



**Interconnection Feasibility Study Report  
280 MW Coal Fired Generation  
Columbia County, Wisconsin**

**G553  
MISO Queue #38625-01**

**February 3, 2006  
American Transmission Company, LLC**

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## 1. Summary

This report contains the Feasibility Study Report for the Generation Interconnection Request Midwest Independent System Operator (“MISO”) project #G553, MISO Queue #38625-01. The purpose of this study is to identify steady state thermal and voltage violations caused by the proposed interconnection. The requested in-service date is June 1, 2011. The requested synchronization date is October 1, 2011.

The G553 generation is proposed to connect to the Columbia substation at 345 kV or 138 kV. Figure 1 shows the existing transmission system including the proposed G553 point of interconnection (“POI”) at 345 kV and Figure 2 represents the G553 POI at 138 kV. The proposed interconnection **does not** show the ultimate expected substation layout. The final interconnection will depend on the thermal, voltage, and stability analysis performed in the Feasibility Study and the Interconnection System Impact Study (“ISIS”) in addition to operational issues and physical space for the new equipment required for support of the interconnection.

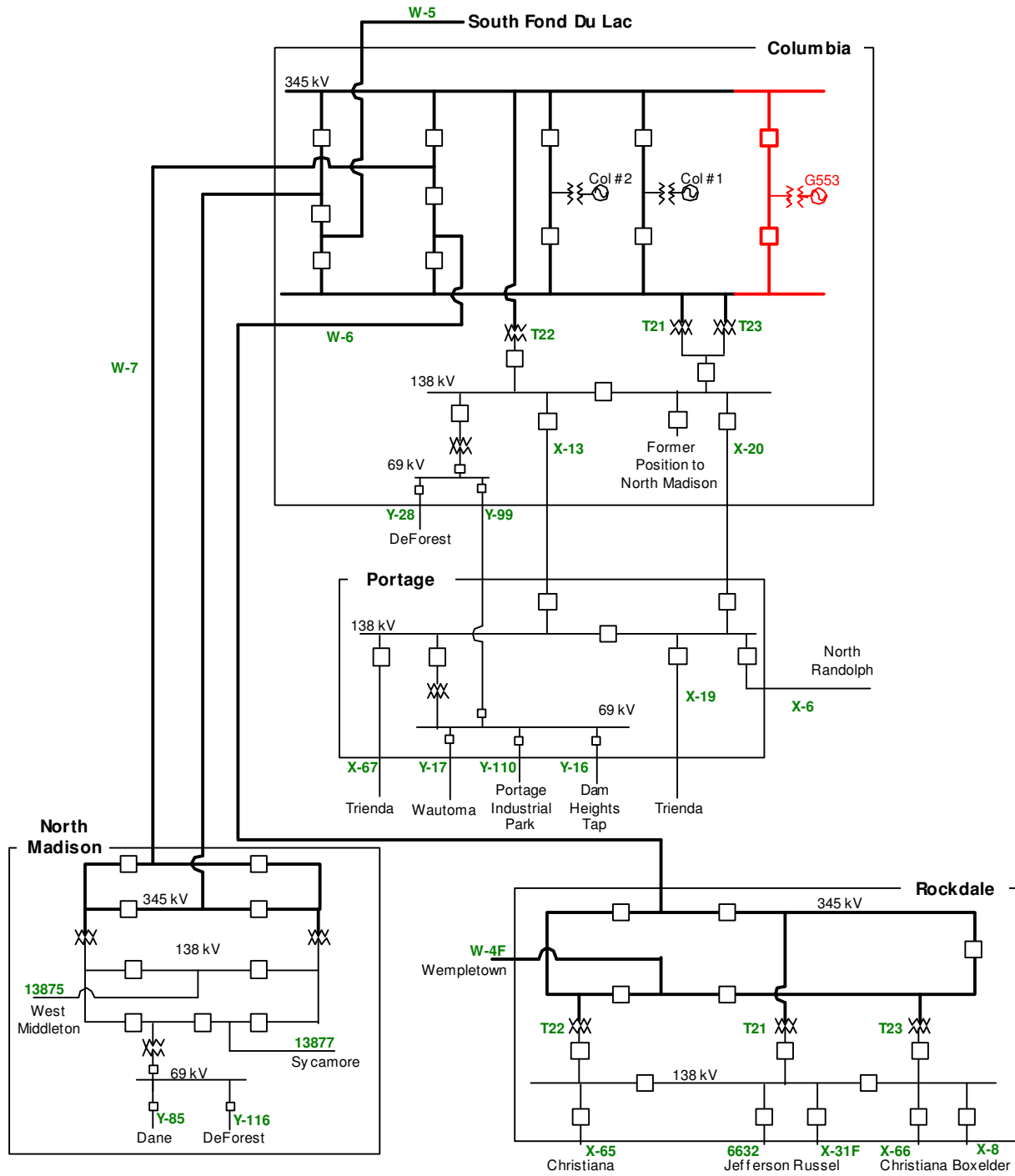


Figure 1: Equivalent modeling of G553 interconnected at the Columbia substation at 345 kV.



An injection analysis study was performed by sourcing 280 MW from G553 and delivering the power to the MISO footprint. The study identified a total of five steady-state NERC Category B (N-1) events resulting in thermal violations as shown in Table A.1. Two of the limits will require mitigation to acquire Energy Resource (ER) or Network Resource (NR) status. These two limits are:

1. Line X-13, Columbia - Portage 138 kV
2. Line X-20, Columbia - Portage 138 kV

The maximum allowable generation due to injection limits was found to be 9 MW for POI at 138 kV and 20 MW for POI at 345 kV as communicated in Table A.2. The plant output may also be limited to zero MW when considering all the identified constraints. The injection study also identified seventeen double contingency violations requiring potential operating restrictions as shown in Table A.3.

