Interconnection Evaluation Study Report

80 MW Wind Generation in

Columbia County, Wisconsin

MISO #G366 (#37909-02)

Prepared for the Midwest ISO

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1. Executive Summary

This report contains the Interconnection Evaluation Study ("IES") for the Generator Interconnection Request ("GIR") MISO project #G366, MISO Queue #37909-02. The purpose of this study is to evaluate the impact of the addition of 80 MW wind generation in Columbia County, Wisconsin. The requested in-service date for this project is December 1, 2005.

Multiple connection configurations for G366 were considered, but only two configurations were studied. In the first configuration, G366 was connected at a voltage of 138 kV on line X6. This configuration was used for the thermal analysis and the majority of stability analysis. For the second configuration, G366 was connected at the proposed Friesland substation approximately 3 miles West of the North Randolph substation. A radial 138 kV line from the North Randolph substation was not chosen as the desired connection configuration for G366 in the Thermal Study due to foreseeable plans by ATCLLC to utilize the open 138 kV position at the North Randolph substation. The one-line diagram of the existing system without the G366 connection is shown in Figure 1.1. The one-line diagrams of the system with the addition of the G366 connection are shown in Figures 1.2 and 1.3.

The proposed G366 wind farm will have a single collection bus at a voltage level of 34.5 kV. A 34.5 kV cable and a 138/34.5 kV transformer will connect the wind farm collection bus to a new straight bus substation that interconnects G366 to the Portage – North Randolph 138 kV line. The generation facility will have a 138 kV breaker on the high side of the generator step up transformer.

This study reviews the stability and thermal violations in the existing system and those due to G366 to determine what system upgrades would be required before the interconnection of G366. Short-circuit impact due to G366 was not evaluated due to the fact that the induction generators typically contribute significant short-circuit current only within the first 1 ~ 1.5 cycles after a fault.

Further Study

The next step in the GIR process is for the Generator to decide whether to proceed with a Facility Study. A Facility Study would investigate whether the enhanced turbine ride-through characteristics will address all of the identified Interconnection Evaluation Study issues. If the proposed machines are modified in such a way that changes the fault current contribution from the wind farm then the Facility Study will evaluate the equipment interrupting duty impacts. The Facility Study would also include a budgetary cost estimate and schedule for any ATC transmission system modifications that are required to resolve the identified impact problems.

Required G366 Interconnection Equipment

A 138kV straight-bus substation is required to interconnect the G366 generation to the ATC transmission system. The Generator is responsible for all apparatus on the G366 side of the Point of Interconnection to the ATC transmission system, including high side disconnect switch and circuit breaker, GSU transformer and all 34.5kV apparatus.

System Upgrades

Existing System Before G366
Stability Related
None.

Breaker Duty Related
The G366 wind farm does not aggravate any existing system condition. Therefore, no upgrades in this regard are required before the in-service date of G366.

Required Upgrades After G366
Stability Related
Improved wind turbine ride-through. Modify relay settings at Portage substation to achieve 17.0 cycle breaker failure clearing time.

Breaker Duty Related
None.

Proposed Upgrades After G366
Thermal Overload Related
The two facilities that were identified as single contingency overloads do have identified solutions that are planned to be in-service. The planned in-service date of those facilities is after the in-service date of G366. Therefore, a Facility Study analysis or a Transmission Service Request Analysis must be performed to further evaluate these elements and the potential solutions.

Operation Restrictions

Operation restrictions on the G366 generation were identified due to thermal constraints for ten prior outage scenarios, a summary of which can be found in Table D.1 in the Appendix D.

No operation restrictions on the G366 generation were identified for any scenarios in the stability analysis.

