



**G550 Interconnection  
Combined Feasibility/System Impact Study Report  
24 MW Simple Cycle Gas Generation  
Jefferson County, Wisconsin  
Revision 1**

**MISO Queue #38512-02**

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## 1. Summary

This report contains the combined Interconnection Feasibility/System Impact Study (ISIS) for the Generation Interconnection Request identified as MISO Project #G550, MISO Queue #38512-02. This study evaluates the impact of a 24MW increase to the existing Concord simple cycle gas generating units interconnected to the Concord 138 kV substation in Jefferson County, Wisconsin. The requested in-service date for this project is June 2006. The one-line diagram for Concord area is shown in Figure 1.1.

Revision 1 incorporates the final deliverability study results from the MISO. Sections 1, 1.3, 1.5 and 2.2.3.3 were updated and two new sections (3.4 and Appendix F) were added to reflect the completion of the MISO deliverability study and the results of that study.

This study identifies the steady state thermal violations and breaker clearing time violations. The identified violations are based on Linear Transfer and AC power flow analyses and angular stability simulations, respectively. The study also identifies the interconnection facilities and the necessary system upgrades, along with preliminary good faith cost estimates, that will eliminate any unacceptable system impacts and allow the generator to interconnect to the system as an Energy Resource (ER) or as a Network Resource (NR). For G550 to interconnect as either ER or NR, it is necessary to complete upgrades required to resolve 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. Completing all identified system upgrades based on the ISIS, including the Deliverability Study performed by MISO, is necessary to qualify G550 as a NR.

### 1.1 Injection Limits

The study identified 1 steady-state thermal violation for NERC Category B events. This thermal violation meets the criteria for injection limits and will require mitigation for G550 to acquire ER or NR status. This injection will require upgrading existing substation equipment and addressing line clearance issues (see Table 3.1 in Section 3). The maximum allowable G550 generation without system upgrades was found to be 0 MW based on injection limits to the system.

Additional sensitivity analysis was performed for this element to determine if changes in local load, plant output, and local projects that are scheduled for 2008 could lessen the severity of the overloads. It was determined that while the various sensitivities lessened the amount the element is overloaded, the upgrades previously defined will still need to be implemented prior to G550 generating the additional capacity.

### 1.2 Operation Restrictions

The study also identified 10 steady-state thermal violations for NERC Category C events (double contingencies) which require potential operation restrictions on G550. These operation restrictions were identified based on N-2 linear transfer analysis on the summer and winter 2006 models. A summary of the operation restrictions on G550 under prior outage conditions is provided in Table B.1 in Appendix B. No additional operation restrictions were identified based on prior outage angular stability simulations.

## 1.3 Network Upgrades

### Existing Network Upgrades Required Before G550 Operation (see Table 1.1)

#### *Angular Stability Related*

The required system upgrades to eliminate the stability violations prior to G550 are listed in Table 1.1. ATC will be responsible for replacing one relay package at the Concord Substation on line 9061 and installing a communication scheme for 138 kV lines 9042 (Concord to Cooney) and 6431 (Cooney to Summit). Please refer to the section below titled “Variations on ATC’s Planning Criteria” for more information on these upgrades.

#### *Breaker Duty Related*

A fault duty study was not required for this request.

### Network Upgrades Required Due to G550 Addition (see Table 1.2)

#### *Injection Upgrades*

The injection upgrades refer to those system upgrades that eliminate thermal violations of facilities in electrical proximity to G550, which are facilities that either have a Distribution Factor (DF) of at least 20% in relation to real power injected at the generator POI and delivered to all of MISO, or facilities that are direct outlets from the generator POI. The injection upgrades are required for both NR and ER services. There is one injection upgrade identified in the power flow analysis and is listed in Table 1.2. The customer should note that a deliverability analysis has not been performed for G550 and may require additional upgrades.

#### *Angular Stability Related*

The required system upgrades to eliminate the stability violations due to the addition of G550 are listed in Table 1.2. Please refer to the section below titled “Variations on ATC’s Planning Criteria” for more information on these upgrades.

#### *Breaker Duty Related*

The G550 generation increase does not add additional fault current to the system. Therefore, no upgrades in this regard are required before the in-service date of G550.

#### *Network Resource (NR) Certification Related*

The MISO deliverability study did not identify any constraints for the full output level of 24 MW requested for G550. Refer to Sections 2.2.3 and 3.4 and Appendix F for more discussion on this subject.

### Variations on ATC Planning Criteria

The *stability* projects listed in Tables 1.1 and 1.2 are required to bring the performance of the system up to ATC’s stability criteria. However, without these upgrades, the system currently meets NERC Reliability Standards, which is a lower standard than ATC uses, and will continue to meet NERC Reliability Standards with the addition of G550.

ATC Planning Criteria addresses these types of situations where the system meets the NERC standards but not ATC's criteria. In addition, ATC Planning Criteria addresses generator interconnection requests in these types of areas. In these instances, the system upgrades to achieve compliance with ATC's criteria can proceed on a normal implementation schedule and the generator interconnection can proceed, as long as the system continues to meet NERC Reliability Standards. Since this is the case with G550, the stability projects listed in Tables 1.1 and 1.2 are not required to be completed prior to the operation of G550. The customer should note that this variation only covers stability projects and not injection, deliverability and fault duty projects.

#### **1.4 Required Interconnection Facilities**

Since this is an increase to the output of an existing facility, no new interconnection facilities will be required.

##### Minimum permissible power factor at POI

For all system conditions, G550 will be required to operate within a power factor range from 0.90 lagging (delivering VARS) to 0.95 leading (absorbing VARS) at the POI. The G550 facility will also be required to maintain a minimum voltage of 1.02 p.u. at the POI, unless ATC system operations directs otherwise.

#### **1.5 Further Study**

The next step in the Generator Interconnection Request process is for the customer to decide if they want to proceed to a Facility Study. A Facility Study will specify in more detail the time and cost of the equipment, engineering, procurement and construction of the system upgrades identified in this system impact study report.

*Table 1.1– Existing Network Upgrades Required Not Due to G550<sup>1</sup>*

Location	Facilities	Reason	Cost Estimate (Y2006)
Concord Substation	Item#1 – Upgrade breaker failure relaying at the Concord and Hartford 138 kV ends of line 9061 with a non-standard SEL421 type relay. See Note 2.	Stability	\$175,814
	Item#2 – Install communication sets between Concord and Cooney Substation (Line 9042) and Cooney and Summit Substation (Line 6431).	Stability	\$130,028

Note 1: Refer to Section 1.3, “Variations on ATC Planning Criteria” for more information.