Voltage analysis determined that the voltage magnitude of all system busses whose magnitude decreases at least 0.01 p.u. after adding G553 remain above 0.95 pu for the intact system and remain above 0.9 p.u. for the single contingency condition. Hence, the study did not identify any voltage limit violation or need for reactive power capability enhancement specifically due to the addition of G553.

### **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 Columbia substation.

### **Required Interconnection Facilities**

To be determined in the ISIS.

### **Network Upgrades**

To be determined in the ISIS.

### **Special Facility Requirements**

To be determined in the ISIS.

### **Operation Restrictions**

The double contingency analysis identified eighteen operating restrictions on G553 due to thermal constraints. A summary of the operation restrictions on G553 under prior outage conditions is provided in Table B.1 in Appendix B.

## **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 voltage analysis. Details of the analysis criteria applied in this study can be found in the Appendix C.

### **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 Requests with an earlier queue position will impact the G553 study results. G366 is considered a competing request for the interconnection of this generator. G366 is an 80 MW wind unit connected to Friesland 138 kV substation. G527 and G528 are considered mutually exclusive from G553, therefore, G527 and G528 were not modeled in studying G553.

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 Power Technologies, Inc (PTI). All AC solutions were performed using the Power Flow module of the Power System Simulation/Engineering-29 (PSS/E, Version 29) program from 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 and voltage analysis for this study were developed based upon the ATC summer peak 2005 model and the July 2005 build of MISO seasonal cases (accessible through the MISO Extranet). Three cases were developed to model the shoulder peak of 2011, the summer peak of 2011 and winter peak of 2011/12.

The ATC system was modified by updating all loads to the expected coincident peak value and including all proposed projects through 2007 and all planned projects through 2008 as listed in the ATC Ten Year Assessment.

### ***2.2.3.2 Deliverability analysis***

Deliverability analysis, required for G553 to attain NR status, was not performed for this study. This will be performed in the ISIS.

