31	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6550 – 42.5 c MSS 6530 – 44.5 c	Breaker failure at Mass 6540	**WPM 1 & 2, VIC 1 & 2 tripped**; rest of system is **Good**
F.32	At Victoria end on Victoria – Mass 69kV	VIC 805 – 19.5 c VIC 809 – 19.5 c MSS 6540 – 27 c	Breaker failure at Victoria 795	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.33	At Ontonagon end on Ontonagon – Winona 138kV	WNA 877 – 5.0 c ONN 3117 – 62.5 c ONN 3103 – 62.5 c	Breaker failure at Ontonagon 3107	**Good**
F.34	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 867 – 63 c WNA 873 – 63 c	Breaker failure at Winona 877	**WPM 1 & 2, VIC 1 & 2 tripped**; rest of system is **Good**
F.35	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3117 – 63 c ONN 3103 – 63 c	Breaker failure at Ontonagon 3107	**Good**

F.36	At Winona end on Winona – Ontonagon 138kV	ONN 3107 – 5.0 c WNA 867 – 62.5 c WNA 873 – 62.5 c	Breaker failure at Winona 877	**Warden, WPM 1 & 2, VIC 1 & 2 tripped**; rest of system is **Good**
F.37	At Mass end on Mass – Iron River 69 kV	MSS 6550 – 20 c MSS 6540 – 20 c IRR 6510 – 27 c	Breaker failure at Mass 6530	**WPM 1 & 2, VIC 1 & 2 tripped**; rest of system is **Good**
F.38	At Mass end on Mass – Iron River 69 kV	MSS 6530 – 4.5 c IRR 6330 – 42.5 c IRR 6220 – 42.5 c IRR 6230 – 42.5 c	Breaker failure at Iron River 6510	**Good**
F.39	At Iron River end on Iron River – Mass 69 kV	IRR 6510 – 4.5 c MSS 6550 – 42.5 c MSS 6540 – 42.5 c	Breaker failure at Mass 6530	**Good**
F.40	At Iron River end on Iron River – Mass 69 kV	IRR 6330 – 20 c IRR 6220 – 20 c IRR 6230 – 20 c MSS 6530 – 27 c	Breaker failure at Iron River 6510	**Good**
F.41	At Winona end on Winona – Atlantic 69kV	ATL 769 – 26 c WNA 875 – 62.5 c WNA 871 – 62.5 c	Breaker failure at Winona 869	**WPM 1 & 2, VIC 1 & 2 tripped; Transient voltage recovery unacceptable at all monitored buses**
F.42	At Atlantic end on Winona – Atlantic 69kV	ATL 769 – 9.5 c WNA 875 – 91 c WNA 871 – 91 c	Breaker failure at Winona 869	**Good**
F.43	At High side of Ontonagon xfmr	ONN 823 – 6.0 c WNA 877 – 14 c ONN 3117 – 147 c	Breaker failure at Ontonagon 3103	**Good**
F.44	At Low side of Ontonagon xfmr	ONN 3103 – 6.0 c VIC 805 – 23 c	Breaker failure at Ontonagon 823	**Good**
F.45	At High side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 11 c M38 2607 – 48 c	Breaker failure at Winona 873	**WPM 1 & 2, VIC 1 & 2 tripped; Transient voltage recovery unacceptable at all monitored buses**
F.46	At High side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 20 c MSS 6550 – 63 c	Breaker failure at Winona 871	**WPM 1 & 2, VIC 1 & 2 tripped**; rest of system is **Good**

F.47	At Low side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 16 c M38 2607 – 30 c	Breaker failure at Winona 873	**Good**
F.48	At Low side of Winona xfmr	WNA 873 – 6.0 c ATL 769 – 26 c MSS 6550 – 27 c	Breaker failure at Winona 871	**WPM 1 & 2, VIC 1 & 2 tripped; Transient voltage recovery unacceptable at VIC69, WPM69, MSS69, ONN69, ONN138**
Faults Involving Prior Outage				
F.49	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Ontonagon 69kV	Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.50	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Mass 69kV	Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.51	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Victoria – Ontonagon 69kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.52	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Ontonagon – Winona 138kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Winona 138/69 kV xfmr	**Transient voltage recovery unacceptable at VIC69, ONN69**
F.54	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Victoria – Mass 69kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.55	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Ontonagon – Winona 138kV	**Good**
F.56	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Winona 138/69 kV xfmr	**Good**

Table A.4 – Stability Impacts for the Expected System in 2004
With 40MW Generation Connected to the White Pine 69kV Substation and with Upgrades
(Proposed system upgrades are colored in green)