Note 2: Item #1, Table 1.1, replaced by Item #2, Table 1.2, if G550 proceeds with interconnection.

*Table 1.2 – Required Network Upgrades due to the Addition of G550<sup>1</sup>*

Location	Facilities	Reason	Cost Estimate	Year Basis for Cost
Concord Substation	Item#1 – Replace the existing 9061 breaker at Concord with a 2-cycle gas breaker (40KA minimum).	Stability	\$164,077	2006
	Item#2 – Upgrade breaker failure relaying at the Concord and Hartford 138 kV ends of line 9061 with a standard SEL352 type relay. See Note 2.		\$188,880	
Concord – Cooney 138 kV Line 9042	Item#3 – Upgrade relaying at the Concord and the Cooney terminals from 287 MVA (SE and WE) to 338 MVA (SE) / 345 MVA (WE), minimum.	Injection	\$176,569	2006
	Item#4 – Upgrade 795 ACSR 26/7 Drake jumpers in both substations from 332 MVA (SE) to 338 (SE) MVA and 345 MVA (WE), minimum.		\$35,362	
	Item#5 – Increase the line clearance of the line conductor (Line 9042) between Concord and Cooney from 293 MVA (SE) to 338 MVA (SE) and 345 MVA (WE), minimum.		\$56,968	

Note 1: Refer to Section 1.3, “Variations on ATC Planning Criteria” for more information.

Note 2: Item #2, Table 1.2 replaces Item #1, Table 1.1, if G550 proceeds with interconnection.

Note 3: SE – Summer Emergency, WE – Winter Emergency

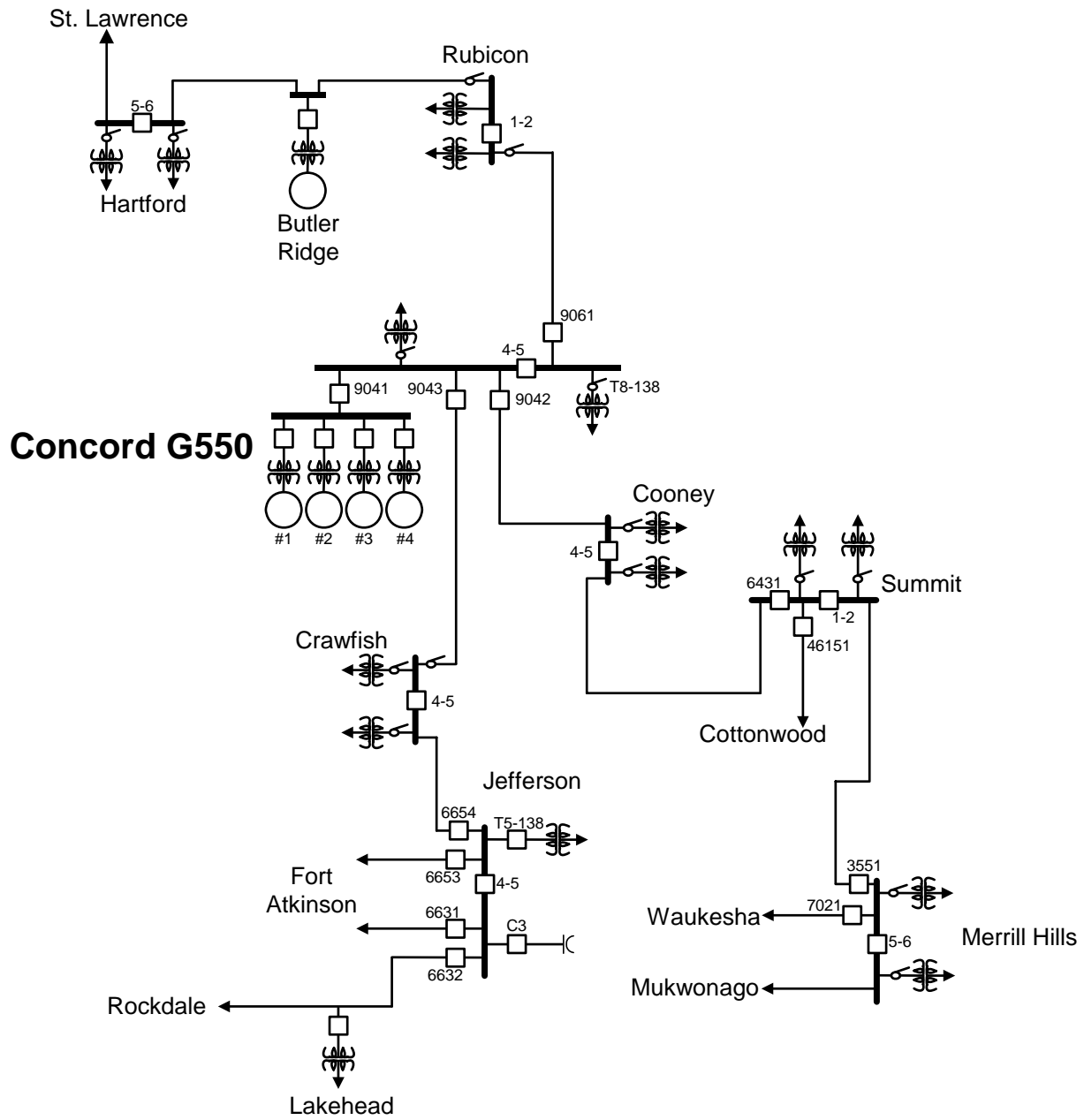


Figure 1.1 – One Line Diagram of the System with G550

## **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 the thermal and angular stability analysis. Details of the analysis criteria applied in this study can be found in the Appendix E.

### **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 queue 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 one Generator Interconnection Request with an earlier queue position will impact the G550 study results. G338 (Butler Ridge Wind Farm) is considered a competing request for the interconnection of this generator and therefore included in each base case. G338 is a 54 MW wind farm facility located in Dodge County, WI.

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***

Power flow analysis includes evaluation of thermal and steady state voltage violations in the intact system and under N-1 contingencies and evaluation of thermal violations and steady state voltage stability under N-2 contingencies. For power flow analysis, two seasonal conditions were evaluated, which represent expected summer and winter 2006 conditions. Base cases used in the power flow analysis were developed based upon the MISO seasonal cases for 2006 summer and winter periods. The MISO seasonal cases are accessible through the MISO Extranet. Sensitivities were also performed to determine the impact that the sink point for the G550 generation would have on the system. G550 generation was first delivered to all loads within the MISO footprint and then loads within the WEC footprint.