## **2.3 Assumptions**

### **2.3.1 Generation Facility Modeling**

The G553 generation was modeled at 280 MW of real power output connected to the Columbia 345 kV or 138 kV substation via a single 18/345 kV or 18/138 kV generator step-up transformer. The low side of the step up transformer was regulated to 1.03 pu for the power flow analysis, due to the existing Columbia Generation units regulating the low side of the step up transformers to 1.03 p.u. Physical ratings of the Columbia bus sections will be reviewed in the ISIS when the final interconnection configuration at the Columbia substation is determined.

## **3. Analysis Results**

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

#### **3.1.1 Voltage Analysis & Reactive Capability**

Voltage analysis determined that the voltage magnitude of all system busses whose magnitude decreases at least 0.01 p.u. after adding G553 remain above 0.95 pu for the intact system and remain above 0.9 p.u. for the single contingency condition. Hence, the study did not identify any voltage limit violations or need for reactive power capability enhancement specifically due to the addition of G553.

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

Study of the 280 MW injection from G553 identified no steady-state thermal violations for NERC Category A events (Intact System). Five transmission element violations for NERC

Category B events (N-1) were identified. Of these five violations, two transmission elements have been identified as injection limits as given in Table A.1.

The maximum allowable real power output without system upgrades was determined by reducing G553 generation until all steady-state thermal violations due to G553 were resolved. The maximum allowable generation due to injection limits was found to be 9 MW for a POI of 138 kV and 20 MW for POI at 345 kV. The plant output may also be limited to zero MW when considering all the identified constraints. Results of the maximum allowable generation analysis can be found in Table A.2 in Appendix A.

For each of the two injection limits identified in the N-1 analysis, a solution of limited scope is proposed in the footnotes of Table A.1 in Appendix A. These potential solutions are reproduced in Table 3.1 below. Additionally, there are no planned or proposed projects in the ATC 10 Year Assessment report that would mitigate these injection overloads. These solutions were developed in the following order.

1. If the line is not limited by the conductor rating, then replace the terminal equipment.
2. If the line is limited by its conductor rating, then increase phase conductor clearance to the maximum operating temperature of the conductor.
3. If the maximum operating temperature of the conductor does not resolve the limit, then a line reconductor or rebuild is proposed.
4. If another potential solution is known to relieve the overload it is proposed along with the line reconductor or rebuild project.

*Table 3.1: Transmission Projects relieving G553 injection limits*

Limiting Element	Potential Solution
Portage-Columbia 138kV Line X-13 and X-20	<ol style="list-style-type: none"> <li>1. Construct a new, third 138 kV line from Columbia to Portage.</li> <li>2. Convert existing 69 kV line from Columbia to Portage for operation at 138 kV.</li> <li>3. Rebuild/reconductor existing 138 kV lines from Columbia to Portage with high temperature, low sag ACSS conductor or larger conductor.</li> <li>4. New 345/138 kV transformer at the North Randolph Substation.</li> </ol>

The viability of each proposed solution cannot be assessed in the Feasibility Study. It may be possible that a solution is not physically or financially reasonable or that new injection limits might appear once the original injection limit is mitigated due to the changed impedance of a proposed solution. Also, each 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. Solutions of this nature will be developed and examined in the ISIS.

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

Thermal and voltage violations were evaluated for NERC Category C events (N-2) in the electrical proximity of G553. The purpose of the N-2 analysis is to reveal potential violations and identify potential operating restrictions to eliminate the violations under prior outage conditions. The N-2 analysis was performed on the summer peak, shoulder peak and winter peak model.

The double contingency constraints are not required to be resolved for the generator to attain either ER or NR status. All identified operating restrictions will be reviewed in the ISIS as solutions are developed for NERC Category A and B violations.

