



**Generator Interconnection Feasibility Study Report  
19 MW Biomass Generation  
Ontonagon County, Michigan**

**G583  
MISO Queue # 38715-02**

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American Transmission Company, LLC**

**Sasan Jalali  
System Planning**

**Ken Jauquet  
Project Management**

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## 1. Summary

This report contains the Feasibility Study for the Generation Interconnection Request identified as MISO Project #G583, MISO Queue #38715-02. This study evaluates the impact of a 19 MW biomass generating unit to be interconnected to the White Pine Substation in Ontonagon County, Michigan. The requested in-service date for this project is June 1, 2008. In addition to G583, the White Pine substation includes two existing steam generating units, local load and also station load with a total net output of 35 MW Summer and 37 MW Winter. Hence, the total output from White Pine substation after the addition of G583 is 54 MW (Summer 2008) and 56 MW (Winter 2008). The one-line diagram for G583 interconnection is shown in Figure 1.

This study identifies the steady state thermal and voltage violations associated with the interconnection of G583. The identified violations are based on Linear Transfer and AC power flow analyses. The study also suggests potential solutions for the thermal and voltage violations that could eliminate the identified unacceptable system impacts

### 1.1 Injection Limits

Injection limits are thermally overloaded facilities that either have a Distribution Factor (DF) of at least 20% in relation to real power injected at the generator Point of Interconnection (POI) and delivered to all of MISO, or they are direct outlets from the generator POI. The study identified two steady-state thermal violations for NERC Category A (intact system) and four steady-state thermal violations for NERC Category B events (single contingencies), as shown in Table A.1 in Appendix A. Five of these thermal violations meet the criteria of injection limits, and are identified below:

1. White Pine – White Pine Village – Victoria 69 kV
2. Victoria Hydro – Rockland – Mass 69 kV
3. Mass – Lake Mine – Winona 69 kV
4. Victoria Hydro – UPSCO – Ontonagon 69 kV
5. Ontonagon 69/138 kV transformer

Solutions to all five injection limits are required for either Energy Resource (ER) or Network Resource (NR) Interconnection Service for the full 19 MW of the requested capacity of G583.

### 1.2 Operation Restrictions

With the injection limits fixed, the study identified five (5) steady-state thermal violations for NERC Category C events (double contingencies) which require potential operation restrictions on G583. These operation restrictions were identified based on N-2 linear transfer analysis and N-2 load flow analysis on the Summer 2008 model after resolving all injection limits. A summary of the operation restrictions on G583 under prior outage conditions is provided in Table B.1 in Appendix B. Note that there may be additional operating restrictions based on stability analysis.

### **1.3 Interconnection Facilities**

Interconnection Facilities include all facilities and equipment between the interconnecting generating facility and the generator POI. The Interconnection System Impact Study (ISIS) will determine the final interconnection configuration at the G583 interconnection and the interconnection facilities.