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***

For the stability analysis, a “Before” with Concord generating a net output of 376 MW’s (light load) was compared against an “After” with Concord generating a net output of 400 MW (light load).

The 2006 50% Summer peak case was developed based on the NERC 2004 series MMWG (Multi-Regional Modeling Working Group) base case, scaling the load in the ATC areas to levels forecasted in the EIA 411 load forecast for 2006, dispatching generation in the ATC footprint according to merit order dispatch. The 24 MW associated with the G550 request was delivered with 75% going to the Commonwealth Edison (ComEd) control area and 25% to the Northern States Power (NSP) control area.

Angular stability analysis includes screening for stable operation at acceptable primary and delayed breaker clearing times for breaker failure contingency conditions, and acceptable primary breaker clearing times for prior outage conditions. These cases are typically the worst conditions for angular stability performance.

### ***2.2.3.3 Deliverability analysis***

The deliverability analysis case was developed by MISO from the 2006 series Midwest ISO Transmission Expansion Planning (MTEP) case for the 2011 Summer Peak season, incorporating feedback from Transmission Owners and following the MISO deliverability study methodology. Details on the MISO Generation Deliverability Study Method can be found in the whitepaper posted at the following link:

[\*\*MISO Deliverability Whitepaper\*\*](#)  
(see appendix F for full web address)

## **2.2.4 Generation Facility Modeling**

The G550 facility was modeled using the current generator data for this site, adjusting the corresponding MW and MVAR limits using the existing generator capability curves.

Unless specified otherwise, the G550 facility was modeled with the plant operating with a GSU high side voltage of 1.02 p.u. for stability analysis.

## **2.2.5 Before and After Comparison Approach Employed in Stability Analysis**

In the stability analysis performed for this study, to identify what impacts should be attributed to the addition of G550 interconnection; two system conditions were examined – “Before” the addition of G550 and “After” the addition of G550. Any violations of the stability study criteria identified in the “Before” state are defined to be existing system violations. Any new violations identified in the “After” state or violations identified in both “Before” and “After” states and are worse in the “After” state are to be attributed to the addition of G550. Only those existing system violations that are made worse by G550 are deemed relevant to the G550 interconnection request and are documented in this report. Any other identified existing system violations that are not made worse by G550 are deemed unrelated to the G550 interconnection request and are documented elsewhere as part of the internal ATC planning projects.

The stability analysis was performed using the Dynamics Simulation and Power Flow modules of the Power System Simulation/Engineering-29 (PSS/E, Version 29) program from Power Technologies, Inc (PTI). This program is accepted industry-wide for dynamic stability analysis.

# **3. Analysis Results**

## **3.1 Power Flow Analysis Results**

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

An injection study was performed by first delivering 100% of the G550 output to the entire MISO footprint and then delivering 100% of the output to the WEC footprint for both summer 2006 and winter 2006. An injection sensitivity study was performed on each of the seasonal base cases with and without the dispatch of Butler Ridge and Christiana generation.

The study identified one thermal injection violation for both summer and winter 2006 for G550 under N-1 condition, as summarized in Tables A.1 – A.4 in Appendix A. The Concord – Cooney 138-kV limit (line 9042) is limited by terminal equipment and line conductor clearances. The terminal equipment and line conductor is not scheduled to be upgraded in the near future. If Christiana is not generating at full capacity, this study found no injection limits regardless of the dispatch of Butler Ridge generation.

*Table 3.1: New Transmission Upgrades Required to Resolve G550 Injection N-1 Limits*

Limiting Element	Solution
Concord – Cooney 138kV Line 9042	<p>Upgrade relaying at the Concord and the Cooney terminals from 287 MVA (SE and WE) to 338 MVA (SE) / 345 MVA (WE), minimum.</p> <p>Upgrade 795 ACSR 26/7 Drake jumpers in both substations from 332 MVA (SE) to 338 (SE) MVA and 345 MVA (WE), minimum.</p> <p>Increase the line clearance of the line conductor (Line 9042) between Concord and Cooney from 293 MVA (SE) to 338 MVA (SE) and 345 MVA (WE), minimum.</p>

Note: SE – Summer Emergency, WE – Winter Emergency

The maximum allowable real power output from G550 was determined by reducing G550 generation until all steady-state thermal violations due to G550 were resolved. Without any system upgrades, the maximum allowable output was identified as 0 MW due to injection limits.

Results of the maximum allowable output from G550 can be found in Table A.5 in Appendix A.

### 3.1.1.1 Additional Sensitivity Analysis

Due to the highly sensitive nature of this area to transfers through the state, additional analysis was performed for the N-1 contingencies defined in 3.1.1 to determine if load variations, MW output of G550 and future transmission projects might lessen the severity of the overloads. Table A.6 shows that while each sensitivity reduces the severity of the overload, a project to increase the capacity of line 9042 will be required prior to G550 generating. G550 will be required to restrict output to 0 MW until the injection related overloads are corrected, as previously mentioned in this report.

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

Thermal constraints were evaluated for NERC Category C events (N-2 contingencies) in the electrical proximity of G550. Thermal violations under a selected number of N-2 contingencies were evaluated using linear transfer analysis. The purpose of the N-2 analysis is (1) to reveal potential thermal violations under prior outage conditions, and (2) to identify potential operating restrictions to mitigate these N-2 thermal violations. The N-2 analysis was performed on all dispatch scenarios and sensitivities identified for this study.

The N-2 thermal violations are listed in Tables A.8 – A.11 in Appendix A. The required operating restrictions for the double contingencies are listed in Table B.1 in Appendix B. The restrictions are based on the most limiting element, which may be an element that was identified in the N-1 analysis. For this reason, Tables A.5 and B.1 may not appear to be developed from the same results.

The double contingency constraints are not required to be resolved for the generator to attain either Energy Resource or Network Resource status. All identified operating restrictions have been reviewed as solutions were developed for NERC Category A and B violations.

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

The angular stability criteria used in this study requires that all machines modeled in the system must remain stable after a three-phase or single-phase to ground fault is cleared from any transmission element under the following scenarios:

1. Three-phase fault cleared in primary time with an otherwise intact system;
2. Three-phase fault cleared in primary clearing time with a prior outage of any other transmission element;
3. Three-phase fault cleared in delayed clearing time (i.e. breaker failure condition) with an otherwise intact system (wind turbines are exempt from the delayed clearing criterion, but must not adversely affect system angular stability performance);
4. Single Line to 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.

Wind turbines are exempt from delayed clearing requirements, but must not aggravate network performance if tripped from the transmission system during a delayed clearing simulation.

