Interconnection Evaluation Study Report

50 MW Wind Generation in
Brown County, Wisconsin
MISO # G421 (#38068-05)

Prepared for the Midwest ISO

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1. Summary

This report contains the Interconnection Evaluation Study ("IES") for Generation Interconnection Request ("GIR") MISO project #G421, MISO Queue #38068-05. This study identifies potential system loading, voltage violations and stability problems that are caused by or aggravated by the connection of G421, a proposed 50 MW wind farm to be located in Brown County, Wisconsin. The requested in-service date for this project is December 1, 2006.

The proposed wind farm will connect to the 69 kV line R-44 between Finger Road and Wesmark substations (approximately 2.4 miles from Wesmark towards Bluestone). Figure 1.1 shows the system one-line diagram before G421 has been added.

The proposed G421 wind farm will have a single collection bus at a voltage level of 34.5 kV. A 34.5 kV cable and a 69/34.5 kV transformer will connect the wind farm collection bus to a new substation to be located near the R-44 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

G421 is required to have a power factor, as measured at the point of interconnection ("POI") between 0.98 leading (absorbing) and 0.98 lagging (generating).

Required G421 Interconnection Equipment

The proposed G421 wind farm will connect to a new substation to be located near the R-44 line in a two breaker straight bus configuration, as shown in the Figure 1.2.

The Generator is responsible for all equipment on the G421 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 summer 2007 and winter 2006/2007, the addition of G421 did not result in any thermal overloads for the intact system and the single contingency conditions. For the single contingency condition of losing either one the two G421 outlets, G421 full output (50 MW) is diverted into remaining R-44 path with a summer emergency rating of 53 MVA. In order to meet the ATC line overload criteria for this single contingency condition, G421 power factor at the point of interconnection is restricted between 0.98 leading and 0.98 lagging. This study did not identify any voltage violations due to the addition G421 when operating in this power factor range.

Stability Impacts

Results of the stability analysis are summarized in Tables A.1 through A.3 in Appendix A. Stability analysis identified that the G421 wind farm trips off line for a number of studied primary and prior-outage contingencies where the fault is placed close-by the wind farm. This condition of the wind farm tripping will be reviewed in the ISIS (if the study would be requested). Potential solutions include more detailed modeling of the impedance of the cable that connects the wind farm collection bus to the ATC substation once this information becomes available from the Generator. If unacceptable wind farm tripping is verified in the Impact Study, other possible remedies will be investigated and proposed.

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 G421.

System Upgrades

Existing System Before G421

This study did not identify any upgrades for the existing system before G421 interconnection.

Required Upgrades After G421

Breaker Duty Related

None.

Stability Related

Wind farm tripping will need to be resolved. Solutions may include series reactors and/or improved modeling. The solutions will be identified in the Impact Study.

Proposed Upgrades After G421

None.

Operation Restrictions

Operation restrictions on the G421 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 ISIS will re-examine stability restrictions on G421 taking into account the selected solution for the wind farm tripping identified in Table A.1.