### ***3.1.3.1 Thermal analysis***

Thermal N-2 analysis was performed using the Summer 2011, Shoulder 2011 and Winter 2011/12 model. The study identified numerous thermal violations as a result of local contingencies. The violations are listed in Table A.3 in Appendix A. In particular, the study identified three double contingencies for which the load flow study could not find an acceptable steady state solution. These three double contingencies are: 1) losing both of the 345 kV lines from Columbia to North Madison, 2) losing all three 345/138 kV Columbia transformers and 3) losing the 138 kV lines from North Madison to Sycamore and North Madison to West Middleton.

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. These restrictions will be reviewed in the ISIS and a complete description of all N-2 limits and operating restrictions will be developed once the required solutions for N-1 limits are identified.

## **Appendix A**

# **Power Flow Analysis Results**

Table A.1 – Identified Thermal Violations due to G553 Delivery to MISO for N-1 Contingencies

Limiting Element	POI Voltage	Existing MVA Rating	Worst MVA G553 = 0 MW	Worst MVA G553 = 280 MW	Required MVA Rating <sup>1</sup>	Worst Contingency	TDF (%)	G553 Outlet	Case Description	Injection Limit	Solution Planned for Limiting Element
Line 63151, Bain – Kenosha 138 kV	138 kV	287	367	377	397	Pleasant Prairie – Zion 345 kV	3.6	No	Summer 2011 <sup>2</sup>	No	No
	345 kV			377			3.6				
Line X-13, Columbia - Portage 138 kV	138 kV	403	381	441	465	Line X-20, Columbia - Portage 138 kV	20.0	Yes <sup>3</sup>	Summer 2011 <sup>2</sup>	Yes	No <sup>4</sup>
	345 kV			409			10.3				
Line X-20, Columbia – Portage 138 kV	138 kV	403	381	441	465	Line X-13, Columbia - Portage 138 kV	20.0	Yes <sup>3</sup>	Summer 2011 <sup>2</sup>	Yes	No <sup>4</sup>
	345 kV			409			10.3				
Line X -19, Portage - Trienda 138 kV	138 kV	240	282	306	323	Line X-67, Portage - Trienda 138 kV	8.7	No	Summer 2011 <sup>2</sup>	No	No
	345 k			297			5.3				
Line X -67, Portage - Trienda 138 kV	138 kV	287	281	305	322	Line X-19, Portage - Trienda 138 kV	8.6	No	Summer 2011 <sup>2</sup>	No	No
	345 kV			295			5.1				

**Notes:**

1. The required MVA rating includes a 5% TRM above the worst MVA loading.
2. The summer season was the only time period found to have N-1 overloads.
3. Substation outlet on the 138 kV side.
4. Limited by line conductor (795.0 kcmil ACSR 26/7 Drake, 200°F Norm, 300°F Emergency). Therefore, a new line, rebuild, reconductor of the existing line, or new 345 kV injection to 138 kV may be required to mitigate the overload.

Table A.2 – Maximum Allowable Generation Without System Upgrades<sup>1</sup>

Limiting Element	G553 @ 138 kV Maximum MW	G553 @ 345 kV Maximum MW	Worst Contingency	Worst Season/Model Description
Line X-13 or X-20, Columbia – Portage 138 kV	9 <sup>2</sup>	20 <sup>2</sup>	Line X-20 or X-13, Columbia – Portage 138 kV	Summer 2011

**Notes:**

1. Only steady state thermal and voltage analysis was considered, stability limitations will be considered in the ISIS.
2. The maximum allowable output is limited due to 5% TRM being applied to the rating of the identified element.

