Interconnection Evaluation Study Report

160 MW Wind Generation in
Green Lake/Fond du Lac County, Wisconsin
MISO # G376 (#37935-03)

Prepared for the Midwest ISO

October 15, 2004

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1. Summary

This report contains the Interconnection Evaluation Study ("IES") for Generation Interconnection Request ("GIR") MISO project #G376, MISO Queue # 37935-03. This study identifies potential system loading, voltage violations and stability problems that are caused by or aggravated by the connection of G376, a proposed 160 MW wind farm to be located at the border of Green Lake and Fond du Lac Counties, Wisconsin. The requested in-service date for this project is June 1, 2006.

The proposed wind farm will connect to the 138 kV line between Green Lake and North Fond du Lac substations (line X-4). Figure 1.1 shows the system one-line diagram before G376 has been added. Alternative interconnections are to the adjacent 138 kV line between Metomen and North Randolph (line X-3) or to both circuits (line X-3 and line X-4).

The proposed G376 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 substation to be located near the X-4 line in a two breaker straight bus configuration, as shown in the Figure 1.2.

Further Study

After reviewing this study report, the next step is for the customer to decide whether or not to proceed with the Interconnection System Impact Study ("ISIS") portion of the MISO Attachment X process. The ISIS will identify the system upgrades that will eliminate all the identified impacts.

Point of Interconnect Power Factor Requirement

Voltage studies identified several low voltage violations due to the addition of G376. To mitigate these voltage problems, G376 is required to have a power factor, as measured at the point of interconnection ("POI"), no less than 0.99 p.u. leading (absorbing).

Required G376 Interconnection Equipment

The proposed G376 wind farm will have a single collection bus at a voltage level of 34.5 kV. A single 138/34.5 kV transformer will connect the wind farm collection bus to a new substation to be located near the X-4 line in a two breaker straight bus configuration, as shown in the Figure 1.2. If the customer desires to connect to both X-3 and X-4, a ring bus configuration will be required.

The Generator is responsible for all equipment on the G376 side of the Point of Interconnection to the ATC transmission system, including a high side disconnect switch, circuit breaker, GSU transformer and all necessary relaying.

Load Flow Impacts

For the summer 2006 and the winter 2006/2007 study cases, the addition of G376 caused overloads in the 138 kV system around the POI. These thermal violations are identified in Table C.1 and Table C.2 in Appendix C.

The primary overload is for the loss of one of the G376 generator outlets (to North Fond du Lac or to Green Lake). This contingency leaves only one path for the full plant output and the existing rating of X-4 is 72 MVA. Therefore, an upgrade to X-4 will be needed to deliver G376. Although a more thorough review will need to be performed for the ISIS, records show that X-4 can be upgraded to the required capacity by replacing some of the relays and current transformers at the North Fond du Lac and Green Lake substations. The remaining single contingency overload is the Wautoma 138/69kV transformer. This facility will need to be more fully reviewed in the ISIS.

The voltage violations listed in Table C.3 (winter 2006/2007 base case) and Table C.4 (summer 2006 base case) are mitigated by a combination of the installation of capacitors previously identified by ATC, one required for G368 and by requiring G376 to operate at no less than 0.99 p.u. leading power factor, as previously noted. The identified capacitor bank projects are at the G368 138 kV bus (G368 study) and at Hartford and Burlington 138 kV busses (ATC Ten Year Assessment). These facilities are expected to be in service before the G376 in-service date.

Thermal studies were also performed to evaluate alternative interconnection of G376 to the line X-3. Intact system and single contingency analysis indicate that this interconnection results in the thermal overload of line X-3, the thermal overload of the Metomen 138/69 kV transformer and the overload of several 69 kV lines. Hence, this interconnection does not appear to be superior to the preferred interconnection (line X-4).

Similarly, thermal studies were also performed to evaluate interconnection of G376 to the line X-3 and the line X-4. This interconnection requires a ring bus connection with six 138 kV breakers (versus three breakers for the straight bus connection.) Intact system and single contingency analysis indicate that this interconnection results in the thermal overload of the Metomen 138/69 kV transformer, the Wautoma 138/69 kV transformer and the overload of G376 to Green Lake 138 kV line. Hence, this interconnection also does not appear to be superior to the original interconnection from a thermal overload analysis perspective.

Stability Impacts

Stability analysis did not identify violations of ATC criteria for any primary faults studied when the G376 generation is at its full capacity of 160 MW. The G376 units tripped for multiple breaker failure contingencies but did not result in a violation of ATC criteria. Prior outage stability studies identified three prior outages that violated ATC stability criteria. For these prior outages, G376 output needs to be restricted to 80 MW. G376 was operating at 0.99 p.u. power factor leading (absorbing.)

Connection to both circuits (X-3 and X-4) provides four outlets for G376 thus allowing a more robust stability performance during a prior outage, primary fault clearing contingency. In particular, this connection mitigates stability operating restriction on G376. On the other hand, connection to X-3 line provides stability performance and operating restrictions similar to the original connection (X-4).

Short-Circuit Impacts
Induction generators typically contribute significant short-circuit current only within the first 1 ~ 1.5 cycles after a fault. Hence, no system upgrades due to breaker duty will be required prior to the interconnection of G376.

System Upgrades
Existing System Before G376

This study did not identify any upgrades for the existing system before G376 interconnection.

Required Upgrades After G376

Breaker Duty Related

None.

Stability Related

None identified. However, for breaker failure contingencies, relay setting modifications may be considered to limit the number of contingencies that could cause the wind farm to trip off line.

Proposed Upgrades After G376

An upgrade of 138 kV line X-4 Green Lake – North Fond du Lac and improvements to the Wautoma 138/69kV transformer rating will need to be identified in the ISIS.