### **1.4 Network Upgrades**

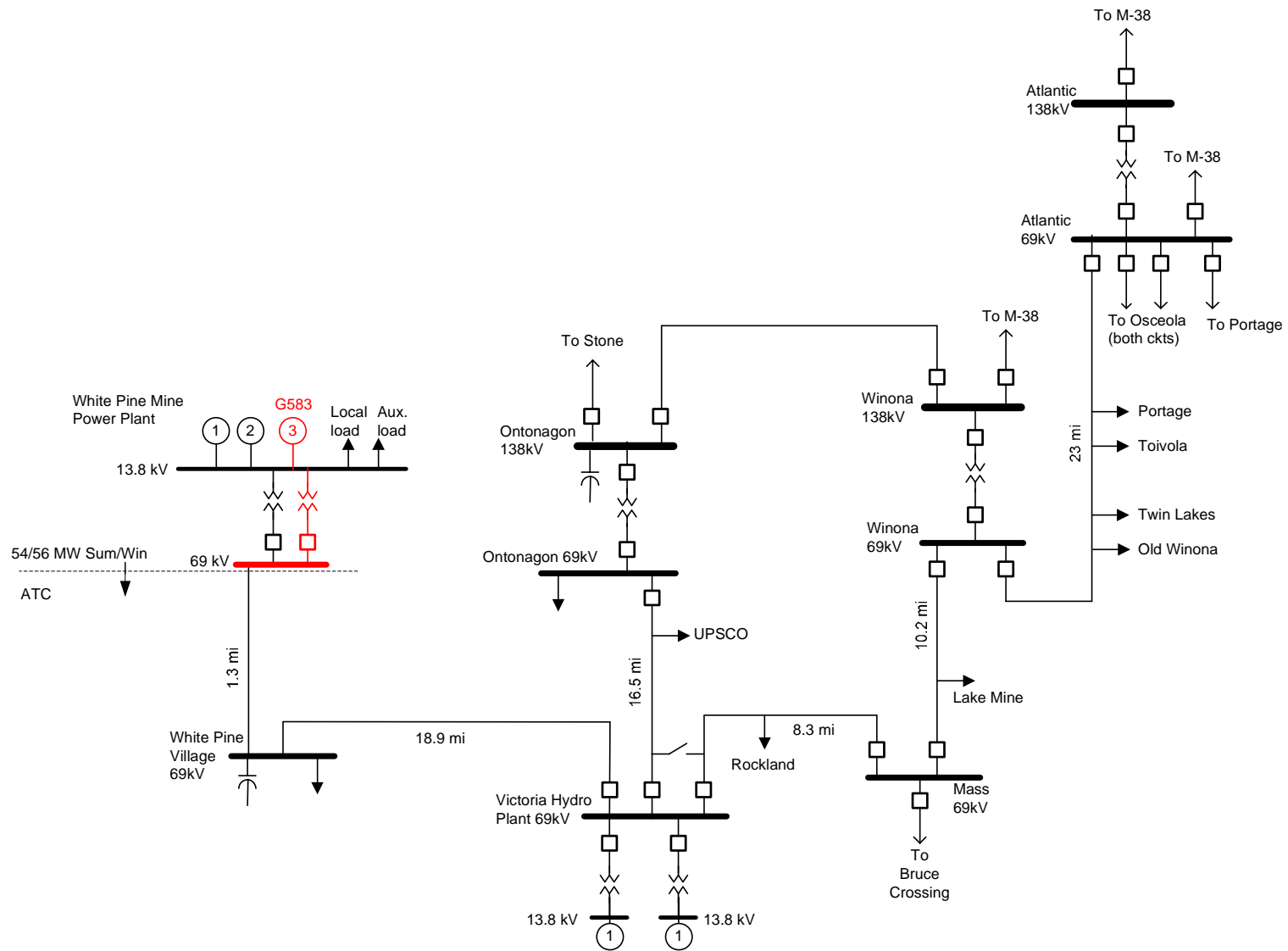
To be determined in the ISIS.

### **1.5 Special Facility Requirements**

To be determined in the ISIS

### **1.6 Further Study**

The next step in the Generator Interconnection Request process is for the Generator customer to decide whether to proceed with an ISIS. The ISIS will determine the system upgrades required to resolve all injection limits identified in this report and will include short circuit, transient and dynamic stability, and deliverability studies, as applicable. Limits identified in the ISIS will also need to be resolved to obtain interconnection service. The ISIS will also determine the final interconnection configuration at the G583 interconnection substation.



**Figure 1:** One Line Diagram of G583 interconnected at White Pine (before network upgrades).

## **2. Criteria, Methodology and Assumptions**

### **2.1 Study Criteria**

All relevant MISO-adopted NERC Reliability Criteria and the American Transmission Company (“ATC”) contingency criteria are to be met for both thermal and voltage analysis. Details of the analysis criteria applied in this study can be found in the Appendix F.

### **2.2 Study Methodology**

The results of this study are subject to change. The results of the study are based on data provided by the Generator and other ATC system information that was available at the time the study was performed, and the injection study does not guarantee deliverability to the MISO energy market. If there are any significant changes in the generator and controls data, in earlier queued Generator Interconnection Requests, in related Transmission Service Requests, or ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this request is subject to restudy. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to MISO and ATC prior to commercial operation.

#### **2.2.1 Competing Generation Requests**

ATC determined in its sole judgment that no Generator Interconnection Request with an earlier queue position will impact the G583 study results.

Public information related to Generator Interconnection Request queue can be found via the MISO web site at <http://oasis.midwestiso.org/documents/ATC/queue.html>.