Figure 1.1 – One Line Diagram of the Existing System Before the Addition of G421

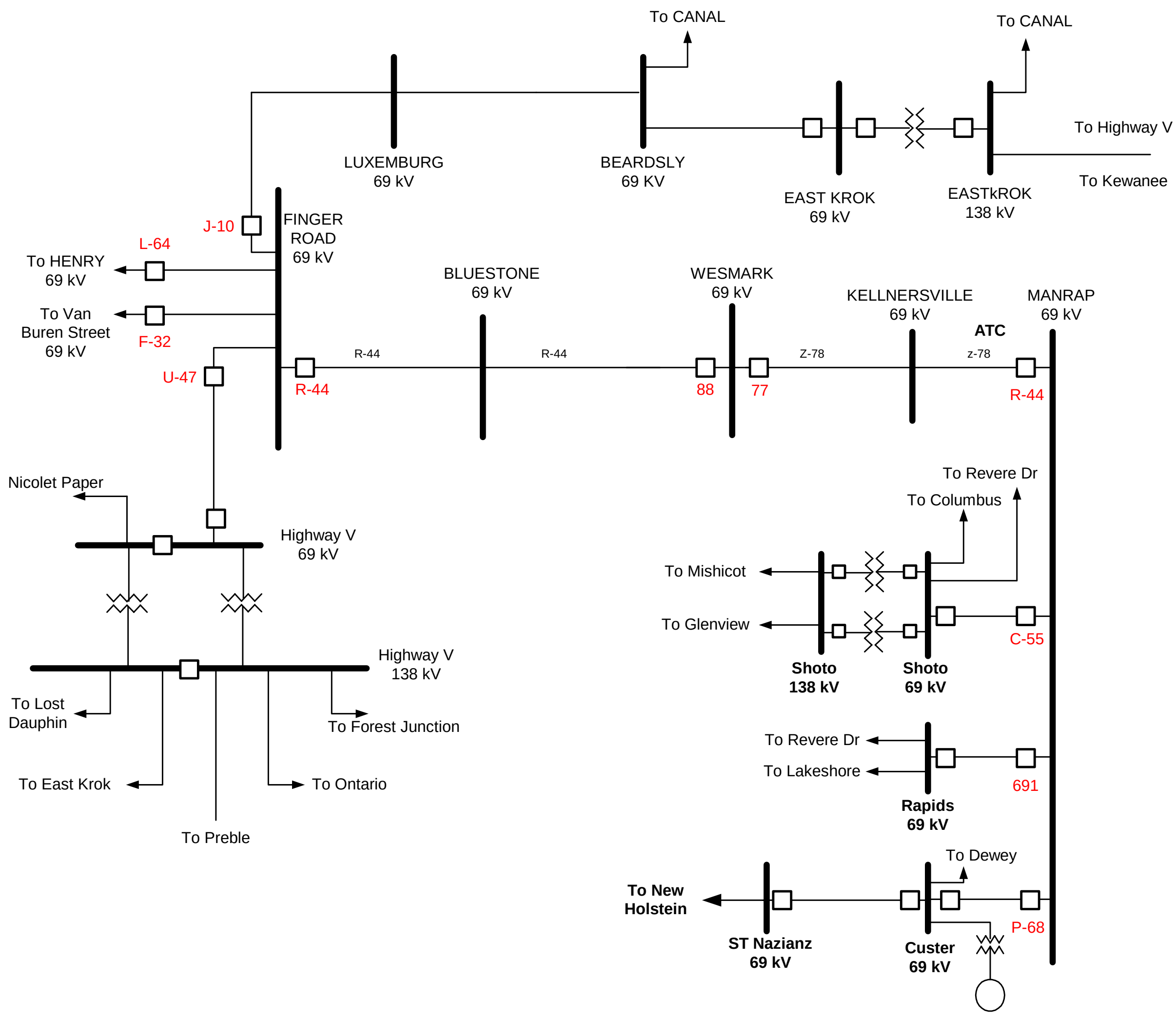
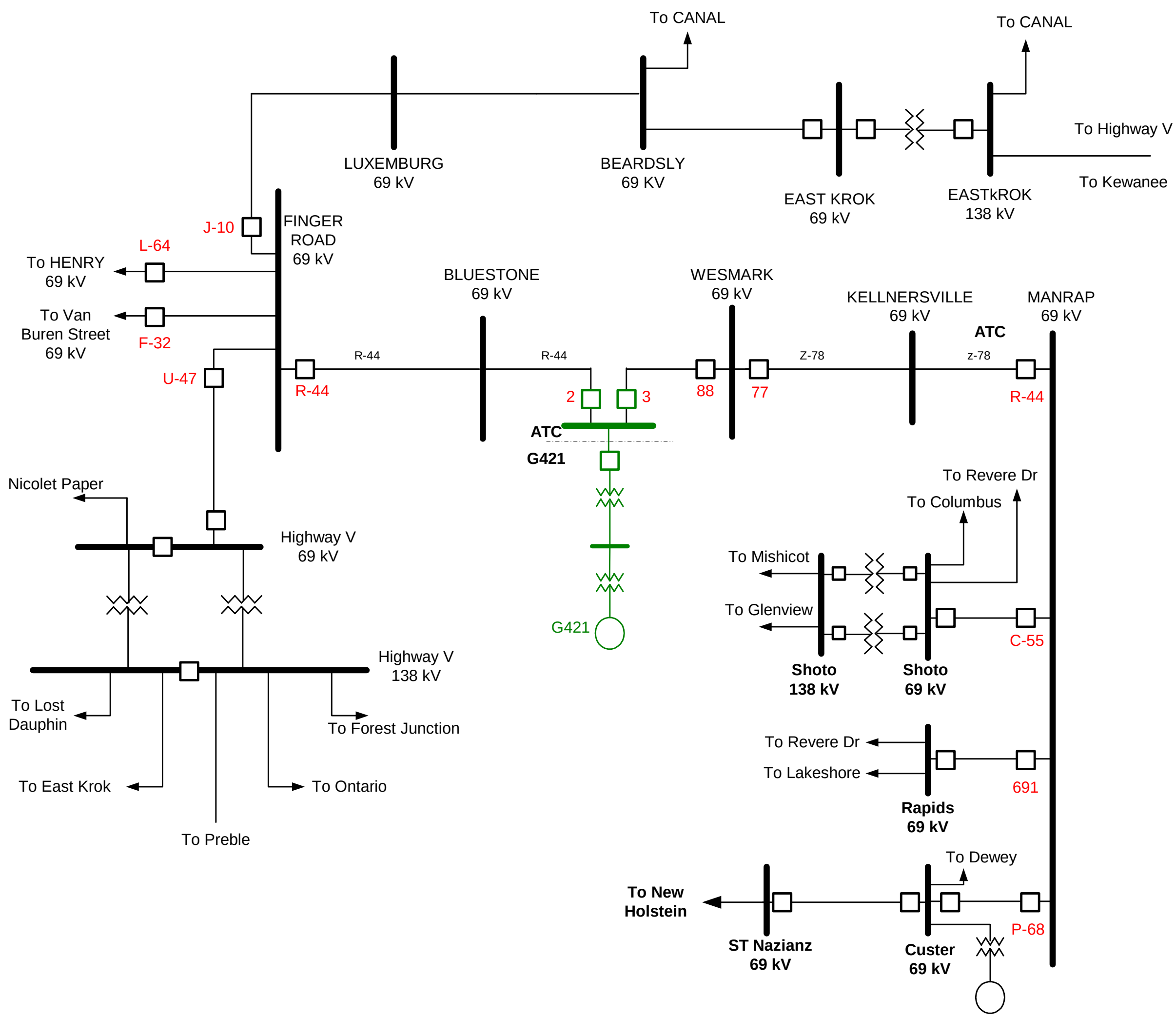