Operation Restrictions
Operation restrictions on the G376 generation are identified in Table D.1 in Appendix D for the thermal and stability constraints found for the double contingencies (N-2) identified in Table C.1, Table C.2 and for prior outages identified Table A.3. The N-2 thermal analysis were performed on the system as existing for the time period of interest without an upgrade of line X-4 or the Wautoma 69/138 kV transformer needed to meet N-1 requirements. Therefore, in Table D.1, operating restrictions for G376 are not given for N-2 scenarios limited by either X-4 or the Wautoma transformer. These particular scenarios will be re-examined in the ISIS. Similarly, the prior outage, primary fault clearing stability studies were performed on the system as existing for without an upgrade of line X-4 or the Wautoma 69/138 kV transformer needed to meet N-1 requirements. Hence, the ISIS will re-examine stability restrictions on G376.

Alternative Interconnections
Alternative interconnections are to the adjacent 138 kV line between Metomen and North Randolph (line X-3) or to both circuits (line X-3 and line X-4).

The alternative interconnection of G376 to the line X-3 results in the thermal overload of line X-3, the thermal overload of the Metomen 138/69 kV transformer and the overload of several 69 kV lines. In addition, this connection results in stability performance and operating restrictions similar to the original connection (X-4). Hence, this interconnection is not superior to the preferred interconnection (line X-4).

The alternative interconnection of G376 to both circuits line X-3 and line X-4 results in the thermal overload of the Metomen 138/69 kV transformer, the Wautoma 138/69 kV transformer and the overload of G376 to Green Lake 138 kV line. In addition, this interconnection requires a ring bus connection with six 138 kV breakers (versus three breakers for the straight bus connection). The ring bus configuration provides four outlets for G376 thus allowing a more robust stability performance. In particular, the stability operating restriction for G376 are eliminated and power factor requirements at the point of interconnect are relaxed. In short, this interconnection does not appear to be superior to the preferred interconnection from a thermal overload analysis perspective but provides better stability performance.

Figure 1.1 – One Line Diagram of the Existing System Before the Addition of G376

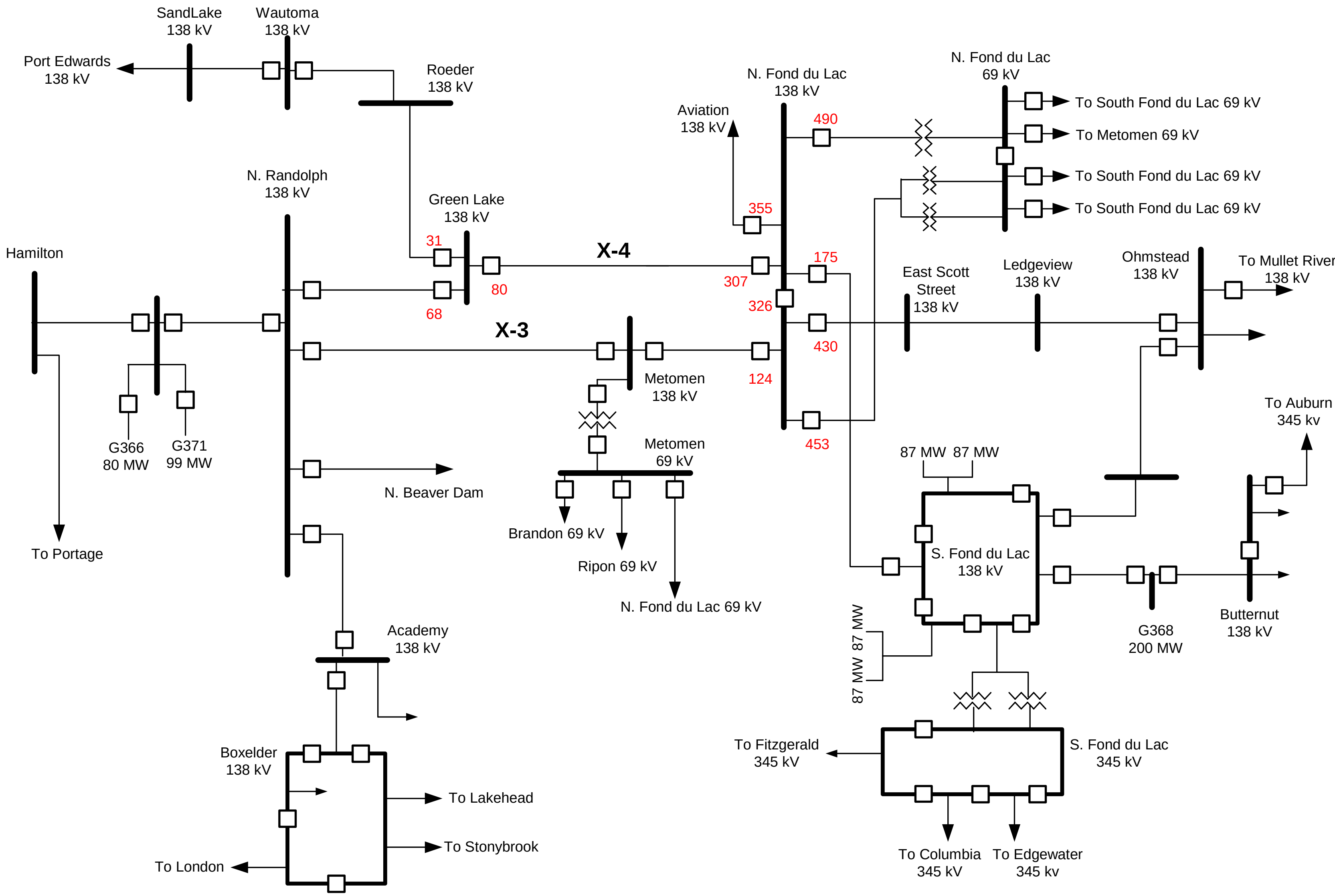
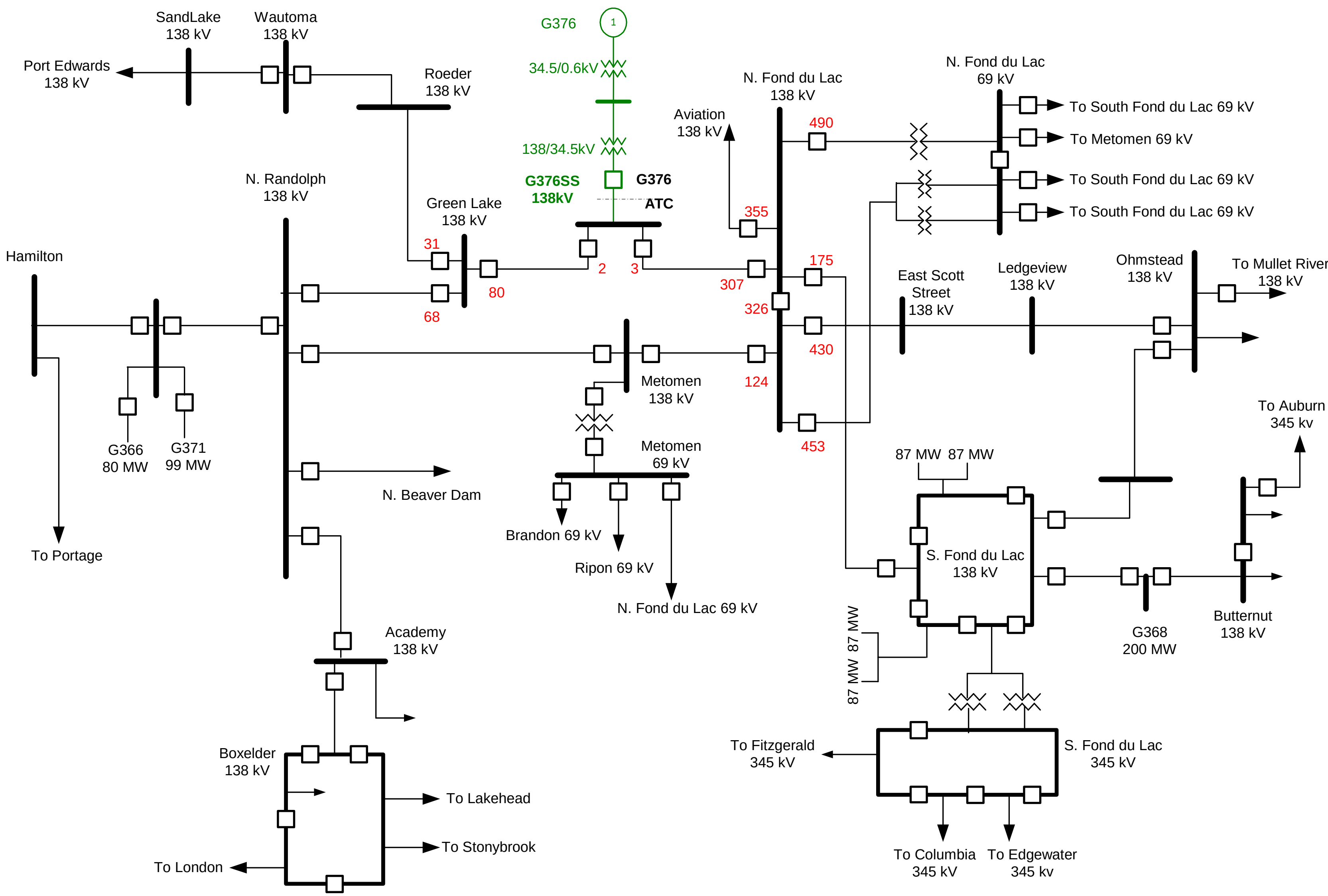