#### **2.2.2 Linear Transfer Analysis and A.C. Power Flow Analysis Methods**

Thermal overloads were identified using linear transfer analysis and then verified with AC power flow solutions. The linear transfer analysis was used to evaluate the intact system, N-1 contingency, N-2 contingency and certain ATC multiple contingency conditions. The linear transfer analysis utilized adjusted MW ratings for facilities to account for reactive power flows and a 5% transmission reserve margin (“TRM”). All AC power flow solutions utilized actual facility ratings in MVA (i.e. 0% TRM) along with real and reactive power flows. However, the 5% TRM was factored in the computation of required MVA rating for the limiting elements.

The linear transfer analysis was performed using the Linear Transfer Analysis modules of the Managing and Utilizing System Transmission-6.03 (MUST, Version 6.03) program from Siemens Power Technologies, Inc (PTI). All AC power flow solutions were performed using the Power Flow module of the Power System Simulation/Engineering-29 (PSS/E, Version 29) program from Siemens Power Technologies, Inc (PTI). These programs are accepted industry-wide for power flow analysis.

## **2.2.3 Base Cases**

### *2.2.3.1 Power flow analysis*

Base cases used in the thermal analysis for this study were developed based upon the ATC summer peak 2005 model and the July 2005 build of MISO seasonal cases. Two base cases were developed to model the winter peak of 2008/2009, and the summer peak of 2008. The ATC system was modified by updating all loads to the expected 2008 coincident peak value and including all proposed projects through 2007 and all planned projects through 2008 as listed in the ATC Ten Year Assessment. The MISO seasonal cases are accessible through the MISO Extranet. The 19 MW output of G583 was delivered to all on-line MISO generation for thermal analysis.

Thermal analysis includes identifying limiting elements that incur thermal violations for an intact system and under N-1 contingencies by using linear transfer analysis and AC power flow analysis. For N-2 contingencies, thermal analysis includes evaluating thermal violations and prior outage operating restrictions based on linear transfer analysis only.

### *2.2.3.2 Angular Stability analysis*

To be determined in the ISIS

### *2.2.3.3 Deliverability analysis*

To be determined in the ISIS

## **2.2.4 Generation Facility Modeling**

The two existing steam generation units and the new G583 generation unit were modeled as three identical units with reactive power limits of 6.9 MVAR leading (absorbing) and 9.6 MVAR lagging (supplying) for each unit, based on the generator capability curve supplied by the customer. The local load and station loads were assumed resistive. Two identical 13.8/69 kV generator step-up transformers were modeled to interconnect the three generating units, the local load and the stations loads to the POI at the White Pine 69 kV bus, based on the one-line supplied by the customer. Both the existing units and the G583 unit regulated the POI voltage to 1.04 p.u. The real power injection at the POI was studied at 54 MW (Summer 2008) and 56 MW (Winter 2008-2009) with G583 producing 19 MW.

## **3. Analysis Results**

### **3.1 Power Flow Analysis Results**

#### **3.1.1 Results of Single Contingencies (N-1)**

##### *3.1.1.1 Thermal Analysis*

An injection study was performed by delivering 100% of the G583 output to the entire MISO footprint. The study identified two (2) steady-state thermal violations for NERC Category A events (intact system) and four (4) steady-state thermal violations for NERC Category B events (single contingency). Results of the N-1 thermal analysis for the injection study can be found in Table A.1 in Appendix A. Five (5) of the thermal violations meet the criteria for injection limits and will have to be resolved for G583 to attain ER or NR status. The inclusion of planned projects with an in-service date of Summer 2008 does not resolve any of the injection limits.

For each of the five injection limits identified in the N-1 analysis, potential solutions have been proposed in the footnotes of Table A.1 in Appendix A. Note that each proposed solution is directly related to the individual constraint. It is possible that a separate plan may address all limits and offer secondary benefits such as relieving N-2 constraints.

The maximum allowable real power output without required network upgrades was determined by reducing G583 generation until all steady-state thermal violations due to G583 were resolved. The maximum allowable generation without resolving the five injection limits was found to be 0 MW. Results of the maximum allowable generation analysis can be found in Table A.2 in Appendix A.

##### *3.1.1.2 Voltage Analysis*

Single contingency voltage analysis determined that the voltage magnitude of several busses are decreased by more than 0.01 pu (after adding G583) and are dropped below 0.90 pu. Table A.4 shows the intact system and single contingency voltage violations.

#### **3.1.2 Results of Double Contingencies (N-2)**

Thermal and voltage constraints were evaluated for NERC Category C events (N-2 contingencies) in the electrical proximity of G583. The N-2 thermal study was performed on the Summer 2008 model after including potential injection upgrades. The N-2 voltage analysis was performed on the Winter 2008/2009 model after including potential injection upgrades.