In this study, potential angular stability problems were screened by studying the two scenarios that produce the most severe conditions for maintaining angular stability; that is, scenario #2 (prior outage) and scenario #3 (breaker failure). Results of the angular stability analysis are summarized in Tables C.1 – C.3 in Appendix C. Further, adequate damping of the local plant mode rotor angle oscillations was verified by running extended transient stability simulations (until 20 seconds) for selected prior outage and breaker failure cases. All prior outage and breaker failure simulations were analyzed for oscillation damping.

#### **3.2.1 Results of Primary Fault Contingencies**

The intact system primary fault contingencies evaluated and the study results are summarized in Table C.1 in Appendix C.

##### Before G550

The study identified no unacceptable stability performance for any of the studied intact system primary fault contingencies in the existing system.

##### After G550

The study identified no unacceptable stability performance for any of the studied intact system primary fault contingencies with the addition of G550.

#### **3.2.2 Results of Delayed Clearing Contingencies**

The breaker failure contingencies evaluated and the study results are summarized in Table C.2 in Appendix C.

### Before G550

The study identified two contingencies with unacceptable stability performance for the studied breaker failure contingencies in the existing system. One of these contingencies will require a breaker failure relay package upgrade for the Concord to Rubicon 138 kV line (9061) at the Concord substation. The other will require relay communication packages to be installed on the Concord to Cooney 138 kV line (9042) and Cooney to Summit 138 kV line (6431).

The required system upgrades to eliminate the stability violations prior to G550 are listed in Table 1.1.

Since the current equipment currently meets present NERC Category C requirements and ATC planning requirements, these items will not be required to be replaced prior to G550 going in service.

### After G550

The study identified one contingency with unacceptable stability performance for the studied breaker failure contingencies with G550. This contingency will require the breaker on the Concord to Rubicon 138 kV line (9061) at Concord substation to be replaced with a 2 cycle gas type breaker and will require the breaker failure relay to be upgraded.

The required system upgrades to eliminate the stability violations due to G550 are listed in Table 1.2.

Since the current equipment currently meets present NERC Category C requirements and ATC planning requirements, these items will not be required to be replaced prior to G550 going in service.

#### **3.2.2.1 Additional Sensitivity Analysis for Delayed Clearing Contingencies**

Additional studies were performed for a high shoulder peak case (85% of system peak load) to determine if an increase in system load would alleviate the stability violations identified in section 3.2.2. It was determined that an increase in system load enhances stability of the Concord generators slightly, but not enough to be able to eliminate the previously identified stability violations.

#### **3.2.3 Results of Prior Outage Primary Fault Contingencies**

The prior outage contingencies evaluated and the study results are summarized in Table C.3 in Appendix C.

### Before G550

The study identified no unacceptable stability performance for any of the studied prior outage primary fault contingencies in the existing system.

### After G550

The study identified no unacceptable stability performance for any of the studied prior outage primary fault contingencies after the addition of G550.

### **3.2.4 Results of Bus Section Fault and/or Internal Breaker Fault Contingencies**

No internal breaker fault/bus section fault contingencies were evaluated for Single-Line to Ground (SLG) fault since the delayed clearing and primary clearing contingencies represent worse case scenarios for this generator.

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

Short-circuit analysis was not performed since the request will not introduce any additional fault current to the transmission system. No system upgrades due to breaker duty are required prior to the interconnection of G550.

### **3.4 Deliverability Analysis Results**

The deliverability analysis did not identify any constraints for the full 24 MW output of G550, as noted in Table F.1 in Appendix F. Therefore, no additional network upgrades to obtain Network Resource Interconnection Service (NRIS) certification are needed.

NRIS certification does not guarantee a resource to serve a specific load or to operate during any particular set of operating circumstances. Additionally, certification of deliverability makes no guarantee as to price of available resources. Congestion charges may, in fact, be extremely high.

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

**Table A.1 – Identified Thermal Violations Prior to G550  
With Delivery to MISO for N-1 Contingencies (TDF>3%)  
Christiana and Butler Ridge Fully Dispatched**

Limiting Element	Existing Rating (MVA)	Required Rating (MVA) <sup>2</sup>	Worst Contingency	TDF (%)	Case <sup>1</sup>	Injection Limit	Solution Planned
Concord – Cooney 138 kV Line 9042	287 SE	335.0	Hartford – Butler Ridge 138 kV	56.2%	2006S-b 2006W-b	Yes	No <sup>3</sup>
	287 WE	343.5	Hartford – Butler Ridge 138 kV	57.2%			

**Table A.2 – Identified Thermal Violations Prior to G550  
With Delivery to WEC for N-1 Contingencies (TDF>3%)  
Christiana and Butler Ridge Fully Dispatched**

Limiting Element	Existing Rating (MVA)	Required Rating (MVA) <sup>2</sup>	Worst Contingency <sup>3</sup>	TDF (%)	Case <sup>1</sup>	Injection Limit	Solution Planned
Concord – Cooney 138 kV Line 9042	287 SE	337.1	Hartford – Butler Ridge 138 kV	64.5%	2006S-b 2006W-b	Yes	No <sup>3</sup>
	287 WE	344.1	Hartford – Butler Ridge 138 kV	59.3%			

**Table A.3 – Identified Thermal Violations Prior to G550  
With Delivery to MISO for N-1 Contingencies (TDF>3%)  
Christiana Fully Dispatched, Butler Ridge Not Dispatched**

Limiting Element	Existing Rating (MVA)	Required Rating (MVA) <sup>2</sup>	Worst Contingency	TDF (%)	Case <sup>1</sup>	Injection Limit	Solution Planned
Concord – Cooney 138 kV Line 9042	287 SE	312.0	Concord – Rubicon 138 kV	56.0%	2006S-b 2006W-b	Yes	No <sup>3</sup>
	287 WE	317.4	Concord – Rubicon 138 kV	57.3%			

**Table A.4 – Identified Thermal Violations Prior to G550  
With Delivery to WEC for N-1 Contingencies (TDF>3%)  
Christiana Fully Dispatched, Butler Ridge Not Dispatched**

Limiting Element	Existing Rating (MVA)	Required Rating (MVA) <sup>2</sup>	Worst Contingency <sup>3</sup>	TDF (%)	Case <sup>1</sup>	Injection Limit	Solution Planned
Concord – Cooney 138 kV Line 9042	287 SE	314.0	Concord – Rubicon 138 kV	64.7%	2006S-b 2006W-b	Yes	No <sup>3</sup>
	287 WE	318.0	Concord – Rubicon 138 kV	59.4%			