Figure 1.1 – One Line Diagram of the Existing System Before the Addition of G366

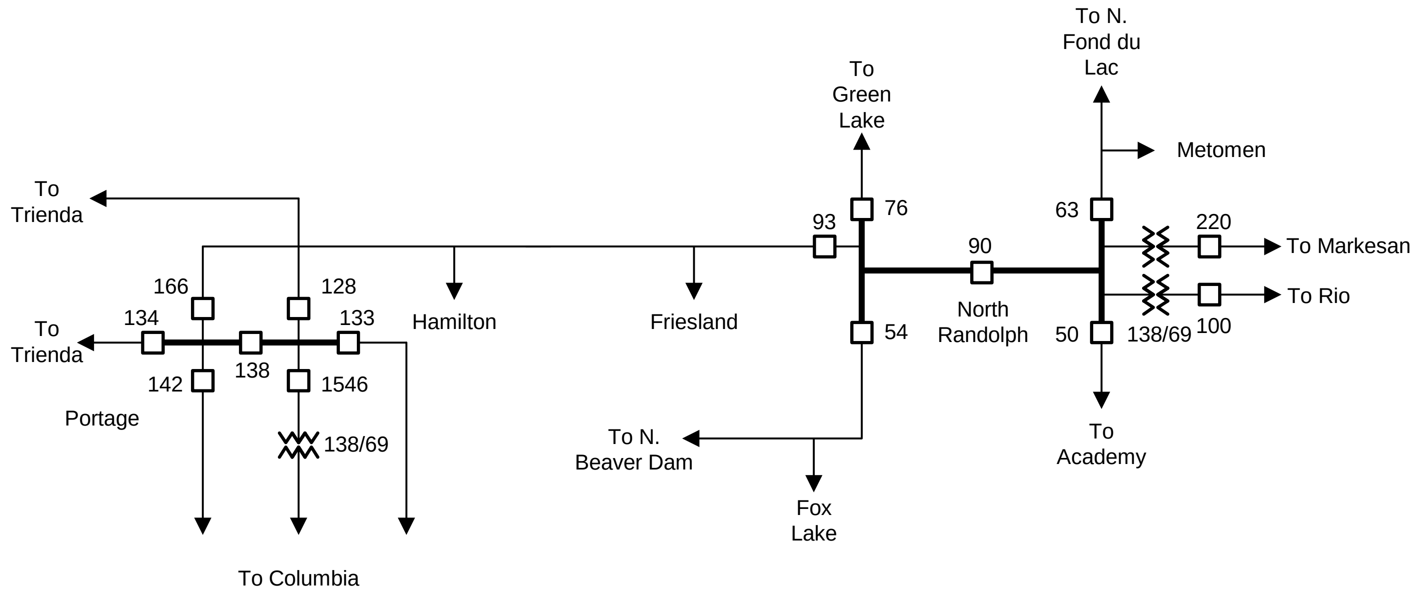


Figure 1.2 – One Line Diagram of the System After the Addition of G366 (Option #1)

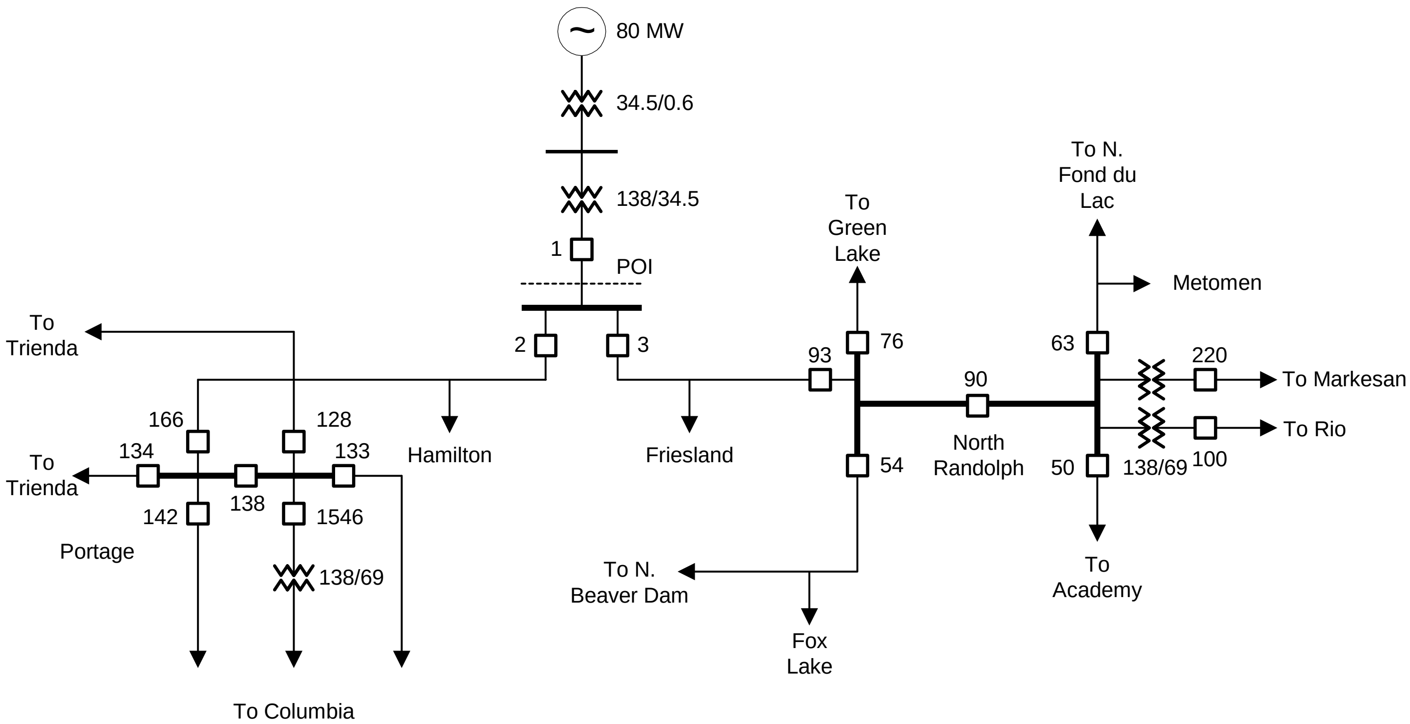
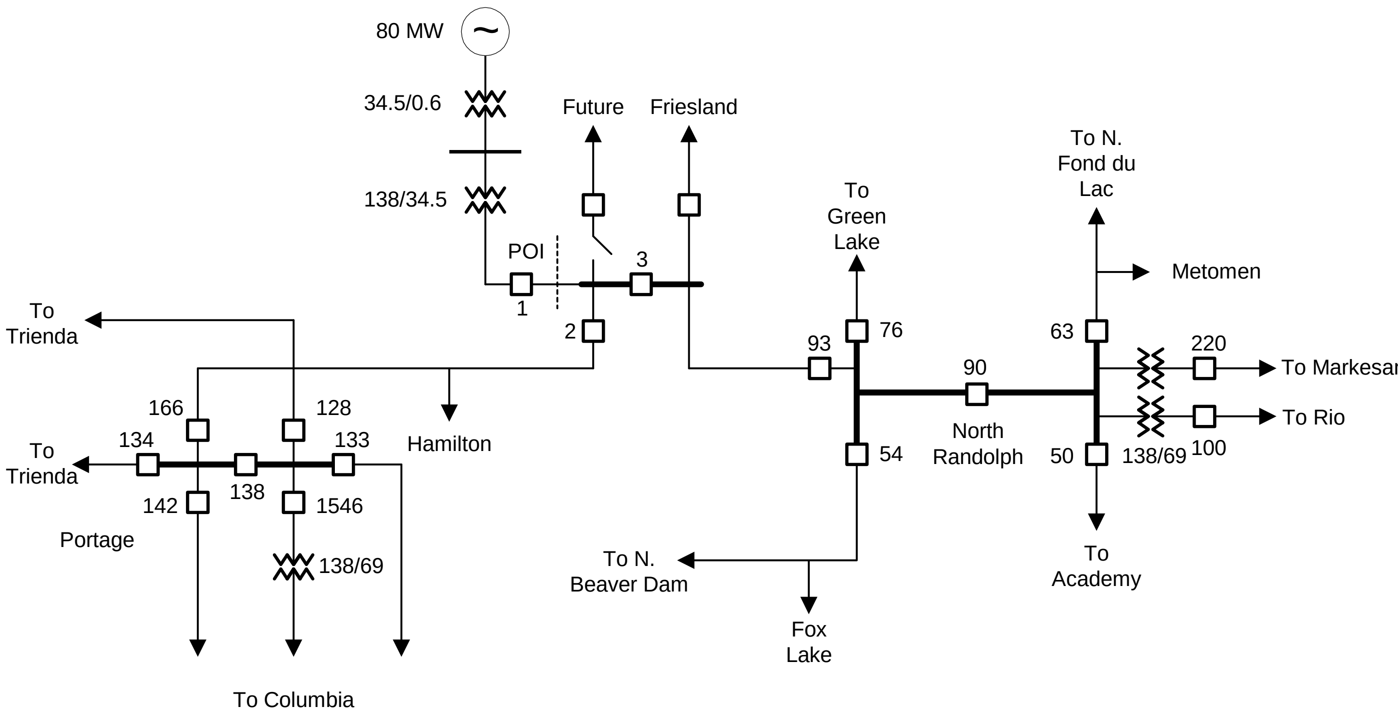