Table A.3 – Identified Thermal Violations due to G553 under N-2 Contingencies

Limiting Element	Existing MVA Rating	Worst MVA Loading	Double Contingency	POI Voltage (kV)	Season <sup>1</sup>	TDF (%)	Solution Planned for Limiting Element	
Load flow did not converge	N/A	N/A	Columbia–North Madison 345 kV # 1 Columbia–North Madison 345 kV # 2	138 & 345	Summer	N/A	No	
Line Y-28, 69 kV Columbia – Poynette	60	103		345	Shoulder	3.9		
Line Y-28, 69 kV Columbia – Poynette	60	106			Winter	6.0		
Load flow did not converge	N/A	N/A	T22 Columbia 345/138 kV Transformer T21 and T23 Columbia 345/138 kV Transformers	345	Summer	N/A	No	
Load Flow did not Converge	N/A	N/A	North Madison - Yahara River 138 kV North Madison – West Middleton 138 kV	138 & 345	Summer	N/A	Yes <sup>2</sup>	
North Madison 138/69 kV Transformer	224	249 257		138	Shoulder	3.5		
	229	252 261		345		Winter		6.2 9.5
13877, 138 kV North Madison – Yahara River Yahara River – American American – Sycamore	316 322 322	362 / 368 346 / 353 323	North Madison – West Middleton 138 kV North Madison 138/69 kV Transformer	138 / 345 138 / 345 345	Summer	6.9 / 9.1 6.9 / 9.1 9.3	Yes <sup>2</sup>	
Line 13877, 138 kV North Madison – Yahara River Yahara River – American	316 322	334 / 340 322 / 329		138 / 345 138 / 345		Shoulder		6.6 / 8.8 6.6 / 8.8
Line 13877, 138 kV North Madison – Yahara River	344	345		345				Winter
Columbia 138/69 kV Transformer	127	194 / 182	Portage – Columbia 138 kV #1 Portage – Columbia 138 kV#2	138 / 345	Summer	7.9 / 3.8	No	
Line Y-99, 69 kV Columbia - Portage	62	110 / 104		138 / 345	Shoulder	6.6 / 4.2		
Columbia 138/69 kV Xfmr	127	145 / 134		138 / 345	Winter	9.0 / 5.0		
Line X-19, 138 kV Portage - Trienda	240	355 / 348	Eden – Wyoming Valley 138 kV Portage – Trienda #2 (Line X-67)	138 / 345	Summer	6.1 / 3.2	No	
Line X-19, 138 kV Portage – Trienda	240	275	Nelson Dewey – Lancaster 138 kV Portage – Trienda #2 (Line X-67)	138	Shoulder	7.3	No	
Line X-67, 138 kV Portage – Trienda	287	354 / 346	Eden – Wyoming Valley 138 kV Portage – Trienda #1 (Line X-19)	138 / 345	Summer	6.1 / 3.4	No	
Portage 138/69 kV Transformer	75	135	North Madison 138/69 kV Transformer Columbia 138/69 kV Transformer	138	Summer	3.1	No	
	96	105			Winter	3.8		
Line X-13, 138 kV Portage – Columbia	403	508 / 483	Columbia – South Fond du Lac 345 kV Portage – Columbia #2 (X-20)	138 / 345	Summer	30.4 / 21.4	No <sup>3</sup>	
	403	409		138	Shoulder	33.9		
Line X-20, 138 kV Portage – Columbia	403	508 / 483	Columbia – South Fond du Lac 345 kV Portage – Columbia #1 (X-13)	138 / 345	Summer	30.4 / 21.4	No <sup>3</sup>	
	403	409		138	Shoulder	33.9		
Line 13875, 138 kV North Madison – West Middleton	305	312	North Madison–Yahara River 138 kV North Madison 138/69 kV Transformer	345	Summer	7.6	Yes <sup>4</sup>	
Line X-52, 138 kV Trienda – Lake Delton	281	300	Nelson Dewey – Lancaster 138 kV Trienda – ACEC Lewiston 138 kV	138	Summer	6.1	No	