The purpose of N-2 analysis is to reveal potential thermal/voltage violations under prior outage conditions, and to identify potential operation restrictions to preempt these N-2 thermal/voltage violations.

Thermal violations under a selected number of N-2 contingencies were evaluated using linear transfer analysis. The N-2 thermal analysis identified 5 thermal violations which are listed in Table A.3 in Appendix A. Operating restrictions identified for G583 due to thermal restrictions are listed in Table B.1 in Appendix B. All three operating restrictions are based on the most

limiting thermal violation for each double contingency. The N-2 thermal constraints are not required to be resolved for the generator to attain either Energy Resource or Network Resource status. All operating restrictions due to N-2 thermal constraints were reviewed as solutions were developed for NERC Category A and B injection limits.

Voltage violations under a selected number of N-2 contingencies were evaluated using power flow analysis. The N-2 voltage analysis did not identify any violations.

### **3.2 Angular Stability Analysis Results**

To be determined in the ISIS

### **3.3 Short-Circuit & Breaker Duty Analysis Results**

To be determined in the ISIS

### **3.4 Deliverability Analysis Results**

To be determined in the ISIS

## **Appendix A: Power Flow Analysis Results**

*Table A.1 – Identified Thermal Violations due to G583 Delivery to MISO for intact system and N-1 Contingencies*

Limiting Element	Existing MVA Rating Sum/win	Worst MVA Loading G583 = 0 MW	Worst MVA Loading G583 = 19 MW	Worst Contingency	TDF (%)	Case Description	Injection Limit	Solution Planned for Limiting Element
White Pine – White Pine Village - Victoria 69 kv	56	37	56	Base case	100 %	Sum 08	yes	No <sup>1</sup>
Victoria 69 Victoria Hydro – Rockland – Mass 69 kv	41	29	39	Base case	53 %	Sum 08	yes	No <sup>2</sup>
Victoria 69 Victoria Hydro – Rockland – Mass 69 kv	46/60	46/47	63/64	Ontonagon 69 Victoria Hydro – UPSCO – Ontonagon 69 kv	90 %	Sum 08/ Win 08/09	yes	No <sup>2</sup>
Mass – Lake Mine – Winona 69 kv	46/60	40/45	52/58	Ontonagon 69 Victoria Hydro – UPSCO – Ontonagon 69 kv	63 %	Sum 08/ Win 08/09	yes	No <sup>3</sup>
Ontonagon 69 Victoria Hydro – UPSCO – Ontonagon 69 kv	46/60	44/46	62/64	Victoria 69 Victoria Hydro – Rockland – Mass 69 kv	95 %	Sum 08/ Win 08/09	yes	No <sup>4</sup>
Ontonagon 69/138 kv transformer	35	41/43	59/61	Victoria 69 Victoria Hydro – Rockland – Mass 69 kv	95%	Sum 08/ Win 08/09	yes	No <sup>5</sup>
3453 – Butler - Granville	332	348	350	Arcadian – Granville 345 kv	9.5 %	Sum 08	No	No <sup>6</sup>

**Notes:**

- 1- Limited by approximately 20.2 miles of 4/0 AWG ACSR 6/1 Penguin, 120°F Norm, 138°F Emergency. This existing line also has a high resistance resulting in a real power loss of 6 MW to 7 MW when delivering 54 MW from White Pine. In addition, the large line impedance also results in considerable voltage drop at Ontonagon 69 kv for some contingencies (see Table A.4). Potential solutions includes re-conductoring the line with 336 kcmil ACSR 26/7 or building a single 69 kv circuit from White Pine 69 kv to Ontonagon 69 kv.
- 2- Limited by approximately 8.1 miles of 1/0 AWG Cu 7, 120°F Norm, 120°F Emergency. Potential solution includes re-conductoring the line with 336 kcmil ACSR 26/7.
- 3- Limited by approximately 10.4 miles of 1/0 AWG Cu 7, 120°F Norm, 120°F F Emergency. Potential solution includes re-conductoring the line with 336 kcmil ACSR 26/7 or ACST T2 26/7.
- 4- Limited by approximately 16.5 miles of 4/0 AWG ACSR 6/1 Penguin, 120°F Norm, 120°F Emergency. Potential solution includes re-conductoring the line with 336 kcmil ACSR 26/7 or ACST T2 26/7.
- 5- Limited by a 28/35 MVA Summer normal/emergency transformer. Needs to be replaced with at least a single 80/80 MVA Summer normal/emergency ratings transformer.
- 6- Limited by approximately 4.4 miles of 795.0 kcmil ACSR 26/7 Drake, 200°F Norm, 275°F Emergency.