Figure 1.2 – One Line Diagram of the System After the Addition of G376



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 F.

2.2 Study Methodology

The results of this study may be 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 Thermal Study does not guarantee a position in the Transmission Service Request Queue. 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 may be 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 Generation Requests

ATC determined in its sole judgment that three GIRs with earlier queue positions might impact the G376 study results. G366, G368 and G371 are considered competing requests for the interconnection of this generator. G368 is a proposed 200 MW wind farm located between South Fond du Lac and Butternut 138 kV substations as shown in Figure 1.2. G366 is an 80 MW wind farm that shares a common 138 kV bus with G371, a 99 MW wind farm, as shown Figure 1.2.

Public information related to GIR queue 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 G376 interconnection; two system conditions were examined - “Before” the addition of G376 and “After” the addition of G376. 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 G376. Only those existing system violations that are made worse by the G376 wind farm are deemed relevant to the G376 interconnection request and are documented in this report. Any other identified existing system violations that are not made worse by the G376 wind farm are deemed unrelated to the G376 interconnection request and are documented elsewhere as part of the internal ATC planning projects.

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

For thermal overload and steady-state voltage evaluation under normal, N-1 and special ATC multiple contingency conditions, AC Contingency Calculation (ACCC) method was used. For thermal overload evaluation under N-2 conditions, Linear Transfer Analysis method was used with adjusted MW ratings to account for reactive power flows.

The Linear Transfer 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). ACCC was performed using the Power Flow module of the Power System Simulation/Engineering-28 (PSS/E, Version 28) program from Power Technologies, Inc (PTI). These programs are accepted industry-wide for power flow analysis.

2.2.4 Base Cases

In the thermal overload analysis of this study, MISO (Midwest Independent System Operator) monthly cases, January 2005 and July 2004 were used. The MISO monthly cases are accessible through MISO Extranet. The January 2005 and July 2004 base cases were utilized to develop Summer 2006 and Winter 2006/2007 base cases. The Winter 2006/2007 base case was developed based on the MISO January 2005 model created from the 2001 Series NERC/MMWG. Loads were scaled to the expected Winter 2006/07 peak levels. All ATC projects expected to be completed and in-service by June 2006 were also added including G366, G368 and G371. The Summer 2006 base case was developed based on a MISO July 2004 model created from the 2002 Series NERC/MMWG. Similar to the Winter case, loads were scaled to the expected Summer 2006 peak levels. All ATC projects expected to be completed and in-service by June 2006 projects were also added. G376 full plant output (160 MW) was delivered to the NSP (25%) and ComEd (75%) control areas. Loads in the control area were increased accordingly for the increased ATC export level.