Figure 1.3 – One Line Diagram of the System After the Addition of G366 (Option #2)



2. Criteria, Methodology and Assumptions

2.1 Study Criteria

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

2.2 Study Methodology

The results of this study are subject to change. The results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the generator and controls data, in earlier queue GIRs, 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 ATC prior to commercial operation.

2.2.1 Competing Generator Requests

ATC determined in its sole judgment that no GIRs with an earlier queue position will impact the G366 study results.

Public information related to GIR queues can be found via the MISO web site at http://oasis.midwestiso.org/documents/ATC/queue.html

2.2.2 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 G366 interconnection; two system conditions were examined - “Before” the addition of G366 and “After” the addition of G366. 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 G366. Only those existing system violations that are made worse by the G366 wind farm are deemed relevant to the G366 interconnection request and are documented in this report. Any other identified existing system violations that are not made worse by the G366 wind farm are deemed unrelated to the G366 interconnection request and are documented elsewhere as part of the internal ATC planning projects.

2.2.2 Linear Transfer Analysis and A.C. Load Flow Analysis Methods Employed in Thermal Overload and Steady-State Voltage Evaluations

Linear Transfer Analysis modules of the Managing and Utilizing System Transmission-5.0 (MUST, Version 5.0) program from Power Technologies, Inc (PTI) was used in this study to initially identify thermal overloads. Models were created to simulate two seasons of operation, summer and winter. Two models were then created for each season, one with G366 and one without G366. Overload violations were initially identified using the models containing G366 at an output of 80 MW. The same conditions causing the overload violations in MUST were then tested in PSS/E – Version 28.0 program from Power Technologies, Inc (PTI) in both the models containing and not containing G366 to determine the net impact that G366 caused on the elements with the overload violations. The identified conditions causing overloads in MUST are then tested in PSS/E using base cases with and without G366 to determine the thermal overloads caused by G366. A distribution factor margin of 3% was used when comparing flows in the base cases with and without G366 for the single contingency analysis.

Voltage violations were identified using PSS/E – Version 28. The models containing G366 were evaluated for bus voltages below ATC standard bus voltage levels of 0.90 per unit for single contingency events and 0.95 per unit for intact system. Identified voltage violations were then tested in the models not containing G366. The two voltage values were compared for net impact under the same outage scenarios. Only the bus voltages that violate ATC's standard voltage criteria and voltages that were lower in the G366 connected model than the model without G366 with a voltage margin of 0.01 p.u. are reported in this thermal study.