Figure 1.2 – One Line Diagram of the System After the Addition of G421



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 had determined in its sole judgment that two GIRs with an earlier queue position will impact the G421 study results. G384 and G410 were considered competing requests for the interconnection of this generator. These two units are modeled as a single 198 MW generating unit that is connected to Kewaunee with a double circuit 138 kV line, to East Krok with a single 138 kV line and to Mishicot with a single 138 kV line. Stability study results for G421 at full output (50 MW) indicate little dynamic impact from G384 and G410. Hence these two requests do not need to be considered competing for G421 stability studies.

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 G421 interconnection; two system conditions were examined - “Before” the addition of G421 and “After” the addition of G421. 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 G421. Only those existing system violations that are made worse by the G421 wind farm are deemed relevant to the G421 interconnection request and are documented in this report. Any other identified existing system violations that are not made worse by the G421 wind farm are deemed unrelated to the G421 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-6.01 (MUST, Version 6.01) 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 for 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 2007 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. All ATC projects expected to be completed and in-service by June 2006 were also added including G384 and G410. The Summer 2007 base case was developed based on a MISO July 2004 model created from the 2002 Series NERC/MMWG. All ATC projects expected to be completed and in-service by June 2006 projects were also added to the Summer 2007 model. G421 full plant output (50 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.

For stability analysis, a 2005 50% summer peak load case was used. This base case was developed based on NERC 2003 series MMWG (Multi-Regional Modeling Working Group) 2004 light load case. In addition, the base case was further modified to include G384 and G410 wind generation dynamic models.

2.3 Assumptions

2.3.1 Generation Facility Modeling

For all analysis, G421 generation was modeled at 0.98 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. Although G421 interconnection in-service date is December 1, 2006, the 2005 light load case is applicable for the stability studies.

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 identified that G421 wind farm trips off line for three of the studied primary fault contingencies where the fault is placed close to the wind farm. The impedance of the cable from the collection bus to the ATC substation was not included in the modeling because of the uncertainty of the location of the collection bus. Once this information becomes available from the Generator, the identified wind farm tripping condition will be reviewed in an ISIS (if it would be requested) and if any unacceptable tripping is verified, possible remedies will be investigated and proposed. A reactor connected in series with the 69/34.5kV transformer could be one possible option. 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. Stability analysis did not identify violations for any breaker failure contingencies when the G421 generation is at its full capacity of 50 MW. The G421 wind farm did not trip for any of these contingencies.