In the stability analysis of this study, a 2005 50% summer peak load case was used. This base case was developed based on a NERC 2002 series MMWG (Multi-Regional Modeling Working Group) 2004 50% summer peak load case. The 2004 50% peak load case was modified by scaling load up by 3% and economically dispatching existing system generation to model the 2005 time period. Planned 138 kV capacitor additions at Burlington and Hartford, along with an accelerated G368 138 kV capacitor, were added to the dynamics model based on steady state voltage analysis results. In addition, the base case was further modified to include G366, G371 and G368 wind generation dynamic models.

2.3 Assumptions

2.3.1 Generation Facility Modeling

For all analysis, G376 generation was modeled at 0.99 leading power factor (absorbing MVAR) at the POI.

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.

A 2005 light load (50% summer peak) 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 clearing times. Any critical clearing times that were less than the actual clearing times would, therefore, be considered unacceptable.

3.1.1 Results of Intact System, Primary Fault Contingencies

The primary contingency results with normal clearing are summarized in Table A.1 in Appendix A. Stability analysis did not identify violations for any primary contingencies with normal clearing when the G376 generation is at its full capacity of 160 MW. No damping violations were found for any of these contingencies.

3.1.2 Results of Breaker Failure Contingencies

The breaker failure contingency results are summarized in Table A.2 in Appendix A. Multiple contingencies studied caused G376 to trip off line. In all of the cases evaluated, the addition of G376 did not aggravate system performance. However, deficiencies that can be corrected with relay setting modifications may be considered to limit the number of contingencies that could cause the wind farm to trip off line. No damping violations were found for any of the breaker failure contingencies studied.

3.1.3 Results of Prior Outage, Primary Fault Contingencies

The prior outage, primary clearing fault study results are summarized in Table A.3 in Appendix A. The prior outage of G376 outlet to N. Fond du Lac followed by the primary clearing of Green

Lake to either Roeder or to N. Randolph results in violation of ATC stability criteria (G376 either trips due to over-voltage or fails to achieve an acceptable steady state operation.) This appears to be due to a weak path from Green Lake to either Roeder or to N. Randolph that is unable to adequately handle the full output of G376 on recovery from fault. Similarly, the prior outage of either Green Lake to Roeder and or Green Lake to N. Randolph result in violation of ATC stability criteria when followed by primary clearing of G376 outlet to N. Fond du Lac. Stability studies show that restricting G376 to 80 MW will mitigate stability problems for these three prior outages (as given in Appendix D).

Connection to both circuits (X-3 and X-4) provides four outlets for G376 thus allowing a more robust stability performance during a prior outage, primary fault clearing contingency. In particular, this connection mitigates stability operating restriction on G376. On the other hand, connection to X-3 line provides stability performance and operating restrictions similar to the original connection (X-4).

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 G376.

The maximum and minimum short-circuit duties at the G376 Point of Interconnection (POI) and the Thevenin equivalent impedances at the G376 POI are provided in Tables B.1 through B.3 in the Appendix B.

3.3 Power Flow Analysis Results

Table C.1 and Table C.2 in Appendix C list the thermal overloads caused by G376 or in which G376 contributes to the loading problem for the intact system and also for the system with single (N-1) and double (N-2) contingency conditions. The primary overload with single contingency condition refers to the loss of one of the G376 generator outlets (to North Fond du Lac or to Green Lake). This contingency leaves only one outlet for the full plant output and the existing rating of X-4 is 72 MVA. Therefore, an upgrade to X-4 will be needed to deliver G376. Although a more thorough review will need to be performed for the ISIS, records show that X-4 can be upgraded to the required capacity by replacing some of the relays and current transformers at the North Fond du Lac and Green Lake substations. The remaining single contingency overload is the Wautoma 138/69kV transformer. This facility will need to be more fully reviewed in the ISIS. Operating restrictions would be used to mitigate the overloaded elements for the system with double (N-2) contingency conditions. Appendix D summarizes the operating restrictions based on the overloads listed in Appendix C.

Thermal studies were also performed to evaluate alternative interconnection of G376 to the line X-3 (Metomen to N. Randolph). Intact system and single contingency analysis indicate that this interconnection results in the thermal overload of line X-3, the thermal overload of the Metomen 138/69 kV transformer and the overload of several 69 kV lines. Hence, this interconnection does not appear to be superior to the preferred interconnection (line X-4).

Similarly, thermal studies were also performed to evaluate interconnection of G376 to the line X-3 and the line X-4. This interconnection requires a ring bus connection with six 138 kV breakers (versus three breakers for the straight bus connection.) Intact system and single contingency analysis indicate that this interconnection results in the thermal overload of the Metomen 138/69 kV transformer, the Wautoma 138/69 kV transformer and the overload of G376 to Green Lake 138 kV line. Hence, this interconnection also does not appear to be superior to the original interconnection from a thermal overload analysis perspective.

For the summer 2006 and the winter 2006/2007 study cases, the addition of G376 caused overloads in the 138 kV system around the POI. These thermal violations are identified in Table C.1 and Table C.2 in Appendix C.

The study identified several under-voltage violations for Winter 2006/2007 and Summer 2006, as shown in Tables C.3 and C.4.

The voltage violations are mitigated by a combination of the installation of capacitors previously identified by ATC, one required for G368 and by requiring G376 to operate at no less than 0.99 p.u. leading power factor, as previously noted. The identified capacitor bank projects are at the G368 138 kV bus (G368 study) and at Hartford and Burlington 138 kV busses (ATC Ten Year Assessment). These facilities are expected to be in service before the G376 in-service date.