Limiting Element	Existing MVA Rating	Worst MVA Loading	Double Contingency	POI Voltage (kV)	Season <sup>1</sup>	TDF (%)	Solution Planned for Limiting Element
Columbia 345/138 kV Transformer T21 and Transformer T23	250 250	270 270	Columbia 345/138 kV Transformer T22 Columbia – South Fond du Lac 345 kV	345	Summer	11.3 11.3	No
Columbia 345/138 kV Transformer T22	478	543	Columbia 345/138 kV Transformer T21 and T23 Columbia – South Fond du Lac 345 kV	345	Summer	22.6	No
Line 6632, 138 kV Rockdale – Lakehead Cambridge Tap	403	411 / 411	Friesland – G366 138 kV Rockdale – Cambridge Tap 138 kV	138 / 345	Summer	5.0 / 5.2	No <sup>5</sup>
Lakehead Cambridge Tap – Jefferson	321	399 / 399		138 / 345		5.0 / 5.2	
Line Y-17, 69 kV Portage – Lakehead Pipeline	42	51	Friesland – G366 138 kV Columbia – South Fond du Lac 345 kV	138	Summer	3.2	Yes <sup>6</sup>
Lakehead Pipeline – ACEC Roslin	42	48				3.2	
ACEC Roslin – Endeavor Tap	42	44				3.2	
Line Y-17, 69 kV Portage – Lakehead Pipeline	42	42		138	Shoulder	3.6	

**Notes:**

1. Summer months are defined as June, July and August. Shoulder months are defined as March, April, May, September, October and November. Winter Months are defined as December, January and February.
2. North Madison T31 138/69 kV Transformer will be mitigated with the construction of the proposed North Madison - Waunakee – Blount 138 kV line with a projected in service date of 2010 for completion of the entire project.
3. The X-13 and X-20, Portage – Columbia 138 kV limits are injections limits that are required to be mitigated in order for G553 to achieve ER or NR status.
4. North Madison – West Middleton 138 kV limit will be mitigated with the planned project of constructing the Rockdale – West Middleton 345 kV project, which is planned for completion in 2011. This project stills requires Wisconsin PSC approval.
5. Lakehead Cambridge Tap – Jefferson 138 kV limit will be mitigated with the planned project of uprating this 138 kV line to the maximum rating allowed by the line conductor. The maximum rating of the line conductor is 403 MVA. This project is planned for completion in 2008. The Rockdale – Lakehead Cambridge Tap 138 kV line is currently at its maximum rating allowed by the existing equipment. This section would become the new limiter once the Lakehead Cambridge Tap – Jefferson section is uprated in 2008.
6. Y-17, Portage – Lakehead Pipeline – ACEC Roslin is scheduled for a maintenance rebuild to be completed by November 2006. Line Y-17 will be rated 49 MVA at Portage if a forward relay setting is not increased with the new impedance of the line conductor. If the forward relay setting is increased the next limiter will be a CT setting limited to 64 MVA.

## **Appendix B**

# **Summary of Operation Restrictions**

Table B.1 – Identified Operation Restrictions on the G553 due to Thermal Constraints<sup>1</sup>