**Notes:**

1. Cases Used: 2006 MISO Summer Peak Case (2006S-a) – G550 @ 24 MW and Butler Ridge @ 54 MW, Christiana @ 0 MW; 2006 MISO Summer Peak Case (2006S-b) – G550 @ 24 MW, Butler Ridge @ 54 MW, Christiana @ 450 MW; 2006 MISO Winter Peak Case (2006W-a) – G550 @ 24 MW, Butler Ridge @ 54 MW, Christiana @ 0 MW; 2006 MISO Winter Peak Case (2006W-b) – G550 @ 24 MW, Butler Ridge @ 54 MW, Christiana @ 450 MW. All models used include planned projects through 2006.
2. Includes provision for 5% TRM. The results from MUST calculations showed minor differences between the delivery to MISO or WEC. The required ratings are calculations using PSS/E, dispatching output to either WEC or MISO.
3. Relay Limits at Concord and Cooney (287 SE/WE) MVA, Conductor Limit (293 SE, 381 WE) MVA, Jumper Limits (332 SE, 394 WE) MVA at Concord and Cooney substations.

**Table A.5 – Maximum Allowable Generation for G550 without System Upgrades**

Limiting Element	Worst Contingency	Model Description	G550 Maximum MW	Max MW with Planned and Proposed Projects <sup>6</sup>
Concord – Cooney 138 kV Line 9042	Hartford – Butler Ridge 138 kV <sup>4</sup>	2006 Summer OR 2006 Winter	0.0	0.0
Concord – Cooney 138 kV Line 9042	Concord – Rubicon 138 kV <sup>5</sup>	2006 Summer OR 2006 Winter	0.0	0.0

**Notes:**

4. Delivery of G550 to MISO or WEC, Christiana and Butler Ridge Fully Dispatched.
5. Delivery of G550 to MISO or WEC, Christiana Fully Dispatched and Butler Ridge Not Dispatched.
6. Planned and Proposed projects from ATC’s 2005 Ten Year Assessment report.

**Table A.6 – Sensitivity of N-1 Overloads (Tables A.1-A.4) Using PSS/E AC Analysis**

Concord – Cooney Required Rating (MVA) Line 9042						
Dispatch	G550 @ 0 MW		G550 @ 12MW		G550 @ 24 MW	
	Summer	Winter	Summer	Winter	Summer	Winter
<b>2006 MISO Case<sup>8</sup></b>						
CHA @ 450 MW BTLR @ 54 MW <sup>14</sup>	320.8	329.2	327.6	336.0	335.0	343.4
CHA @ 450 MW BTLR @ 0 MW <sup>15</sup>	297.8	303.0	304.6	310.0	311.9	317.4
<b>2006 MISO Case<sup>8</sup> with updated 2006 Loads<sup>9</sup></b>						
CHA @ 450 MW BTLR @ 54 MW <sup>14</sup>	311.3	NA	318.1	NA	325.4	NA
CHA @ 450 MW BTLR @ 0 MW <sup>15</sup>	288.5	NA	295.3	NA	302.6	NA
<b>2006 MISO Case<sup>8</sup> with updated 2007 Loads<sup>10</sup> and 2008 Planned Local projects<sup>11</sup></b>						
CHA @ 450 MW BTLR @ 54 MW <sup>14</sup>	272.2	NA	277.9	NA	284.1	NA
CHA @ 450 MW BTLR @ 0 MW <sup>15</sup>	282.6	NA	289.0	NA	295.9	NA

**Notes:**

7. Line 9042 currently rated at 287 MVA Summer Emergency and 287 MVA Winter Emergency. Required ratings include a 5% TRM.
8. Delivery of G550 for comparison purposes is MISO footprint.
9. Non-coincident loads modified per projected forecasts for 2006.
10. Non-coincident loads modified per projected forecasts for 2007.
11. Two local transmission projects modeled with in-service date of 2008.
12. NA – Analysis only run for summer. Higher line loading expected for winter.
13. CHA – Christiana, BTLR – Butler Ridge.
14. Hartford – Butler Ridge 138-kV line (Line 9061) out of service.
15. Concord – Rubicon 138-kV line (Line 9061) out of service.

**Table A.7 – Concord Bus Loading with G550**

Limiting Element	Worst Contingency	Case	Maximum Loading (MVA)	Maximum Designed Capability (MVA)
Concord Bus Section 4 - 5	No Outages	Summer 2006 <sup>16</sup>	431.0	566
Concord Bus Section 4 - 5	Concord – Rubicon Line 9061	Winter 2006 <sup>16</sup>	422.7	676

**Notes:**

16. Christiana and Butler Ridge dispatched.

**Table A.8 – Identified Thermal Violations under N-2 Contingencies**  
**Summer and Winter Delivery to MISO**  
**With Butler Ridge Dispatched Fully**  
**With and Without Christiana Dispatched Fully**

Limiting Element	Existing MVA Rating	Worst MW Loading	Worst Double Contingency	TDF (%)	Solution Planned for Limiting Element
Jefferson – Crawfish 138kV Line 6654	293 SE 381 WE	316.2 Sa 315.8 Sb	Butler Ridge – Hartford 138kV Line Concord – Cooney 138kV Line 6853	100.0	No
Concord – Rubicon 138kV Line 9061	293 SE	310.2 Sa 310.2 Sb	Concord – Crawfish River 138kV Line Concord – Cooney 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	348.7 Sa 348.3 Sb 378.7 Wa 378.5 Wb	Butler Ridge – Hartford 138 kV Line Concord – Crawfish 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	326.4 Sb 324.7 Wb	Concord Bus Tie 5-6	57.9	No
Concord – Crawfish 138 kV Line 9043	287 SE 287 WE	348.7 Sa 348.4 Sb 378.6 Wa 378.4 Wb	Butler Ridge – Hartford 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Hartford – Butler Ridge 138 kV Line 9061	293 SE 344 WE	348.7 Sa 348.3 Sb 378.6 Wa 378.4 Wb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Hartford – St. Lawrence 138 kV Line 8031	293 SE 381 WE	305.1 Sa 304.7 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Pleasant Valley – Arthur Road 138 kV 8252	121 SE 172 WE	121.2 Sa 123.9 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	52.9 53.3	No
Butler Ridge – Rubicon 138 kV Line 9061	293 SE	294.6 Sa 294.3 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
St. Lawrence – Arthur Road 138 kV Line	121 SE 172 WE	142.0 Sa 142.0 Sb 174.0 Wb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Cooney – Summit 138 kV Line	287 SE 287 WE	290.5 Sa 289.3 Sb 327.6 Wa 326.6 Wb	Butler Ridge – Hartford 138 kV Line Concord – Crawfish 138 kV Line	100.0	No

**Notes:**

1. N-2 linear transfer analysis performed using the following cases: 2006 MISO Summer Peak Case (2006Sa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Summer Peak Case (2006Sb) – G550 @ 24 MW, Christiana @ 450 MW; 2006 MISO Winter Peak Case (2006Wa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Winter Peak Case (2006Wb) – G550 @ 24 MW, Christiana @ 450 MW.