Appendix A

Stability Analysis Results

Notes:

1. All analysis performed with G376 operating at 0.99 leading (absorbing) power factor.
2. Table abbreviations: NOR – North Randolph, GSS – Green Lake, NFL – North Fond du Lac, AVI – Aviation, MET – Metomen, SFL – South Fond du Lac, EST – Ohmstead, RDR - Roeder
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.
5. Voltage Recovery column indicates if voltage recovery after fault is cleared was acceptable (system bus voltage magnitudes must recover to be at least 70% of the nominal system voltages immediately after fault removal and 80% of the nominal system voltages in 0.5 second after fault removal.)
6. G376 trips when the terminal voltage is less than 0.5 pu for more than 0.2 seconds (see Appendix E).
7. N/A – Run not applicable.

Table A.1 – Stability Analysis Results of Primary Fault Contingencies Utilizing 2005 System After the Addition of G376 Generation[1]

Item	Faulted Facilities[2,3]	MECT[4]	Calculated CCT [4]	Voltage Recovery [5]	Comments
1	G376 – GSS 138 kV	5	> 6	acceptable	None
2	G376 – NFL 138 kV	5	> 6	acceptable	None
3	NFL – G376 138 kV	5	> 6	acceptable	None
4	NFL – AVI 138 kV	5	> 6	acceptable	None
5	NFL – MET 138 kV	5	> 6	acceptable	None
6	NFL – SFL 138 kV	5	> 6	acceptable	None
7	NFL – EST 138 kV	5	> 6	acceptable	None
8	NFL 138/69 kV	5	> 6	acceptable	None
9	GSS- G376 138 kV	5	> 6	acceptable	None
10	GSS- RDR 138 kV	5	> 6	acceptable	None
11	GSS- NOR 138 kV	5	> 6	acceptable	None

Table A.2 – Stability Analysis Results of Breaker Failure Contingencies utilizing 2005 System After the Addition of G376 Generation[1]

Item	Faulted Facilities	Failed Ckt. Brkr	Element(s) Cleared In Breaker Failure	MECT	Calculated CCT [4]	Voltage Recovery [5]	Transient Problems
1	NFL – G376 138 kV	307	490, 355, 175, 326	18	≥19 [5]	acceptable	None
2	NFL – AVI 138 kV	355	490, 307, 175, 326	18	≥19 [5]	acceptable	G376 tripped 17 cycles after fault [7]
3	NFL – MET 138 kV	124	326, 430, 453	18	≥19 [5]	acceptable	G376 tripped 17 cycles after fault [7]
4	NFL – SFL 138 kV	175	490, 355, 307, 326	18	≥19 [5]	acceptable	G376 tripped 17 cycles after fault [7]
5	NFL – EST 138 kV	430	326, 124, 453	18	≥19 [5]	acceptable	G376 tripped 17 cycles after fault [7]
6	NFL 138/69 kV (# 1)	453	124, 326, 430	19	≥20 [5]	acceptable	G376 tripped 17 cycles after fault [7]
7	NFL 138/69 kV (# 2)	490	175, 307, 326, 355	19	≥20 [5]	acceptable	G376 tripped 17 cycles after fault [7]
8	GSS- G376 138 kV	80	68, 31	18	≥19 [5]	acceptable	None
9	GSS- RDR 138 kV	31	68, 80	18	≥19 [5]	acceptable	G376 tripped 17 cycles after fault [7]
10	GSS- NOR 138 kV	68	31 , 80	18	≥19 [5]	acceptable	G376 tripped 17 cycles after fault [7]

Table A.3 – Stability Analysis Results of Prior Outage Contingencies Utilizing 2005 System After the Addition of G376 Generation[1]

Prior Outage	Item	Faulted Facilities	MECT	Calculated CCT [4]	Voltage Recovery [5]	Comments
G376 – NFL 138 kV	1a	G376 – NFL 138 kV	N/a			
	1b	G376 – GSS 138 kV	5	-	-	G376 trips (no outlet reamining)
	1c	NFL – AVI 138 kV	5	> 6	acceptable	None
	1d	NFL – MET 138 kV	5	> 6	acceptable	None
	1e	NFL – SFL 138 kV	5	> 6	acceptable	None
	1f	NFL – EST 138 kV	5	> 6	acceptable	None
	1g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	1h	GSS- RDR 138 kV	5	< 5	Not acceptable	Nearby 138 kV voltage contains higher ferquency compoenents
	1i	GSS- NOR 138 kV	5	< 5	Not acceptable	G376 trips due to over-voltage
G376 – GSS 138 kV	2a	G376 – NFL 138 kV	5	-	-	G376 trips (no outlet reamining)
	2b	G376 – GSS 138 kV	N/a			
	2c	NFL – AVI 138 kV	5	> 6	acceptable	None
	2d	NFL – MET 138 kV	5	> 6	acceptable	None
	2e	NFL – SFL 138 kV	5	> 6	acceptable	None
	2f	NFL – EST 138 kV	5	> 6	acceptable	None
	2g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	2h	GSS- RDR 138 kV	5	> 6	acceptable	None
	2i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL – AVI 138 kV	3a	G376 – NFL 138 kV	5	> 6	acceptable	None
	3b	G376 – GSS 138 kV	5	> 6	acceptable	None
	3c	NFL – AVI 138 kV	N/a			
	3d	NFL – MET 138 kV	5	> 6	acceptable	None
	3e	NFL – SFL 138 kV	5	> 6	acceptable	None
	3f	NFL – EST 138 kV	5	> 6	acceptable	None
	3g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	3h	GSS- RDR 138 kV	5	> 6	acceptable	None
	3i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL – MET 138 kV	4a	G376 – NFL 138 kV	5	> 6	acceptable	None
	4b	G376 – GSS 138 kV	5	> 6	acceptable	None
	4c	NFL – AVI 138 kV	5	> 6	acceptable	None
	4d	NFL – MET 138 kV	N/a			
	4e	NFL – SFL 138 kV	5	> 6	acceptable	None
	4f	NFL – EST 138 kV	5	> 6	acceptable	None
	4g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	4h	GSS- RDR 138 kV	5	> 6	acceptable	None
	4i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL – SFL 138 kV	5a	G376 – NFL 138 kV	5	> 6	acceptable	None
	5b	G376 – GSS 138 kV	5	> 6	acceptable	None
	5c	NFL – AVI 138 kV	5	> 6	acceptable	None
	5d	NFL – MET 138 kV	5	> 6	acceptable	None
	5e	NFL – SFL 138 kV	N/a			
	5f	NFL – EST 138 kV	5	> 6	acceptable	None
	5g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	5h	GSS- RDR 138 kV	5	> 6	acceptable	None
	5i	GSS- NOR 138 kV	5	> 6	acceptable	None