ID	3-Phase Fault	Breaker #, Clearing Time	Conditions	Transient Performance
				W/ 2 units 40 MW net export
Primary Faults				
F.1	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 809 – 23 c		Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.2	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c		Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.3	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c		**Good**
F.4	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 805 – 8.0 c		**Good**
F.5	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c **MSS 6540 – 8.0 c**		**Good**
F.6	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c **VIC 795 – 6.0 c**		**Good**
F.7	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c WNA 877 – 5.0 c		**Good**
F.8	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3107 – 5.0 c		**Good**
F.9	At Mass end on Mass – Iron River 69kV	MSS 6530 – 6.5 c IRR 6510 – 27 c		**Good**
F.10	At Iron River end on Iron River – Mass 69kV	IRR 6510 – 4.5 c MSS 6530 – 29 c		**Good**

F.11	At Winona end on Winona – Atlantic 69kV	WNA 869 – 4.5 c ATL 769 – 26 c		**Good**
F.12	At Atlantic end on Atlantic – Winona 69kV	ATL 769 – 9.5 c WNA 869 – 33.0 c		**Good**
F.13	At High side of Ontonagon xfmr	ONN 3103 – 6.0 c ONN 823 – 6.0 c		**Good**
F.14	At Low side of Ontonagon xfmr	ONN 823 – 6.0 c ONN 3103 – 6.0 c		**Good**
F.15	At High side of Winona xfmr	WNA 873 – 6.0 c WNA 871 – 6.0 c		**Good**
F.16	At Low side of Winona xfmr	WNA 871 – 6.0 c WNA 873 – 6.0 c		**Good**
F.17	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 875 – 33 c		**Good**
F.18	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c **MSS 6550 – 8.0 c**		**Good**
Faults Involving Breaker Failure				
F.19	At Mass end on Mass – Winona 69kV	**MSS 6540 – 12 c** **MSS 6530 – 12 c** **WNA 875 – 8.0 c**	Breaker failure at Mass 6550	**Good**
F.20	At Mass end on Mass – Winona 69kV	MSS 6550 – 4.5 c WNA 871 – 91 c WNA 869 – 91 c	Breaker failure at Winona 875	**Good**
F.21	At Winona end on Winona – Mass 69kV	WNA 875 – 4.5 c **MSS 6540 – 12 c** **MSS 6530 – 12 c**	Breaker failure At Mass 6550	**Good**
F.22	At Winona end on Winona – Mass 69kV	**MSS 6550 – 8.0 c** **WNA 871 – 12 c** **WNA 869 – 12 c**	Breaker failure At Winona 875	**Good**

F.23	At Victoria end on Victoria – White Pine 69kV	VIC 795 – 19.5 c VIC 805 – 19.5 c WPM 839 – 26 c	Breaker failure At Victoria 809	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**

F.24	At White Pine end on White Pine – Victoria 69kV	WPM 839 – 26 c VIC 795 – 36 c VIC 805 – 36 c	Breaker failure at Victoria 809	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.25	At Ontonagon end on Ontonagon – Victoria 69kV	VIC 805 – 8 c ONN 823 – 86 c	Breaker failure at Ontonagon 829	**Good**
F.26	At Ontonagon end on Ontonagon – Victoria 69kV	ONN 829 – 4.5 c VIC 809 – 20.5 c VIC 795 – 20.5 c	Breaker failure at Victoria 805	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.27	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 823 – 177 c	Breaker failure at Ontonagon 829	**Good**
F.28	At Victoria end on Victoria – Ontonagon 69kV	VIC 795 – 19.5 c VIC 809 – 19.5 c ONN 829 – 27 c	Breaker failure at Victoria 805	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.29	At Mass end on Mass – Victoria 69kV	**MSS 6550 – 12 c** **MSS 6530 – 12 c** **VIC 795 – 6.0 c**	Breaker failure at Mass 6540	**Good**
F.30	At Mass end on Mass – Victoria 69kV	MSS 6540 – 4.5 c VIC 805 – 36 c VIC 809 – 36 c	Breaker failure at Victoria 795	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.31	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c **MSS 6550 – 10 c** **MSS 6530 – 10 c**	Breaker failure at Mass 6540	**Good**
F.32	At Victoria end on Victoria – Mass 69kV	VIC 805 – 19.5 c VIC 809 – 19.5 c MSS 6540 – 27 c	Breaker failure at Victoria 795	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.33	At Ontonagon end on Ontonagon – Winona 138kV	WNA 877 – 5.0 c ONN 3117 – 62.5 c ONN 3103 – 62.5 c	Breaker failure at Ontonagon 3107	**Good**
F.34	At Ontonagon end on Ontonagon – Winona 138kV	ONN 3107 – 4.5 c **WNA 867 – 16 c** **WNA 873 – 16 c**	Breaker failure at Winona 877	**Good**