2.2.3 Base Cases

In the stability analysis of this study, a 2005 50% summer peak load case was used. This base case was developed based on the NERC 2002 series MMWG (Multi-Regional Modeling Working Group) 2005 summer peak load case. The original case was modified by scaling the load up by 3% and economically dispatching generation.

In the thermal overload analysis of this study, MISO (Midwest Independent System Operator) monthly cases of January 2005 and July 2004 were used. The MISO monthly cases are accessible through MISO Extranet.

2.3 Assumptions

2.3.1 Generation Facility Modeling

The G366 wind farm is modeled by a lumped representation in this study. It is modeled as a generator in the load flow case and represented by a user-written model in the dynamic simulations. This user-written model includes dynamic representations of the induction generator, frequency relays and tripping. The wind turbine fault ride-through capability is included in the modeling as shown in Appendix D.

3. Analysis Results

3.1 Stability Analysis Results

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

Only one base scenario, 50% of summer 2005 peak load, was evaluated in the stability analysis.

The stability criteria used in this study require that all machines modeled in the system must remain stable after a three-phase fault is cleared from any transmission element under the following conditions:

1) Fault cleared in primary time with an otherwise intact system
2) Fault cleared in primary clearing time with a pre-existing outage of any other transmission element.

The stability criteria also require that all machines remain stable for a fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system. Wind turbines are exempt from this criterion, but must not aggravate system deficiencies.

Transient stability studies were performed to determine if the critical clearing times for all pertinent contingencies were less than the maximum expected breaker failure clearing times. Any critical clearing times that were less than the actual breaker failure clearing times would, therefore, be considered unacceptable.

3.1.1 Results of Primary Fault Contingencies

The primary fault contingencies evaluated and the study results are summarized in Table A.1 in Appendix A. Stability analysis did not identify stability violations for any primary fault contingencies studied when the G366 generation is at its full capacity of 80 MW. No damping violations were found for any of the primary fault contingencies studied.

3.1.2 Results of Breaker Failure Contingencies

The breaker failure contingencies evaluated and the study results are summarized in Table A.2 in Appendix A. Stability analysis did not identify stability violations for any of breaker failure contingencies studied when the G366 generation is at its full capacity of 80 MW. Stability analysis was performed in the existing system for the only unacceptable breaker failure contingency identified after the addition of G366. This contingency is summarized in Table A.3 in Appendix A. No damping violations were found for any of the breaker failure contingencies studied.

3.1.3 Results of Prior Outage Contingencies

The prior outage contingencies evaluated and the study results are summarized in Table A.4 in Appendix A. Stability analysis did not identify stability violations for any prior outage contingencies studied when the G366 generation is at its full capacity of 80 MW. No damping violations were found for any of the prior outage contingencies studied.

3.1.5 Recommended Solutions for the Wind Turbines

This study identified that using the original fault ride-through capability, the wind turbines trip for many of the studied primary and prior outage contingencies, which is unacceptable. Improved fault ride-through capability for the wind turbines is required for the G366 interconnection.

An improved ride-through capability can be achieved by enhancing the turbine ride-through characteristics - voltage threshold and/or time delay. Application of Static VAR Compensation will also help improve the turbine ride-through capability under disturbances.

A properly sized and located Static VAR Compensation device alone may be sufficient for minimizing system voltage violations, while a combination of Static VAR Compensation device and enhanced turbine ride-through characteristics will be required to significantly improve turbine ride-through capability under disturbances.

3.2 Short-Circuit Analysis Results

Short-circuit analysis was not performed due to the fact that the induction generators typically contribute significant short-circuit current only within the first 1 ~ 1.5 cycles after a fault. No system upgrades due to breaker duty are required prior to the interconnection of G366.

The maximum and minimum short-circuit duties at the G366 Point of Interconnection (POI) and the Thevenin equivalent impedances at the G366 POI are provided in Tables B.1 through B.3 in the Appendix B.

3.3 Thermal Analysis Results

The thermal overload analysis was performed using the Linear Transfer Analysis modules of the Managing and Utilizing System Transmission-5.0 (MUST, Version 5.0) program from Power Technologies, Inc (PTI). This program is accepted industry-wide for transfer analysis. Thermal overload analysis was also performed using the AC Contingency Solution analysis tool within the PSS/E – Version 28.0 program from Power Technologies, Inc (PTI). This program is accepted industry-wide for thermal overload analysis.

The thermal analysis was performed using two MISO monthly base cases. A model was created to simulate conditions in January 2006 and July 2006. The January 2006 model was initially a MISO January 2005 model created from the 2001 Series NERC/MMWG. Loads were scaled to expected Winter 2005/06 peak levels. All ATC projects projected to be completed and in-service by June 2005 were added to the January 2006 model.

The July 2006 model was initially a MISO July 2004 model created from the 2002 Series NERC/MMWG. Loads were scaled to expected Summer 2006 peak levels. All ATC projects expected to be completed and in-service by June 2006 were added to the July 2006 model. The 80MW G366 generation was delivered to the MGE control area in this study. The G366 generation was assumed operating at 95% leading power factor.