Table A.3 Cont. – Stability Analysis Results of Prior Outage Contingencies Utilizing 2005 System After the Addition of G376 Generation[1]

Prior Outage	Item	Faulted Facilities	MECT	Calculated CCT	Voltage Recovery	Comments
NFL – EST 138 kV	6a	G376 – NFL 138 kV	5	> 6	acceptable	None
	6b	G376 – GSS 138 kV	5	> 6	acceptable	None
	6c	NFL – AVI 138 kV	5	> 6	acceptable	None
	6d	NFL – MET 138 kV	5	> 6	acceptable	None
	6e	NFL – SFL 138 kV	5	> 6	acceptable	None
	6f	NFL – EST 138 kV	N/a			
	6g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	6h	GSS- RDR 138 kV	5	> 6	acceptable	None
	6i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL 138/69 kV # 1	7a	G376 – NFL 138 kV	5	> 6	acceptable	None
	7b	G376 – GSS 138 kV	5	> 6	acceptable	None
	7c	NFL – AVI 138 kV	5	> 6	acceptable	None
	7d	NFL – MET 138 kV	5	> 6	acceptable	None
	7e	NFL – SFL 138 kV	5	> 6	acceptable	None
	7f	NFL – EST 138 kV	5	> 6	acceptable	None
	7g	NFL 138/69 kV (# 1)	N/a			
	7h	GSS- RDR 138 kV	5	> 6	acceptable	None
	7i	GSS- NOR 138 kV	5	> 6	acceptable	None
GSS- RDR 138 kV	8a	G376 – NFL 138 kV	5	< 5	Not acceptable	Nearby 138 kV voltage contains higher ferquency compoenents
	8b	G376 – GSS 138 kV	5	> 6	acceptable	None
	8c	NFL – AVI 138 kV	5	> 6	acceptable	None
	8d	NFL – MET 138 kV	5	> 6	acceptable	None
	8e	NFL – SFL 138 kV	5	> 6	acceptable	None
	8f	NFL – EST 138 kV	5	> 6	acceptable	None
	8g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	8h	GSS- RDR 138 kV	N/a			
	8i	GSS- NOR 138 kV	5	> 6	acceptable	None
GSS- NOR 138 kV	9a	G376 – NFL 138 kV	5	< 5	Not acceptable	G376 trips due to over-voltage
	9b	G376 – GSS 138 kV	5	> 6	acceptable	None
	9c	NFL – AVI 138 kV	5	> 6	acceptable	None
	9d	NFL – MET 138 kV	5	> 6	acceptable	None
	9e	NFL – SFL 138 kV	5	> 6	acceptable	None
	9f	NFL – EST 138 kV	5	> 6	acceptable	None
	9g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	9h	GSS- RDR 138 kV	5	> 6	acceptable	None
	9i	GSS- NOR 138 kV	N/a			

Appendix B

Short Circuit Analysis

Table B.1 – Maximum and minimum fault duties at the G376 point of interconnection without the contribution from G376.

Maximum Fault Duty		Minimum Fault Duty	
Single-phase	**Three-Phase**	**Single-phase**	**Three-Phase**
4900 Amps	**6900 Amps**	**2800 Amps**	**3670 Amps**

Note: Minimum fault duty was calculated with the G376 - North Fond du Lac 138 kV line out of service.

Table B.2 – Thevenin equivalent impedances (in Ohms) in intact system at the G376 point of interconnection without contribution from G376.

Pos Seq.	Neg. Seq.	Zero Seq.
2.88 + j 11.4 Ω	2.88 + j 11.4 Ω	6.93 + j 24.7 Ω

Table B.3 – Thevenin equivalent impedances (in Ohms) measured at the G376 point of interconnection without the contribution from G376 and also with the G376 – North Fond du Lac 138kV Line out of service.

Pos Seq.	Neg. Seq.	Zero Seq.
5.67 + j 20.97	5.67 + j 20.97	10.62 + j 40.30

Appendix C

Power Flow Analysis

Table C.1 – Summer 2006 Thermal Overloads Identified. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%)

Limiting Element	Existing MVA Rating	Worst Contingency	MVA Flow without G376	MVA Flow with G376	Solution for Limiting Element
		Base case			
		There were no base case violations			
		Single Contingencies			
X-4 Green Lake – G376 138 kV	72	G376 – N. Fond du Lac 138 kV	0	160.6	No [1]
X-4 G376 – North Fond du Lac 138 kV	72	Green Lake – G376 138 kV	0	160.6	No [1]
Wautoma 69/138 kV Transformer	46.7	Wautoma – Sand Lake 138 kV	47.0	58.5	No [2]
		Additional overloads due to Double Contingencies			
Y-93 Northwest Ripon –Ripon 69 kV	54	N. Fond du Lac - Aviation 138 kV Green Lake – Roeder 138 kV	58.3	64.2	No [3]
Y-27 Metomen – Rosendale 69 kV	36	N. Fond du Lac - Metomen 138 kV Green Lake – G376 138 kV	37.8	43.7	No [3]
Y-27 North Fond du Lac - Rosendale 69 kV	48	N. Fond du Lac - Metomen 138 kV Green Lake – G376 138 kV	46.4	52.8	No [3]
G-111 N. Fond Du Lac - Aviation 138 kV	230	Granville – Cedarsauk 345 kV S. Fond du Lac – Fitzgerald 345 kV	206	230	No [3]

Note:

1- There is no previously identified project by ATC to solve the loading problem. The required work to upgrade the line number X-4 (North Fond du Lac to Green Lake 138 kV) in order to accommodate for G376 interconnection include the upgrade of some of the relays and current transformers at the North Fond du Lac and Green Lake substations. An ISIS must be performed to further evaluate this element and the potential solution.