**Table A.9 – Identified Thermal Violations under N-2 Contingencies**  
**Summer and Winter Delivery to MISO**  
**Without Butler Ridge Dispatched**  
**With and Without Christiana Dispatched Fully**

Limiting Element	Existing MVA Rating	Worst MW Loading	Worst Double Contingency	TDF (%)	Solution Planned for Limiting Element
Concord – Rubicon 138kV Line 9061	293 SE	310.3 Sa 310.2 Sb	Concord – Crawfish River 138kV Line Concord – Cooney 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	310.3 Sa 310.2 Sb 335.7 Wa 335.8 Wb	Concord – Crawfish 138 kV Line Concord – Rubicon 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	328.1 Sb 326.2 Wb	Concord Bus Tie 5-6	57.9	No
Concord – Crawfish 138 kV Line 9043	287 SE 287 WE	310.3 Sa 310.1 Sb 335.7 Wa 335.8 Wb	Concord – Rubicon 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Hartford – Butler Ridge 138 kV Line 9061	293 SE 344 WE	294.1 Sa 293.5 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Butler Ridge – Rubicon 138 kV Line 9061	293 SE	294.2 Sa 293.7 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No

**Notes:**

- N-2 linear transfer analysis performed using the following cases: 2006 MISO Summer Peak Case (2006Sa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Summer Peak Case (2006Sb) – G550 @ 24 MW, Christiana @ 450 MW; 2006 MISO Winter Peak Case (2006Wa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Winter Peak Case (2006Wb) – G550 @ 24 MW, Christiana @ 450 MW.

**Table A.10 – Identified Thermal Violations under N-2 Contingencies  
Summer and Winter Delivery to WEC  
With Butler Ridge Dispatched Fully  
With and Without Christiana Dispatched Fully**

Limiting Element	Existing MVA Rating	Worst MW Loading	Worst Double Contingency	TDF (%)	Solution Planned for Limiting Element
Jefferson – Crawfish 138kV Line 6654	293 SE 381 WE	316.2 Sa 315.8 Sb	Butler Ridge – Hartford 138kV Line Concord – Cooney 138kV Line 6853	100.0	No
Concord – Rubicon 138kV Line 9061	293 SE	310.2 Sa 310.2 Sb	Concord – Crawfish River 138kV Line Concord – Cooney 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	348.7 Sa 348.3 Sb 378.7 Wa 378.5 Wb	Butler Ridge – Hartford 138 kV Line Concord – Crawfish 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	326.9 Sb 325.1 Wb	Concord Bus Tie 5-6	59.9	No
Concord – Crawfish 138 kV Line 9043	287 SE 287 WE	348.7 Sa 348.4 Sb 378.6 Wa 378.4 Wb	Butler Ridge – Hartford 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Hartford – Butler Ridge 138 kV Line 9061	293 SE 344 WE	348.7 Sa 348.3 Sb 378.6 Wa 378.4 Wb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Hartford – St. Lawrence 138 kV Line 8031	293 SE 381 WE	305.1 Sa 304.7 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Pleasant Valley – Arthur Road 138 kV 8252	121 SE 172 WE	121.2 Sa 124.0 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	52.9 53.3	No
Butler Ridge – Rubicon 138 kV Line 9061	293 SE	294.6 Sa 294.3 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
St. Lawrence – Arthur Road 138 kV Line	121 SE 172 WE	142.0 Sa 144.8 Sb 174.0 Wb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Cooney – Summit 138 kV Line	287 SE 287 WE	290.5 Sa 289.3 Sb 327.6 Wa 326.6 Wb	Butler Ridge – Hartford 138 kV Line Concord – Crawfish 138 kV Line	100.0	No

**Notes:**

- N-2 linear transfer analysis performed using the following cases: 2006 MISO Summer Peak Case (2006Sa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Summer Peak Case (2006Sb) – G550 @ 24 MW, Christiana @ 450 MW; 2006 MISO Winter Peak Case (2006Wa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Winter Peak Case (2006Wb) – G550 @ 24 MW, Christiana @ 450 MW.

**Table A.11 – Identified Thermal Violations under N-2 Contingencies**  
**Summer and Winter Delivery to WEC**  
**Without Butler Ridge Dispatched at 54 MW**  
**With and Without Christiana Dispatched Fully**

Limiting Element	Existing MVA Rating	Worst MW Loading	Worst Double Contingency	TDF (%)	Solution Planned for Limiting Element
Concord – Rubicon 138kV Line 9061	293 SE	310.3 Sa 310.2 Sb	Concord – Crawfish River 138kV Line Concord – Cooney 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	310.3 Sa 310.1 Sb 335.7 Wa 335.8 Wb	Concord – Crawfish 138 kV Line Concord – Rubicon 138 kV Line	100.0	No
Concord – Cooney 138 kV Line 9042	287 SE 287 WE	328.5 Sb 326.6 Wb	Concord Bus Tie 5-6	59.9	No
Concord – Crawfish 138 kV Line 9043	287 SE 287 WE	310.3 Sa 310.1 Sb 335.7 Wa 335.8 Wb	Concord – Rubicon 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Hartford – Butler Ridge 138 kV Line 9061	293 SE 344 WE	294.1 Sa 293.5 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No
Butler Ridge – Rubicon 138 kV Line 9061	293 SE	294.2 Sa 293.7 Sb	Concord – Crawfish 138 kV Line Concord – Cooney 138 kV Line	100.0	No

**Notes:**

- N-2 linear transfer analysis performed using the following cases: 2006 MISO Summer Peak Case (2006Sa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Summer Peak Case (2006Sb) – G550 @ 24 MW, Christiana @ 450 MW; 2006 MISO Winter Peak Case (2006Wa) – G550 @ 24 MW, Christiana @ 0 MW; 2006 MISO Winter Peak Case (2006Wb) – G550 @ 24 MW, Christiana @ 450 MW.