Table C.1 and C.2 list the thermal overloads in which G366 contributes to the loading problem. Table C.3 lists the voltage violations in which G366 contributes to the voltage violation.

Appendix A

Stability Analysis Results

Notes:

1. All analysis performed with G366 operating at unity power factor.
2. Table abbreviations: NOR – North Randolph, POR – Portage, GSS – Green Lake, NBD – North Beaver Dam, RIO – Rio Pumping Station, COL – Columbia, TRI – Trienda, NMA – North Madison. All items with a "b" suffix were analyzed using the Option #2 configuration.
3. The fault is applied at the first named terminal of the faulted element unless otherwise noted. All faults modeled were 3-phase faults.
4. Calculated CCT = Critical Clearing Time (cycles). MECT = Actual Maximum Expected Clearing Time (cycles). Red cell indicates actual equipment clearing times that times that are inadequate.

Table A.1 – Stability Analysis Results of Primary Fault Contingencies For the Expected 2005 System After the Addition of G366 Generation

Item	Faulted Facilities	MECT	Calculated CCT	Transient problems
1	G366 – NOR 138kV	-	≥6.0	G366 tripped
2	G366 – POR 138kV	-	≥6.0	G366 tripped
3	NOR – G366 138kV	5.0	≥6.0	G366 tripped
3b	NOR – G366 138kV	5.0	≥6.0	G366 tripped
4	NOR – GSS 138kV	5.0	≥6.0	G366 tripped
5	NOR – NBD 138kV	5.0	≥6.0	G366 tripped
6	NOR – RIO 69kV	5.0	≥6.0	G366 tripped
7	POR – COL 138kV	5.0	≥6.0	G366 tripped
8	POR – G366 138kV	5.0	≥6.0	G366 tripped
8b	POR – G366 138kV	5.0	≥6.0	G366 tripped
9	POR – TRI 138kV	5.0	≥6.0	G366 tripped
10	POR – COL 69kV	5.0	≥6.0	G366 tripped

Table A.2 – Stability Analysis Results of Breaker Failure Contingencies For the Expected 2005 System After the Addition of G366 Generation

Item	Faulted Facilities	Failed Circuit Breaker	Element(s) Cleared In Breaker Failure	MECT	Calculated CCT	Transient problems
1	G366 – NOR 138kV	G366 3	G366 1, 2	-	≥28.0	G366 tripped
2	G366 – POR 138kV	G366 2	G366 1, 3	-	≥28.0	G366 tripped
3	NOR – G366 138kV	NOR 93	NOR 54, 76, 90	18.0	≥28.0	G366 tripped
3b	NOR – G366 138kV	NOR 93	NOR 54, 76, 90	18.0	≥28.0	G366 tripped
4	NOR – GSS 138kV	NOR 76	NOR 54, 90, 93	18.0	≥28.0	G366 tripped
5	NOR – NBD 138kV	NOR 54	NOR 76, 90, 93	18.0	≥28.0	G366 tripped
6	NOR – RIO 69kV	NOR 102	NOR 100, 220, 638	18.0	≥28.0	G366 tripped
7	POR – COL 138kV	POR 142	POR 134, 138, 166	18.0	22.0	G366 tripped
8	POR – G366 138kV	POR 166	POR 134, 138, 142	18.0	19.0	G366 tripped
8b	POR – G366 138kV	POR 166	POR 134, 138, 142	18.0	19.0	G366 tripped
9	POR – TRI 138kV **Unacceptable**	POR 134	POR 138, 142, 166	18.0	18.0	G366 tripped
10	POR – COL 69kV	POR 1546	POR 128, 133, 138	18.0	≥28.0	G366 tripped

Table A.3 – Stability Analysis Results of Breaker Failure Contingencies For the Expected 2005 System Without G366 Generation

Item	Faulted Facilities	Failed Circuit Breaker	Element(s) Cleared In Breaker Failure	MECT	Calculated CCT	Transient problems
1	POR – TRI 138kV	POR 134	POR 134, 138, 166	18.0	≥19.0	FV at POR, COL, TRIA, and NMA

Table A.4 – Stability Analysis Results of Prior Outage Contingencies For the Expected 2005 System After the Addition of G366 Generation