2- There is no previously identified project by ATC to solve the loading problem. An ISIS must be performed to further evaluate this element and the potential solution.

3- There is no previously identified project by ATC to solve the loading problem. G376 would likely be required to backed down during prior outage events involving one of these two transmission elements.

Table C.2 – Winter 2006/2007 Thermal Overloads Identified. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%)

Limiting Element	**Existing MVA Rating**	**Worst Contingency**		**MVA Flow without G376**	**MVA Flow with G376**	**Solution for Limiting Element**
		Base case				
		There were no base case violations				
		Single Contingencies				
X-4 Green Lake – G376 138 kV	72	G376 – N. Fond du Lac	138 kV	0	160.6	No [1]
X-4 G376 – North Fond du Lac 138 kV	72	Green Lake – G376	138 kV	0	160.6	No [1]
		Additional overloads due to Double Contingencies				
13878 Columbia – North Madison 138 kV	288	Columbia - Rockdale Columbia – North Madison	345 kV 345 kV	298	306	Yes [2]
Cedarsauk 345/138 kV Transformer	504	Granville – Cedarsauk S. Fond Du Lac – Fitzgerald	345 kV 345 kV	529	554	No [3]

Note:
1- There is no previously identified project by ATC to solve the loading problem. The required work to upgrade the line number X-4 (North Fond du Lac to Green Lake 138 kV) in order to accommodate for G376 interconnection include the upgrade of some of the relays and current transformers at the North Fond du Lac and Green Lake substations. An ISIS must be performed to further evaluate this element and the potential solution.

2- ATC has Public Service Commission of Wisconsin approval to convert this line to 345 kV operation in 2006.

3- There is no previously identified project by ATC to solve the loading problem. G376 would likely be required to be backed down during prior outage events involving one of these two transmission elements.

Table C.3 – Identified under-voltage violations for Winter 2006/2007. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%). Power factor of 0.95 leading (absorbing VARs)

Worst Contingency	Bus with Violation Voltage	Bus Voltage without G376	Bus Voltage with G376	Solution for Voltage Violation
796L41 Edgewater – Cedarsauk 345 kV	Auburn 138 kV	0.892	0.881	Yes *

* Previously identified capacitor bank projects (at G368 138 kV bus, Hartford 138 kV bus and Burlington 138 kV bus) expected to be in service before G376 service date will mitigate this under voltage violations.

Table C.4 – Identified under-voltage violations for Summer 2006. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%). Power factor of 0.98 leading (absorbing VARs)

Worst Contingency	Bus with Violation Voltage	Bus Voltage without G376	Bus Voltage with G376	Solution for Voltage Violation
G376 - North Fond du Lac 138 kV	Roeder 138 kV	0.911	0.896	Yes *
	Wautoma 138 kV	0.908	0.890	

* Operating G376 at 0.99 power factor leading (absorbing) mitigates the identified under-voltage violation.

Appendix D

Summary of Operation Restrictions

Table D.1 – Identified Operation Restrictions on the G376 Generation Under Prior Outage Scenarios

Prior Outage[1]	**G376 Max Allowable Output (MW)**	**Worst Next Contingency**	**Limiting Element**[2]	**MVA Rating**	**Reason**	**Season**
N. Fond du Lac - Aviation 138 kV	0	Green Lake – Roeder 138 kV	Nortwest Ripon - Ripon 69 kV	54	Thermal	Summer 2006
Green Lake – Roeder 138 kV	0	N. Fond du Lac - Aviation 138 kV	Nortwest Ripon - Ripon 69 kV	54	Thermal	Summer 2006
N. Fond du Lac – Metomen 138 kV	0	Green Lake – G376 138 kV	Metomen – Rosendale 69 kV	36	Thermal	Summer 2006
Green Lake – G376 138 kV	0	N. Fond du Lac – Metomen 138 kV	Metomen – Rosendale 69 kV	36	Thermal	Summer 2006
Granville – Cedarsauk 345 kV	0	S. Fond du Lac – Fitzgerald 345 kV	Cedarsauk 138/345 kV transformer	504	Thermal	Winter 2006/07
S. Fond du Lac – Fitzgerald 345 kV	0	Granville – Cedarsauk 345 kV	Cedarsauk 138/345 kV transformer	504	Thermal	Winter 2006/07
Green Lake – Roeder 138 kV	80 MW	Green Lake – North Fond du Lac 138 kV	G376 trips due to over-voltage	N/A	Stability	Year Round
Green Lake – N. Randolph 138 kV	80 MW	Green Lake – North Fond du Lac 138 kV	Unable to find a stable operating point	N/A	Stability	Year Round
Green Lake – N. Fond du Lac	80 MW	Green Lake – Roeder 138 kV	G376 trips due to over- voltage	N/A	Stability	Year Round

1. All entries where the limiting element was either X-4 (N. Fond du Lac – Green Lake) or 138/69 kV Wautoma transformer were eliminated from consideration for Table D.1. The ISIS will examine the impact of upgrading X-4 and the Wautoma transformer on Operating Restrictions for G376.
2. The ISIS can examine if minor upgrades to these limiting elements are possible, if desired.