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

Table B.1 – Summary of Identified Operating Restrictions on G550 due to Thermal Constraints<sup>1,2</sup>

<b>Butler Ridge Fully Dispatched</b>					
<b>Prior outage</b>	<b>Allowable G550 MW Output<sup>6</sup></b>	<b>Worst Next Contingency</b>	<b>Most Limiting Element</b>	<b>MVA Rating</b>	<b>TDF %</b>
Butler Ridge – Hartford Line	0	Concord – Crawfish River 138kV Line	Concord - Cooney 138kV Line	287 SE 287 WE	100.0
Concord – Crawfish River 138kV Line	0	Butler Ridge – Hartford 138 kV Line	Concord - Cooney 138kV Line	287 SE 287 WE	100.0
Concord – Cooney 138 kV Line	0	Butler Ridge – Hartford 138 kV Line	Concord – Crawfish 138 kV Line	287 SE 287 WE	100.0
Butler Ridge – Hartford 138 kV Line	0	Concord – Cooney 138 kV Line	Concord – Crawfish 138 kV Line	287 SE 287 WE	100.0
Concord – Cooney 138 kV Line	0	Concord – Crawfish River 138kV Line	Butler Ridge – Hartford 138 kV Line	293 SE 344 WE	100.0
Concord – Crawfish River 138kV Line	0	Concord – Cooney 138 kV Line	Butler Ridge – Hartford 138 kV Line	293 SE 344 WE	100.0
Butler – Hartford 138 kV Line	3.2 <sup>3</sup> 4.7 <sup>4</sup>	Concord – Crawfish River 138 kV Line	Cooney – Summit 138 kV Line	287 SE 287 WE	100.0 100.0
Concord – Crawfish River 138 kV Line	3.2 <sup>3</sup> 4.7 <sup>4</sup>	Butler – Hartford 138 kV Line	Cooney – Summit 138 kV Line	287 SE 287 WE	100.0 100.0
Concord – Crawfish River 138kV Line	10.3 <sup>3</sup> 5.9 <sup>4</sup>	Concord – Cooney 138 kV Line	Pleasant Valley – Arthur Road 138 kV Line	121 SE 172 WE	53.3 <sup>5</sup> 53.3 <sup>5</sup>
Concord – Cooney 138 kV Line	10.3 <sup>3</sup> 5.9 <sup>4</sup>	Concord – Crawfish River 138kV Line	Pleasant Valley – Arthur Road 138 kV Line	121 SE 172 WE	53.3 <sup>5</sup> 53.3 <sup>5</sup>
<b>Butler Ridge Not Dispatched</b>					
<b>Prior outage</b>	<b>Allowable G550 MW Output<sup>6</sup></b>	<b>Worst Next Contingency</b>	<b>Most Limiting Element</b>	<b>MVA Rating</b>	<b>TDF %</b>
Concord – Crawfish 138 kV Line	0	Concord – Cooney 138 kV Line	Concord - Rubicon 138kV Line	293 SE	100.0
Concord – Cooney 138 kV Line	0	Concord – Crawfish 138 kV Line	Concord - Rubicon 138kV Line	293 SE	100.0
Concord – Crawfish 138 kV Line	0	Concord - Rubicon 138kV Line	Concord – Cooney 138 kV Line	287 SE 287 WE	100.0
Concord - Rubicon 138kV Line	0	Concord – Crawfish 138 kV Line	Concord – Cooney 138 kV Line	287 SE 287 WE	100.0
Concord - Rubicon 138kV Line	0	Concord – Cooney 138 kV Line	Concord – Crawfish 138 kV Line	287 SE 287 WE	100.0
Concord – Cooney 138 kV Line	0	Concord - Rubicon 138kV Line	Concord – Crawfish 138 kV Line	287 SE 287 WE	100.0

**Notes:**

1. N-2 contingencies were analyzed by linear transfer analysis for the summer 2006 and winter 2006 models.
2. No additional operating restrictions were identified based on angular stability analysis.
3. 2006 G550 delivery to WEC or MISO without Christiana Generating.
4. 2006 G550 delivery to WEC or MISO with Christiana Generating.
5. Depending on the delivery to either WEC or MISO, the TDF can vary by 0.4
6. Estimated MW output from MUST linear analysis.

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

**Notes applicable to Tables C.1 through C.4:**

1. Substation name abbreviations: CCD – CONCORD, CWF – CRAWFISH RIVER, CNY – COONEY, RUB – RUBICON, JEF – JEFFERSON, BTL – BUTLER RIDGE, ROE – ROCKDALE, SUM – SUMMIT, HTF – HARTFORD, MEH – MERRILL HILLS, LHD – LAKEHEAD, ST. LAWRENCE.
2. Color scheme – Green represents acceptable stability performance; Red represents unacceptable stability performance; bolded blue highlights new or upgraded equipment.
3. Fault is three-phase and applied at from end of the “Faulted Facility” unless specified otherwise.
4. WNS – Was Not Simulated. A particular contingency was not simulated for a particular season because the outcome is predictable based on the simulation for the other season, or the outcome would not affect the conclusion of acceptable/unacceptable stability performance or the required upgrade for this contingency.
5. (RS) – Relay Setting Change Required.
6. (RR) – Breaker Failure Relay Replacement Required.
7. (BR) – Breaker Replacement Required.
8. (CM) – Communication Upgrade Required.
9. Far End Primary Clearing Times are approximate values and not actual settings in the field.
10. Breaker failure clear times are exact figures obtained from System Protection.
11. Far End Primary Clearing Times are approximate test limits and not actual settings in the field. Longer times will not affect the results for this study.

**Table C.1 – Stability Analysis Results of Intact System Primary Fault Contingencies For the Expected 2006 Systems Before and After the Addition of G550 Generation**

Item	Faulted Facility	Fault Location	Near, Far Ends Primary Clearing Time (Cycles) <sup>9</sup>	Pre-exist system	With G550	Changes Required
	From – To Ckt			2006 50% Peak Load G550 @ 0 MW	2006 50% Peak Load G550 @ 24 MW	2006 50% Peak Load
1	CCD – CWF	CCD	5.75, 6.0	12.0	11.0	None
2	CCD – CWF (ZONE 2)	CWF	26.0, 6.0	>30.0	>30.0	None
3	CCD – CNY	CCD	6.0, 6.0	12.5	11.5	None
4	CCD – CNY (ZONE 2)	CNY	26.0, 6.0	>30.0	>30.0	None
5	CCD – RUB	CCD	6.0, 6.0	12.5	11.5	None
6	CCD – RUB (ZONE 2)	RUB	26.0, 6.0	>30.0	>30.0	None
7	CCD T8	CCD	6.5, 6.0	>16.0	>16.0	None