*Table A.2 – Maximum Allowable Generation Before Network Upgrades*

<b>Limiting Element</b>	<b>G583 Maximum MW before required network upgrades</b>	<b>Worst Contingency</b>	<b>Worst Season/Model Description</b>
White Pine – White Pine Village - Victoria 69 kV	16	Base case	Summer 2008
Victoria 69 Victoria Hydro – Rockland – Mass 69 kV	0	Ontonagon 69 Victoria Hydro – UPSCO – Ontonagon 69 kV	Summer 2008
Mass – Lake Mine – Winona 69 kV Ontonagon 69	5	Ontonagon 69 Victoria Hydro – UPSCO – Ontonagon 69 kV	Summer 2008
Victoria Hydro – UPSCO – Ontonagon 69 kV	0	Victoria 69 Victoria Hydro – Rockland – Mass 69 kV	Summer 2008
Ontonagon 69/138 kV transformer	0	Victoria 69 Victoria Hydro – Rockland – Mass 69 kV	Summer 2008
Ontonagon 69 kV voltage	5	Victoria 69 Victoria Hydro – Rockland – Mass 69 kV	Winter 2008/09

*Table A.3 – Identified Thermal Violations under N-2 Contingencies (after proposed thermal upgrades <sup>1</sup>).*

<b>Limiting Element</b>	<b>Existing MVA Rating</b>	<b>Worst MVA loading</b>	<b>G583 Maximum allowable MW</b>	<b>Double Contingency</b>	<b>TDF (%)</b>	<b>Solution Planned for Limiting Element</b>
6510 Mass- Bruce Crossing 69 kV	35	62	0	Victoria Hydro – Ontonagon 69 kV Mass - Winona 69 kV	100	No
6510 Bruce Crossing – Watersmeet - Land 69 kV	43	59	0	Victoria Hydro – Ontonagon 69 kV Mass - Winona 69 kV	100	No
6510 Watersmeet – Land O Lakes 69 kV	43	53	0	Victoria Hydro – Ontonagon 69 kV Mass - Winona 69 kV	100	No
6510 Land O Lakes – Conover 69 kV	43	50	0	Victoria Hydro – Ontonagon 69 kV Mass - Winona 69 kV	100	No
Winona 69 – Winona – Atlantic 69 kV	46	47	13	Victoria Hydro – Ontonagon 69 kV Winona 138/69 kV transformer	60.	No

**Notes:**

1- Proposed upgrades refers to the preliminary thermal upgrades suggested in the foot notes of Table A.1

*Table A.4 – Voltage violations due to the addition of G583*

<b>Bus</b>	<b>Voltage (pu) G583 = 0 MW</b>	<b>Voltage (pu) G583 = 19 MW</b>	<b>Worst contingencies</b>	<b>Worst Season</b>	<b>Solution Planned for Limiting Element</b>
Ontonagon 69 kV	0.93	0.84	Victoria Hydro – Rockland – Mass 69 kV	Winter 08/09	No <sup>1</sup>
Elevation St. 69 kV	0.91	0.89	Atlantic 138/69 kV transformer	Winter 08/09	No <sup>1</sup>
Henry street 69 kV	0.91	0.88	Atlantic 138/69 kV transformer	Winter 08/09	No <sup>1</sup>
Michigan Tech University 69 kV	0.91	0.88	Atlantic 138/69 kV transformer	Winter 08/09	No <sup>1</sup>
Osceola 69 kV	0.91	0.89	Atlantic 138/69 kV transformer	Winter 08/09	No <sup>1</sup>
Keweenaw 69 kV	0.90	0.89	Atlantic 138/69 kV transformer	Winter 08/09	No <sup>1</sup>

**Notes:**

1- Applying the thermal solutions suggested in the Table A.1 footnotes, mitigates the voltage violation.