Prior Outage	Item	Faulted Facilities	MECT	Calculated CCT	Transient problems
COL – SFL 345kV	1	G366 – NOR 138kV	-	≥6.0	G366 tripped
	2	G366 – POR 138kV	-	≥6.0	G366 tripped
	3	NOR – G366 138kV	5.0	≥6.0	G366 tripped
	4	NOR – GSS 138kV	5.0	≥6.0	G366 tripped
	5	NOR – NBD 138kV	5.0	≥6.0	G366 tripped
	6	POR – COL 138kV	5.0	≥6.0	G366 tripped
	7	POR – G366 138kV	5.0	≥6.0	G366 tripped
	8	POR – TRI 138kV	5.0	≥6.0	G366 tripped
NOR – G366 138kV	9	G366 – NOR 138kV	N/A	N/A	N/A
	10	G366 – POR 138kV	N/A	N/A	N/A
	11	NOR – G366 138kV	N/A	N/A	N/A
	12	NOR – GSS 138kV	5.0	≥6.0	None
	13	NOR – NBD 138kV	5.0	≥6.0	None
	14	POR – COL 138kV	5.0	≥6.0	G366 tripped
	15	POR – G366 138kV	N/A	N/A	N/A
	16	POR – TRI 138kV	5.0	≥6.0	G366 tripped
NOR – GSS 138kV	17	G366 – NOR 138kV	5.0	≥6.0	G366 tripped
	18	G366 – POR 138kV	5.0	≥6.0	G366 tripped
	19	NOR – G366 138kV	5.0	≥6.0	G366 tripped
	20	NOR – GSS 138kV	N/A	N/A	N/A
	21	NOR – NBD 138kV	5.0	≥6.0	G366 tripped
	22	POR – COL 138kV	5.0	≥6.0	G366 tripped
	23	POR – G366 138kV	5.0	≥6.0	G366 tripped
	24	POR – TRI 138kV	5.0	≥6.0	G366 tripped
POR – COL 138kV	25	G366 – NOR 138kV	5.0	≥6.0	G366 tripped
	26	G366 – POR 138kV	5.0	≥6.0	G366 tripped
	27	NOR – G366 138kV	5.0	≥6.0	G366 tripped
	28	NOR – GSS 138kV	5.0	≥6.0	G366 tripped
	29	NOR – NBD 138kV	5.0	≥6.0	G366 tripped
	30	POR – COL 138kV	N/A	N/A	N/A
	31	POR – G366 138kV	5.0	≥6.0	G366 tripped
	32	POR – TRI 138kV	5.0	≥6.0	G366 tripped
POR – G366 138kV	33	G366 – NOR 138kV	N/A	N/A	N/A
	34	G366 – POR 138kV	N/A	N/A	N/A
	35	NOR – G366 138kV	N/A	N/A	N/A
	36	NOR – GSS 138kV	5.0	≥6.0	G366 tripped
	37	NOR – NBD 138kV	5.0	≥6.0	G366 tripped
	38	POR – COL 138kV	5.0	≥6.0	None
	39	POR – G366 138kV	N/A	N/A	N/A
	40	POR – TRI 138kV	5.0	≥6.0	None

Appendix B

Short Circuit Analysis

Table B.1 – Maximum and Minimum Fault Duties
At the G366 Point of Interconnection without the Contribution from G366

Maximum Fault Duty		**Minimum Fault Duty**	
Single-phase	**Three-Phase**	**Single-phase**	**Three-Phase**
7200 Amps	9900 Amps	2530 Amps	3950 Amps

Note: Minimum fault duty was calculated with the 138kV line North Randolph – G366 out of service.

Table B.2 – Thevenin Equivalent Impedances in Ohms in Intact System
At the G366 Point of Interconnection without the Contribution from G366

Pos Seq.	**Neg. Seq.**	**Zero Seq.**
1.52 + j7.92	1.52 + j7.92	3.77 + j16.6

Table B.3 – Thevenin Equivalent Impedances in Ohms
In the System without the 138kV Line North Randolph – G366
At the G366 Point of Interconnection without the Contribution from G366

Pos Seq.	**Neg. Seq.**	**Zero Seq.**
3.08 + j19.9	3.08 + j19.9	13.0 + j52.7

Appendix C

Power Flow Analysis

Table C.1 – January 2006 Thermal Overloads Identified
80 MW Generation Delivery from G366 to MGE Control Area

Limiting Element	Existing MVA Rating	Worst Contingency	MVA Flow without G366	MVA Flow with G366	Solution for Limiting Element
Single Contingencies					
West Middleton – Blackhawk 69 kV	111	North Madison – Yahara River 138 kV	89	120	Yes[1]
Fitchburg – Wingra 69 kV	82	North Madison – Yahara River 138 kV	62	82	Yes[1]
Double Contingencies					
North Madison 345/138 kV Transformer #2	255	Columbia-North Madison 345 kV & North Madison Transformer #1	283	310	Yes[2]
North Madison 345/138 kV Transformer #1	255	Columbia-North Madison 345 kV & North Madison Transformer #2	283	310	Yes[2]
Columbia – Manley Sand 69 kV	72	Columbia-North Madison 345 kV & Columbia-North Madison 138 kV	86	94	No[3]
Manley Sand – Poynette 69 kV	72	Columbia-North Madison 345 kV & Columbia-North Madison 138 kV	80	88	No[3]
Poynette – Deforest 69 kV	72	Columbia-North Madison 345 kV & Columbia-North Madison 138 kV	71	79	No[3]

Note: All ratings referenced in this table are winter emergency ratings.

1. The Kegonsa – McFarland – Femrite 69 kV conversion to 138 kV, Sycamore – Reiner – Sprecher 69 kV conversion to 138 kV and the Femrite – Sprecher 138 kV new construction will remove this overload. This project is scheduled for completion by June 1, 2007.
2. The Columbia – North Madison 138 kV conversion to 345 kV project includes replacement of the existing North Madison 345/138 kV Transformers to 500 MVA units. This project is scheduled for completion by June 1, 2006.
3. There is no proposed solution to solve the loading problems on the Columbia – Manley Sand – Poynette – Deforest 69 kV line. If this situation would be encountered, ATC would take action by redispatching generation to reduce this overload condition.