Prior outage	Allowable MW Output	Season <sup>2</sup>	POI Voltage (kV)	Worst Next Contingency	Most Limiting Element	MVA Rating
Columbia – North Madison 345 kV circuit # 1	0 / 0	Summer	138 / 345	Columbia – North Madison 345 kV circuit # 2	Load flow does not converge	N/A
	0	Shoulder	345		Columbia – Poynette 69 kV	60
	0	Winter	345			60
Columbia – North Madison 345 kV circuit # 2	0 / 0	Summer	138 / 345	Columbia – North Madison 345 kV circuit # 1	Load flow does not converge	N/A
	0	Shoulder	345		Columbia – Poynette 69 kV	60
	0	Winter	345			60
T22 Columbia 345/138 kV Transformer	0	Summer	345	T21 and T23 Columbia 345/138 kV Transformers	Load flow does not converge	N/A
	106	Summer	345	Columbia – South Fond du Lac 345 kV	T21 & T23 Columbia 345/138 kV Transformer	250
T21 and T23 Columbia 345/138 kV Transformers	0	Summer	345	T22 Columbia 345/138 kV Transformer	Load flow does not converge	N/A
	0	Summer	345	Columbia – South Fond du Lac 345 kV	T22 Columbia 345/138 kV Transformer	478
Columbia – South Fond du Lac 345 kV	106	Summer	345	T22 Columbia 345/138 kV Transformer	T21 & T23 Columbia 345/138 kV Transformer	250
	0	Summer	345	T21 & T23 Columbia 345/138 kV Transformer	T22 Columbia 345/138 kV Transformer	478
	0 / 0	Summer	138 / 345	Line X-13, Portage – Columbia 138 kV	Line X-20, Portage – Columbia 138 kV <sup>3</sup>	403
	262	Shoulder	138		403	
	0 / 0	Summer	138 / 345	Line X-20, Portage – Columbia 138 kV	Line X-13, Portage – Columbia 138 kV <sup>3</sup>	403
	262	Shoulder	138		403	
	0	Summer	138	Friesland – G366 138 kV	Line Y-17, Portage – Lakehead Pipeline <sup>4</sup>	42
	277	Shoulder			42	
Line X-13, Portage – Columbia 138 kV	0 / 0	Summer	138 / 345	Columbia – South Fond du Lac 345 kV	Line X-20, Portage – Columbia 138 kV <sup>3</sup>	403
	262	Shoulder	138		403	
	0 / 0	Summer	138 / 345	Line X-20, Portage – Columbia 138 kV	Columbia 138/69 kV Transformer	127
	0 / 0	Shoulder	138 / 345		Line Y-99, Columbia – Portage 69 kV	62
	0 / 0	Winter	138 / 345		76	

Prior outage	Allowable MW Output	Season <sup>2</sup>	POI Voltage (kV)	Worst Next Contingency	Most Limiting Element	MVA Rating
Line X-20, Portage – Columbia 138 kV	0 / 0	Summer	138 / 345	Columbia – South Fond du Lac 345 kV	Line X-13, Portage – Columbia 138 kV <sup>3</sup>	403
	262	Shoulder	138			403
	0 / 0	Summer	138 / 345	Line X-13, Portage – Columbia 138 kV	Columbia 138/69 kV Transformer	127
	0 / 0	Shoulder	138 / 345		Line Y-99, Columbia – Portage 69 kV	62
	0 / 0	Winter	138 / 345		76	
Friesland – G366 138 kV	0	Summer	138	Columbia – South Fond du Lac 345 kV	Line Y-17, Portage – Lakehead Pipeline <sup>4</sup>	42
	277	Shoulder			42	
	0 / 0	Summer	138 / 345	Rockdale – Cambridge Tap 138 kV	Lakehead Cambridge – Jefferson <sup>5</sup>	321
Rockdale – Cambridge Tap 138 kV	0 / 0	Summer	138 / 345	Friesland – G366 138 kV	Lakehead Cambridge – Jefferson <sup>5</sup>	321
North Madison – Yahara River 138 kV	0 / 0	Summer	138 / 345	North Madison – West Middleton 138 kV	Load Flow does not Converge	N/A
	0 / 0	Shoulder	138 / 345		North Madison 138/69 kV Transformer	224
	0 / 0	Winter	138 / 345		229	
	184	Summer	345	North Madison 138/69 kV Transformer	North Madison – West Middleton 138 kV	305
North Madison – West Middleton 138 kV	0 / 0	Summer	138 / 345	North Madison – Yahara River 138 kV	Load Flow does not Converge	N/A
	0 / 0	Shoulder	138 / 345		North Madison 138/69 kV Transformer	224
	0 / 0	Winter	138 / 345		229	
	0 / 0	Summer	138 / 345	North Madison 138/69 kV Transformer	North Madison – Yahara River 138 kV <sup>6</sup>	316
	0 / 0	Shoulder	138 / 345		316	
	271	Winter	345		344	
North Madison 138/69 kV Transformer	0 / 0	Summer	138 / 345	North Madison – West Middleton 138 kV	North Madison – Yahara River 138 kV <sup>6</sup>	316
	0 / 0	Shoulder	138 / 345		316	
	271	Winter	345		344	
	0	Summer	138	Columbia 138/69 kV Transformer	Portage 138/69 kV Transformer	75
	52	Winter			96	
	184	Summer	345	North Madison – Yahara River 138 kV	North Madison – West Middleton 138 kV	312
Columbia 138/69 kV Transformer	0	Summer	138	North Madison 138/69 kV Transformer	Portage 138/69 kV Transformer	75
	52	Winter				96