F.35	At Winona end on Winona – Ontonagon 138kV	WNA 877 – 4.5 c ONN 3117 – 63 c ONN 3103 – 63 c	Breaker failure at Ontonagon 3107	**Good**
F.36	At Winona end on Winona – Ontonagon 138kV	ONN 3107 – 5.0 c **WNA 867 – 12 c** **WNA 873 – 12 c**	Breaker failure at Winona 877	**Good**
F.37	At Mass end on Mass – Iron River 69 kV	**MSS 6550 – 10 c** **MSS 6540 – 10 c** IRR 6510 – 27 c	Breaker failure at Mass 6530	**Good**
F.38	At Mass end on Mass – Iron River 69 kV	MSS 6530 – 4.5 c IRR 6330 – 42.5 c IRR 6220 – 42.5 c IRR 6230 – 42.5 c	Breaker failure at Iron River 6510	**Good**
F.39	At Iron River end on Iron River – Mass 69 kV	IRR 6510 – 4.5 c MSS 6550 – 42.5 c MSS 6540 – 42.5 c	Breaker failure at Mass 6530	**Good**
F.40	At Iron River end on Iron River – Mass 69 kV	IRR 6330 – 20 c IRR 6220 – 20 c IRR 6230 – 20 c MSS 6530 – 27 c	Breaker failure at Iron River 6510	**Good**
F.41	At Winona end on Winona – Atlantic 69kV	ATL 769 – 26 c **WNA 875 – 12 c** **WNA 871 – 12 c**	Breaker failure at Winona 869	**Good**
F.42	At Atlantic end on Winona – Atlantic 69kV	ATL 769 – 9.5 c WNA 875 – 91 c WNA 871 – 91 c	Breaker failure at Winona 869	**Good**
F.43	At High side of Ontonagon xfmr	ONN 823 – 6.0 c WNA 877 – 14 c ONN 3117 – 147 c	Breaker failure at Ontonagon 3103	**Good**
F.44	At Low side of Ontonagon xfmr	ONN 3103 – 6.0 c VIC 805 – 23 c	Breaker failure at Ontonagon 823	**Good**
F.45	At High side of Winona xfmr	WNA 871 – 6.0 c **WNA 877 – 12 c** **WNA 867 – 12 c**	Breaker failure at Winona 873	**Good**

F.46	At High side of Winona xfmr	WNA 873 – 6.0 c **WNA 875 – 12 c** **WNA 869 – 12 c**	Breaker failure at Winona 871	**Good**
F.47	At Low side of Winona xfmr	WNA 871 – 6.0 c ONN 3107 – 16 c M38 2607 – 30 c	Breaker failure at Winona 873	**Good**
F.48	At Low side of Winona xfmr	WNA 873 – 6.0 c **WNA 875 – 12 c** **WNA 869 – 12 c**	Breaker failure at Winona 871	**Good**
Faults Involving Prior Outage				
F.49	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Ontonagon 69kV	Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.50	At Victoria end on Victoria – White Pine 69kV	VIC 809 – 6.5 c WPM 839 – 26 c	Prior outage Victoria – Mass 69kV	Island formed; WPM 1 & 2 tripped; rest of system is **Good**
F.51	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Victoria – Ontonagon 69kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.52	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c MSS 6540 – 27 c	Prior outage Ontonagon – Winona 138kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.53	At Victoria end on Victoria – Mass 69kV	VIC 795 – 6.5 c **MSS 6540 – 8.0 c**	Prior outage Winona 138/69 kV xfmr	**Good**
F.54	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Victoria – Mass 69kV	Island formed; WPM 1 & 2, VIC 1 & 2 tripped; rest of system is **Good**
F.55	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Ontonagon – Winona 138kV	**Good**
F.56	At Victoria end on Victoria – Ontonagon 69kV	VIC 805 – 6.5 c ONN 829 – 27 c	Prior outage Winona 138/69 kV xfmr	**Good**

Appendix B

Short Circuit Analysis

This page intentionally left blank.

Appendix C

Power Flow Analysis

This page intentionally left blank.

Appendix D

Study Criteria

D.1 Study Criteria

D.1.1 Contingencies

For stability analysis, a set of branches in the vicinity of the generator/power plant of concern is selected as contingencies, based on engineering judgment. Fault analysis is performed for the following three categories of contingency conditions:

1. Fault cleared in primary time with an otherwise intact system.
2. Fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system.
3. Fault cleared in primary clearing time with a pre-existing outage of any other transmission element.

For the thermal analysis, the contingencies include the normal (intact) system configuration, standard N-1 contingencies that ATC has determined to be significant.

D.1.2 Monitored Elements

For thermal analysis, load carrying elements of voltage levels equal to or above 69 kV in the upper Michigan area were monitored.

D.1.3 Thermal Loading Criteria

For the normal (intact) system conditions, the loading of all transmission system elements significantly affected by the investigated generator(s) must not exceed 100% of the summer normal rating (Rate A). For contingency system conditions, the loading of all transmission system elements significantly affected by the investigated generator(s) must not exceed 100% of the summer emergency rating (Rate B).

D.1.4 Stability Criteria

Critical Clearing Time (CCT) is a period relative to the start of a fault, within which all generators in the system remain stable (synchronized). CCT is obtained from simulation. Maximum Expected Clearing Time (MECT) determines a period of time that is needed to clear a fault using the existing system facilities. MECT is dictated by the existing system facilities. In any contingency, if the computed CCT is less than the MECT plus a margin determined by ATC (0.5 cycle in this Study), it is considered an unstable situation and is unacceptable.