**Table C.2 – Stability Analysis Results of Delayed Clearing Contingencies  
For the Expected 2006 System Before and After the Addition of G550 Generation**

Item	Faulted Facilities	Failed Circuit Breaker	Element(s) Cleared In Breaker Failure	Backup Breaker Clearing Time Actual <sup>10</sup> (Cycles)	Far End Primary Clearing Time, Actual <sup>9</sup> (Cycles)	G550 @ 0 MW (Before)		G550 @ 12 MW (After)		G550 @ 24 MW (After)	
						2006 50% peak load 1.02 VS		2006 85% peak load 1.02 VS		2006 50% peak load 1.02 VS	
						Required Clearing Time	Required Changes	Required Clearing Time	Required Changes	Required Clearing Time	Required Changes
1	CCD – RUB	CCD 9061	CCD 4-5	14.0	~6.0	<b>12.5</b>	<b>RR</b>	<b>12.5</b>	<b>RR</b>	<b>11.5</b>	<b>BR</b>
2	CCD – RUB (SLG)	CCD 9061	CCD 4-5	14.0	~6.0	>18.0	None	WNS	WNS	>18.0	None
3	CNY – SUM	CNY 4-5	CCD 9042	46.0	~6.0	<b>31.0</b>	<b>CM</b>	<b>33.0</b>	<b>CM</b>	<b>26.5</b>	<b>CM</b>
4	CNY – SUM (SLG)	CNY 4-5	CCD 9042	46.0	~6.0	>47.0	None	WNS	WNS	>47.0	None
5	CWF – JEF	JEF 4-5	CCD 9043	12.75	~6.0	>30.0	None	WNS	WNS	>30.0	None
6	RUB – BTL	CCD 9061	CCD 4-5	14.0	~6.0	>30.0	None	WNS	WNS	>30.0	None
7	JEF – ROE	JEF 6632	JEF 6631, C3, 4-5	14.25	~6.0	>30.0	None	WNS	WNS	>30.0	None
8	HTF - STL	HTF 5-6	CCD 9061	46.0	~6.0	>47.0	None	WNS	WNS	>47.0	None

**Table C.3 – Stability Analysis Results of Prior Outage Primary Fault Contingencies For the Expected 2006 Systems Before and After the Addition of G550 Generation**

Item	Pre-Existing System Outage	Faulted Facility	Near and Far Ends Primary  Clearing Time  (Cycles) <sup>11</sup>	Pre-existing System	With G550	
	From –To Ckt	From–To Ckt		2006 50% Peak Load G550 @ 0 MW	2006 50% Peak Load G550 @ 24 MW	Allowable MW Output & Power Factor Restriction
1	CCD – CWF	CCD-CNY	6.0,6.0	8.0	6.5	None
2		CCD-RUB	5.5,6.0	9.0	8.0	None
3		CCD T8	6.5,6.0	>16.0	>16	None
4	CCD - RUB	CCD-CWF	5.75,6.0	9.5	8.5	None
5		CCD-CNY	6.0,6.0	8.5	6.5	None
6		CCD T8	6.5,6.0	>16.0	>16.0	None
7	CCD – CNY	CCD-CWF	5.75,6.0	7.5	6.5	None
8		CCD-RUB	5.5,6.0	7.5	5.5	None
9		CCD T8	6.5,6.0	>16.0	14.0	None
10	CNY – SUM	CCD-CWF	5.75,6.0	8.0	7.0	None
11		CCD-CNY	6.0,6.0	11.5	10.5	None
12		CCD-RUB	5.5,6.0	8.0	6.5	None
13		CCD T8	6.5,6.0	>16.0	>16.0	None
14	RUB – BTL	CCD-CWF	5.75,6.0	12.0	11.0	None
15		CCD-CNY	6.0,6.0	12.5	11.0	None
16		CCD-RUB	5.5,6.0	12.5	11.5	None
17		CCD T8	6.5,6.0	>16.0	>16	None
18	JEF – LHD	CCD-CWF	5.75,6.0	12.0	11.0	None
19		CCD-CNY	6.0,6.0	9.0	7.5	None
20		CCD-RUB	5.5,6.0	9.5	8.5	None
21		CCD T8	6.5,6.0	>16.0	>16.0	None
22	SUM - MEH	CCD-CWF	5.75,6.0	11.0	10.0	None
23		CCD-CNY	6.0,6.0	12.5	11.5	None
24		CCD-RUB	5.5,6.0	11.5	10.5	None
25		CCD T8	6.5,6.0	>16.0	>16.0	None
26	CWF - JEF	CCD-CWF	5.75,6.0	12.0	11.0	None
27		CCD-CNY	6.0,6.0	8.5	7.0	None
28		CCD-RUB	5.5,6.0	9.0	8.0	None
29		CCD T8	6.5,6.0	>16.0	>16.0	None
30	BTL - HTF	CCD-CWF	5.75,6.0	12.0	11.0	None
31		CCD-CNY	6.0,6.0	12.5	11.0	None
32		CCD-RUB	5.5,6.0	12.5	11.5	None
33		CCD T8	6.5,6.0	>16.0	>16.0	None

**Table C.4 – Stability Analysis Results of Breaker Internal or Bus Section Fault  
For the Expected 2006 System After the Addition of G550 Generation**

**Not Performed**

## **Appendix D: Short Circuit Analysis Results**

**(Not Performed)**

## **Appendix E: Study Criteria**

## Study Criteria

### E.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.

### E.2 Monitored Elements

#### *E.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.

### E.3 Thermal Loading Criteria

#### *E.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.

#### *E.3.2 Operation Restriction Calculation*

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

### E.4 Steady State Voltage Criteria

#### *E.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 p.u. due to the Generator must not be lower than 0.95 p.u. Under contingency conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 p.u. due to the Generator must not be lower than 0.90 p.u.

#### *E.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.

### E.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.

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.

## **Appendix F: Deliverability Analysis Results**

*Table F.1 – Deliverability Analysis Restrictions*

<b>Limiting Element</b>	<b>Contingency</b>	<b>G550 MW Deliverable</b>	<b>Potential Solution</b>
None	N/A	24 MW	No restrictions

Further details on the MISO Generation Deliverability Study Method can be found in the whitepaper located at:

[http://www.midwestmarket.org/publish/Document/3e2d0\\_106c60936d4\\_-767f0a48324a?rev=4](http://www.midwestmarket.org/publish/Document/3e2d0_106c60936d4_-767f0a48324a?rev=4)

(Navigate to: [www.midwestmarket.org](http://www.midwestmarket.org) > Planning > Generator Interconnection > Generator Deliverability Tests)