Prior outage	Allowable MW Output	Season <sup>2</sup>	POI Voltage (kV)	Worst Next Contingency	Most Limiting Element	MVA Rating
Line X-67, Portage – Trienda 138 kV	0 / 0	Summer	138 / 345	Eden – Wyoming Valley 138 kV	Line X-19, Portage – Trienda 138 kV	240
	0	Shoulder	138	Nelson Dewey – Lancaster 138 kV		240
Line X-19, Portage – Trienda 138 kV	0 / 0	Summer	138 / 345	Eden – Wyoming Valley 138 kV	Line X-67, Portage – Trienda 138 kV	287
Eden – Wyoming Valley 138 kV	0 / 0	Summer	138 / 345	Line X-67, Portage – Trienda 138 kV	Line X-19, Portage – Trienda 138 kV	240
	0 / 0	Summer	138 / 345	Line X-19, Portage – Trienda 138 kV	Line X-67, Portage – Trienda 138 kV	287
Nelson Dewey – Lancaster 138 kV	0	Shoulder	138	Line X-67, Portage – Trienda 138 kV	Line X-19, Portage – Trienda 138 kV	240
	0	Summer	138	Trienda – ACEC Lewiston 138 kV	Trienda – Lake Delton 138 kV	281
Trienda – ACEC Lewiston 138 kV	0	Summer	138	Nelson Dewey – Lancaster 138 kV	Trienda – Lake Delton 138 kV	281

**Notes:**

1. Additional operating restrictions may be identified in the ISIS due to stability analysis.
2. Summer months are defined as June, July and August. Shoulder months are defined as March, April, May, September, October and November. Winter Months are defined as December, January and February.
3. The X-13 and X-20, Portage – Columbia 138 kV limits are injections limits that are required to be mitigated in order for G553 to achieve ER or NR status.
4. Portage – Lakehead Pipeline is the first line section to experience an overload on line Y-17. The Lakehead Pipeline – ACEC Roslin – Endeavor Tap 69 kV line sections also experience an overload for the same prior outage condition. Y-17, Portage – Lakehead Pipeline – ACEC Roslin is scheduled for a maintenance rebuild to be completed by November 2006. Line Y-17 will be rated 49 MVA at Portage if a forward relay setting is not increased with the new impedance of the line conductor. If the forward relay setting is increased the next limiter will be a CT setting limited to 64 MVA.
5. Lake head Cambridge – Jefferson is first line section to experience an overload on line 6632. The Rockdale – Lakehead Cambridge line section also experiences an overload for the same prior outage condition. Lakehead Cambridge Tap – Jefferson 138 kV limit will be mitigated with the planned project of uprating this 138 kV line to the maximum rating allowed by the line conductor. The maximum rating of the line conductor is 403 MVA. This project is planned for completion in 2008. The Rockdale – Lakehead Cambridge Tap 138 kV line is currently at its maximum rating allowed by the existing equipment. This section would become the new limiter once the Lakehead Cambridge Tap – Jefferson section is uprated in 2008.
6. North Madison – Yahara River is the first line section to experience an overload on line 13877. The Yahara River – American Center – Sycamore line sections also experience an overload for the same prior outage condition.

## **Appendix C**

# **Study Criteria**

## Study Criteria

### C.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.

### C.2 Monitored Elements

#### *C.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.

### C.3 Thermal Loading Criteria

#### C.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.

#### C.3.2 *Operation Restriction Calculation*

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

### C.4 Steady State Voltage Criteria

#### C.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.

#### C.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.

### C.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.