## **Appendix B: Summary of Operation Restrictions**

*Table B.1 – Summary of Identified Operating Restrictions on G583 due to Thermal Constraints*

<b>Prior outage</b>	<b>Allowable MW Output</b>	<b>Worst Next Contingency</b>	<b>Most Limiting Element</b>	<b>MVA Rating</b>
Victoria Hydro – Ontonagon 69 kV	0	Mass - Winona 69 kV	6510 Mass- Bruce Crossing 69 kV	35
Mass - Winona 69 kV	0	Victoria Hydro – Ontonagon 69 kV	6510 Mass- Bruce Crossing 69 kV	35
Winona 138/69 kV transformer	13	Victoria Hydro – Ontonagon 69 kV	Winona 69 – Winona – Atlantic 69 kV	46

## **Appendix C: Angular Stability Analysis Results**

Angular Stability Analysis results will be determined in the ISIS

## **Appendix D: Short Circuit / Breaker Duty Analysis Results**

Short Circuit Analysis results will be determined in the ISIS

## **Appendix E: Deliverability Analysis Results**

Deliverability Analysis results will be determined in the ISIS

## **Appendix F: Study Criteria**

## Study Criteria

### F.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 six categories of contingency conditions:

1. Three-phase fault cleared in primary time with an otherwise intact system.
2. Three-phase fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system.
3. Three-phase fault cleared in primary clearing time with a pre-existing outage of any other transmission element.
4. Single Line Ground (SLG) bus section fault cleared in primary clearing time with an otherwise intact system.
5. SLG internal breaker fault cleared in primary clearing time with an otherwise intact system.
6. SLG fault of double circuits on common tower cleared in primary time with an otherwise intact system.

For power flow analysis, contingencies include:

1. N-1 contingencies – all lines and transformers operated at 69kV and above in the following control areas/zones: ATC Planning Zones 1-5 and ties to those zones, and all branches of voltage level 69kV and above in the Dairyland Power Cooperative, Northern States Power Control Area, Commonwealth Edison, and Alliant West control areas.
2. Selected N-2 and multiple contingencies that ATC has determined to be significant.

### F.2 Monitored Elements

#### *F.2.1 Intact System, N-1, N-2, and Special Multiple Contingency Evaluation Using Linear Transfer Analysis Method*

All load carrying elements operated at 69kV and above in the following control areas/zones were studied: ATC Planning Zones 1-5 and ties to those zones, and all branches of voltage level 69kV and above in the Dairyland Power Cooperative, Northern States Power Control Area, Commonwealth Edison, and Alliant West control areas.

A Transmission Reliability Margin (TRM) of 5% was applied to MVA ratings of all monitored elements. Thermal violations are reported based upon the TRM adjustment of MVA ratings.

### F.3 Thermal Loading Criteria

#### F.3.1 *Injection Violations*

Generation injection violations include 1) thermal violations of the transmission elements that connect the Generator to the rest of the transmission network (outlet congestion); 2) thermal violations of the transmission elements that have TDF  $\geq 20\%$  anywhere in the studied system.

#### F.3.2 *Operation Restriction Calculation*

$$\text{Allowable Generation Output} = \frac{\text{Equipment Rating} - [\text{Line Flow} - (\text{Generation Output} * \text{TDF})]}{\text{TDF}}$$

### F.4 Steady State Voltage Criteria

#### F.4.1 *Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC*

Under intact system conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 pu due to the Generator must not be lower than 0.95 pu. Under contingency conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 pu due to the Generator must not be lower than 0.90 pu.

#### F.4.2 *N-2 Contingency Evaluation*

Power flow solutions must converge for a selected number of N-2 contingencies in the electrical proximity of the studied Generator. Divergence of a power flow solution indicates potential voltage collapse.

### F.5 Angular 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 (1.0 cycle in this study), it is considered an unstable situation and is unacceptable. Otherwise, it is considered acceptable stability performance.

Note that ATC stability criteria and NERC stability criteria differ on the study assumptions used for breaker failure analysis. ATC study criterion models breaker failure by modeling a three-phase fault during the primary time, reduced to SLG fault if the failed breaker is an Independent Pole Operated (IPO) breaker during delayed clearing and cleared at the end of the delayed clearing time. On the other hand, NERC study criterion assumes a single line to ground fault for the entire breaker failure analysis. Hence, the CCT computed from ATC stability criteria is always less than or equal to the value computed using the NERC study criteria. This report assumes ATC stability criteria unless otherwise stated.

In the context of angular stability analysis, voltages of all transmission system buses must recover to at least 70% of the nominal system voltage immediately after fault removal and 80% of the nominal system voltage within 0.5 second after fault removal.