Appendix E

Proposed Fault Ride-Through Characteristics For G376 Wind Turbines

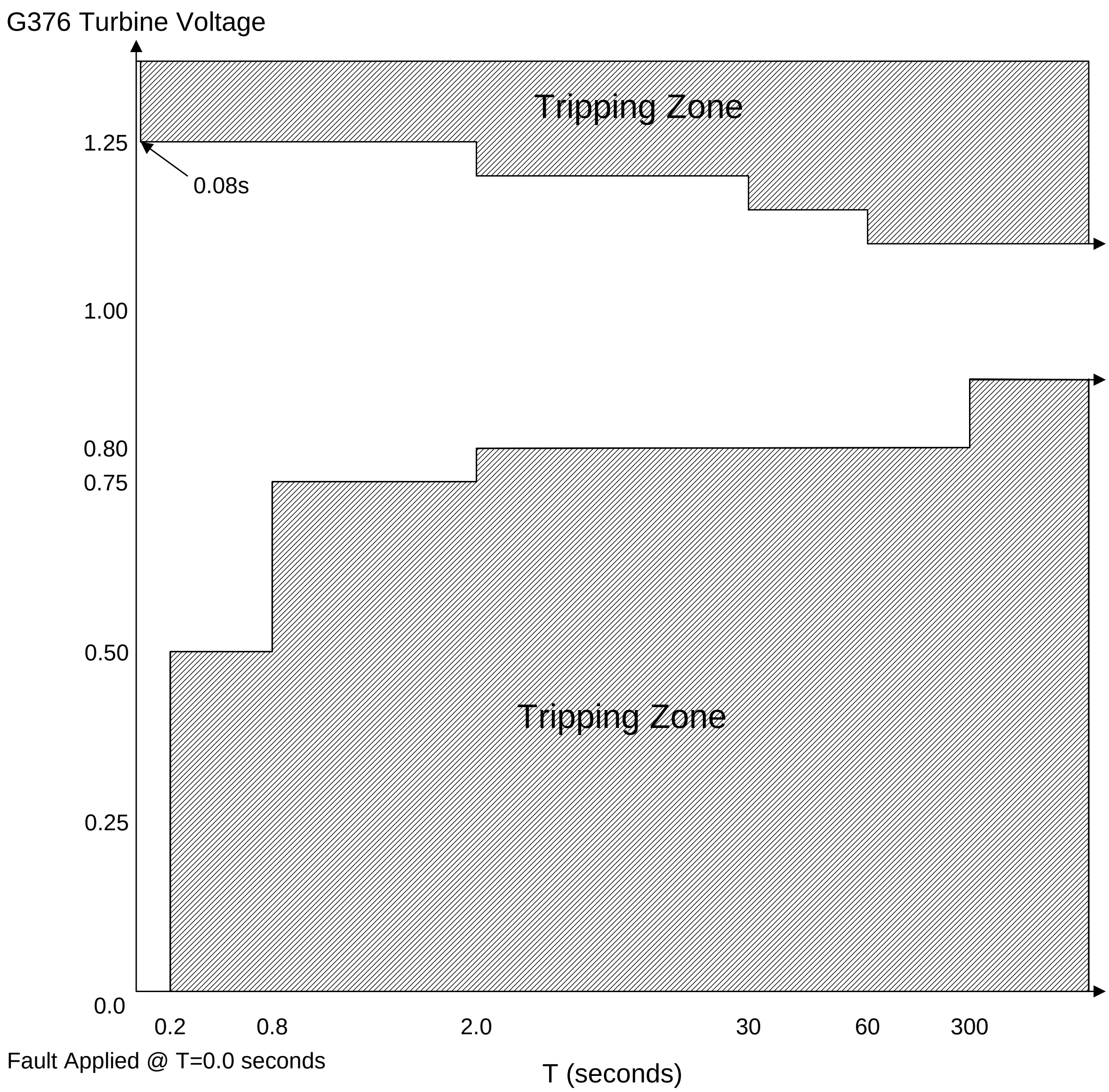


Figure E.1 – Proposed Fault Ride-Through Characteristics Related to Voltage Tripping of G376 Wind Turbines

Appendix F

Study Criteria

Study Criteria

Study Criteria

F.1 Contingencies

For stability analysis, a set of branches one or two busses away from the generator/power plant of concern is selected as contingencies, based on engineering judgment.

For power flow analysis, contingencies include:

a. N-1 contingencies: All lines and transformers operated at 69kV and above in Wisconsin Power & Light Co. (Alliant Energy – East), Wisconsin Electric Power Co., Wisconsin Public Service Corp., Madison Gas & Electric Co., Upper Peninsula Power Co. control areas; All line and transformers operated at 345 kV and above in the Commonwealth Edison, Northern States Power, Alliant West and Minnesota Power control areas; All line and transformers operated at 161 kV and above in the Dairyland Power Cooperative control area.
b. Selected N-2 and multiple contingencies that ATC has determined to be significant.

F.2 Monitored Elements

F.2.1 Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC

All load carrying elements operated at 69kV and above in the following control areas/zones were studied: ATC Planning Zone 1 and ties to that zone, Northern States Power Control Area and Dairyland Power Cooperative Control Area.

F.2.2 N-2 Contingency Evaluation Using Linear Transfer Analysis Method

All load carrying elements operated at 69kV and above in the following control areas/zones were monitored in this study: Wisconsin Power & Light Co. (Alliant Energy – East), Wisconsin Electric Power Co., Wisconsin Public Service Corp., Madison Gas & Electric Co., Upper Peninsula Power Co., Northern States Power and Dairyland Power Cooperative.

F.3 Thermal Loading Criteria

F.3.1 Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC

Under intact system conditions, the loading of all transmission elements with distribution factors greater than 0.05 per unit must not exceed the applicable normal rating (Rate A). Under contingency conditions, the loading of all transmission system elements with distribution factors greater than 0.03 per unit must not exceed the applicable emergency rating (Rate B).

F.3.2 N-2 Contingency Evaluation Using Linear Transfer Analysis Method

Under N-2 contingency conditions, the loading of all transmission system elements with distribution factors greater than 0.03 per unit must not exceed 95% of the applicable emergency rating.

F.4 Steady State Under Voltage Criteria

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

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

F.4.2 N-2 Contingency Evaluation

Voltage violations were not evaluated for N-2 contingencies.

F.5 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 fault removal and 80% of the nominal system voltages in 0.5 second after fault removal.