Table C.2 – July 2006 Thermal Overloads Identified
80 MW Generation Delivery from G366 to MGE Control Area

Limiting Element	Existing MVA Rating	Worst Contingency	MVA Flow without G366	MVA Flow with G366	Solution for Limiting Element
Single Contingencies					
There were no single contingencies found to cause overloads in the Summer Model					
Double Contingencies					
Columbia – Manley Sand 69 kV	69	Columbia-North Madison 345 kV Circuit #1 & #2	92	98	No[1]
Manely Sand – Poynette 69 kV	69	Columbia-North Madison 345 kV Circuit #1 & #2	82	88	No[1]
Poynette – Deforest 69 kV	69	Columbia-North Madison 345 kV Circuit #1 & #2	71	77	No[1]
G366 Generation Bus – North Randolph 138 kV	240	Columbia-South Fond du lac 345 kV & Rockdale-Cambridge Tap 138 kV	244	284	No[2]
North Fond du Lac – Aviation 138 kV	228	South Fond du Lac-Fitzgerald 345 kV & Edgewater-Cedarsauk 345 kV	221	232	No[3]
Chaffee Creek – Coloma Tap 69 kV	36	Columbia-South Fond du Lac 345 kV & North Randolph-G366 138 kV	35.3	37.5	No[4]

Note: All ratings referenced in this table are summer emergency ratings.

1. There is no previously identified project by ATC to solve the loading problems on the Columbia – Manley Sand – Poynette – Deforest 69 kV line. If this situation would be encountered, ATC would take action by redispatching generation to reduce this overload condition.
2. There is no previously identified project by ATC to relieve this overload. The line conductor operating temperature can possibly be increased to achieve the necessary rating, or an operating restriction could be placed on G366 during prior outage events involving one of these two transmission elements. Increasing the operating temperature of the line conductor would require further investigation by ATC Design Engineering and a line survey.
3. There is no previously identified project by ATC to solve the loading problem on the North Fond du Lac – Aviation 138 kV line. This line would have to be reconductored or rebuilt to increase it's rating or an operating restriction may be placed upon G366 output.
4. There is no previously identified project by ATC to solve the loading problem on the Chaffee Creek – Columa Tap 69 kV line. The line rating could possibly be increased with a CT setting change at Chaffee Creek. This would have to be approved by the ATC System Protection Group.

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Appendix D

Summary of Operation Restrictions

Table D.1 – Identified Operation Restrictions on the G366 Generation Under Prior Outage Scenarios

Prior Outage	G335 Max Allowable Output	Worst Next Contingency	Limiting Element	MVA Rating	Reason	Season
Columbia – North Madison 345 kV Circuit #1	0.0 MW	North Madison 345/138 kV Transformer #1 or #2	North Madison 345/138 kV Transformer #2 or #1	255	Thermal	Winter[1]
North Madison 345/138 kV Transformer #1 or #2	0.0 MW	Columbia – North Madison 345 kV Circuit #1	North Madison 345/138 kV Transformer #2 or #1	255	Thermal	Winter[1]
Columbia – North Madison 138 kV Circuit #1	0.0 MW	Columbia – North Madison 345 kV Circuit #1	Columbia – Manley Sand – Poynette – Deforest 69 kV	72	Thermal	Winter[2]
Columbia – North Madison 345 kV Circuit #1 or #2	0.0 MW	Columbia – North Madison 345 kV Circuit #2 or #1	Columbia – Manley Sand – Poynette – Deforest 69 kV	69	Thermal	Summer
Columbia – South Fond du Lac 345 kV Circuit #1	0.0 MW	Rockdale – Cambridge Tap 138 kV Circuit #1	G366 – North Randolph 138 kV Circuit #1	240	Thermal	Summer
	25.5 MW	North Randolph – G366 138 kV Circuit #1	Chaffee Creek – Coloma Tap 69 kV Circuit #1	36	Thermal	Summer
Rockdale – Cambridge Tap 138 kV Circuit #1	0.0 MW	Columbia – South Fond du Lac 345 kV Circuit #1	G366 – North Randolph 138 kV Circuit #1	240	Thermal	Summer
South Fond du Lac – Fitzgerald 345 kV Circuit #1	50.9 MW	Edgewater – Cedarsauk 345 kV Circuit #1	North Fond du Lac – Aviation 138 kV Circuit #1	228	Thermal	Summer
Edgewater – Cedarsauk 345 kV Circuit #1	50.9 MW	South Fond du Lac – Fitzgerald 345 kV Circuit #1	North Fond du Lac – Aviation 138 kV Circuit #1	228	Thermal	Summer
North Randolph – G366 138 kV Circuit #1	25.5 MW	Columbia – South Fond du Lac 345 kV Circuit #1	Chaffee Creek – Coloma Tap 69 kV Circuit #1	36	Thermal	Summer

1. The existing North Madison 345/138 kV Transformers that are emergency rated at 255 MVA will be replaced with 625 MVA emergency rated transformers prior to the summer of 2006, but not prior to the winter of 2005/06.
2. The existing Columbia – North Madison 138 kV line will be converted to 345 kV operation prior to the summer of 2006, but is will remain at 138 kV operation for the winter of 2005/06.

Appendix E

Proposed Fault Ride-Through Characteristics For G366 Wind Turbines

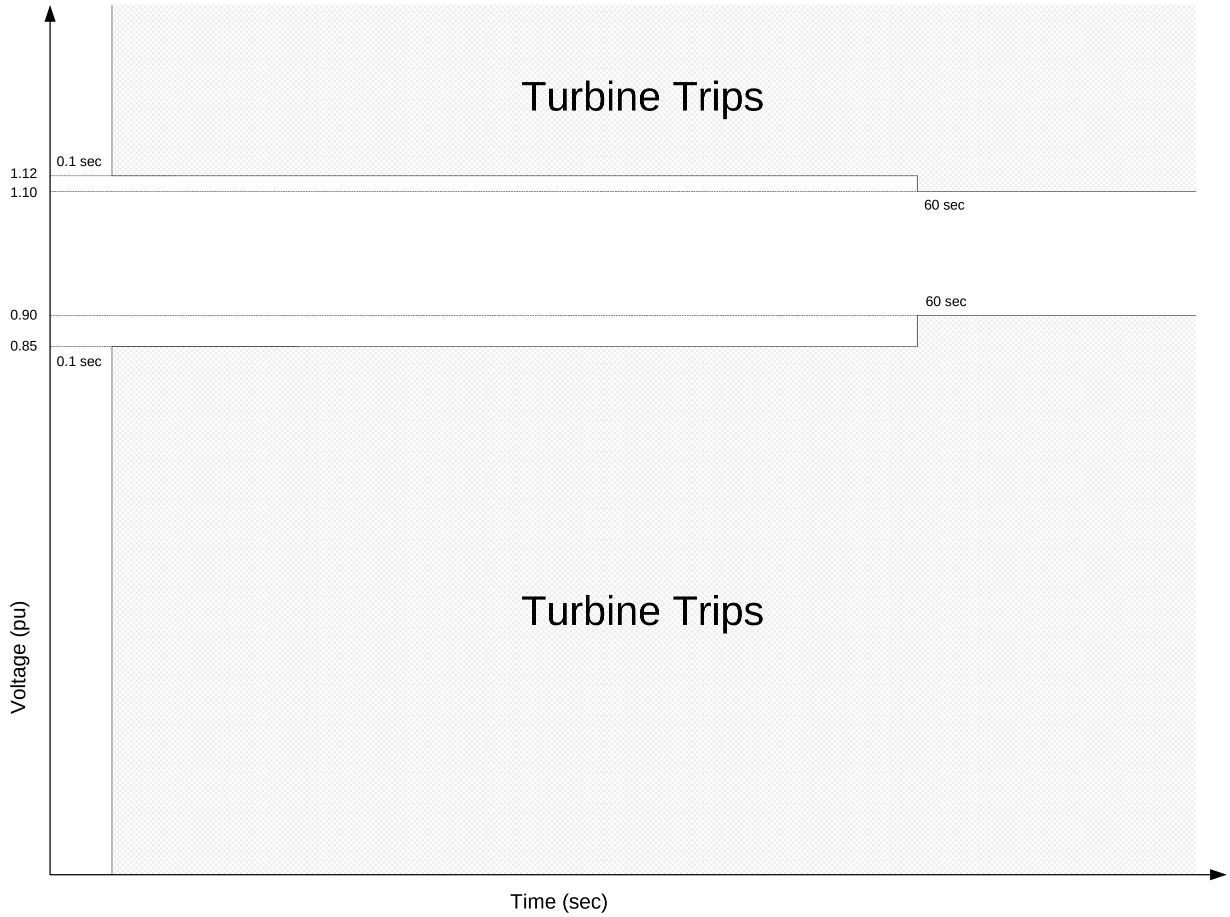

Figure E.1 – Proposed Fault Ride-Through Characteristics Related to Under Voltage Tripping of G366 Wind Turbines

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 three categories of contingency conditions:

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

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

F.2 Monitored Elements

For power flow analysis, load carrying elements of voltage level above 69kV in the ATC areas – Alliant East Control Area, Wisconsin Electric Power Co. Control area, Wisconsin Public Service Corp Control Area and Upper Peninsula Power Co. Control Area were monitored in this Study. Flowgates in MISO footprint are also monitored, the results of which can be referenced by MISO.

F.3 Thermal Loading Criteria

For the normal (intact) system conditions, the loading of all transmission system elements with distribution factors greater than 0.05 must not exceed 95% of the summer normal rating (Rate A). For contingency system conditions, the loading of all transmission system elements with distribution factors greater than 0.03 must not exceed 95% of the summer emergency rating (Rate B).

F.4 Stability Criteria

Critical Clearing Time (CCT) is a period relative to the start of a fault, within which all generators in the system remain stable (synchronized). CCT is obtained from simulation. Maximum Expected Clearing Time (MECT) determines a period of time that is needed to clear a fault using the existing system facilities. MECT is dictated by the existing system facilities. In any contingency, if the computed CCT is less than the MECT plus a margin determined by ATC (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 stability analysis, voltages of all transmission system buses must recover to be at least 70% of the nominal system voltages immediately after the fault removal and 80% of the nominal system voltages in 0.5 second after fault removal.