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. Either the prior outage of G421 outlet to Wesmark or the prior outage of Wesmark to Manrap results in the G421 wind farm tripping off line for a three phase fault near Finger Road 69 kV substation. Similarly, the prior outage of G421 outlet to Finger Road results in G421 tripping off line for a three near Manrap 69 kV substation. The tripping is due to the insufficient low voltage ride through characteristics of the G421 machines. This characteristic is shown in Appendix E. The wind farm tripping will be reviewed in the ISIS, as noted in 3.1.1.

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 G421.

The maximum and minimum short-circuit duties at the G421 Point of Interconnection (POI) and the Thevenin equivalent impedances at the G421 POI are provided in Tables B.1 through B.3 in the Appendix B.

3.3 Thermal Analysis Results

Table C.1 and Table C.2 in Appendix C list the thermal overloads caused by G421 or in which G421 contributes to the loading problem for the intact system and also for the system with single (N-1) and double (N-2) contingency conditions.

For the single contingency condition of losing either one the two G421 outlets, G421 full output (50 MW) is diverted into the remaining R-44 path with a summer emergency rating of 53 MVA. In order to meet the ATC line overload criteria for this single contingency condition, G421 power factor at the Point of Interconnection is restricted between 0.98 leading and 0.98 lagging.

Several double contingency conditions resulted in thermal overloads. Solutions for the overloads under the N-2 conditions were not reviewed in this study. Appendix D lists the G421 operating restrictions needed to mitigate the N-2 overloads identified. The solution(s) for the N-2 overloads can be reviewed during the ISIS, if the customer requests that review.

This study did not identify any steady state voltage violations due to the addition G421 when operating in the prescribed power factor range.

Appendix A

Stability Analysis Results

Notes:

1. All analysis performed with G421 operating at 0.95 leading (absorbing) power factor.
2. Table abbreviations: FIN – Finger Road, HWV – Highway V, VBR – Van Buren Street, HEN – Henry, LUX – Luxermburg, WES – Wesmark, KEL – Kellnersville, MRP – Manrap, SHO – Shoto, RPD – Rapids, CUS – Custer
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). Note that if fault is at far end and there is no communication between breakers, the far end breaker MECT is longer reflecting the relay pick up time in Zone 1. 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. G421 trips when the terminal voltage is less than 0.15 pu for more than 2.5 cycles (see Appendix E).
7. N/A – Not applicable.

Table A.1 – Stability Analysis Results of Primary Fault Contingencies Utilizing 2005 System After the Addition of G421 Generation[1]

Item	Faulted Facilities[2,3]	Breaker # Faulted end	MECT[4]	Breaker # Remote end	MECT[4]	Calculated CCT [4]	Voltage Recovery [5]	Comments
1	G421 – WES 69 kV	3	4.5	88	6.5	> 8	acceptable	G 421 trips at 6 cycles
2	G421 – FIN 69 kV	2	4.5	R-44	6.5	> 8	acceptable	G 421 trips at 6 cycles
3	FIN – G421 69 kV	R-44	6.5	2	4.5	> 8	acceptable	None
4	FIN – LUX 69 kV	J-10	8	N/A	N/A	> 8	acceptable	None
5	FIN – HEN 69 kV	L-64	6.5	N/A	N/A	> 8	acceptable	None
6	FIN – VBR 69 kV	F-32	6.5	N/A	N/A	> 8	acceptable	None
7	FIN – HWY 69 kV	U-47	6.5	N/A	N/A	> 8	acceptable	None
8	WES – G421 69 kV	3	6.5	88	4.5	> 8	acceptable	None
9	WES – MRP 69 kV	77	8	R-44	8	> 8	acceptable	None
10	MRP – WES 69 kV	R-44	8	77	44	> 45	acceptable	None
11	MRP – SHO 69 kV	C-55	8	N/A	N/A	> 8	acceptable	None
12	MRP – RPD 69 kV	691	7.5	N/A	N/A	> 8	acceptable	None
13	MRP – CUS 69 kV	P-68	6.5	N/A	N/A	> 8	acceptable	None

Table A.2 – Stability Analysis Results of Breaker Failure Contingencies utilizing 2005 System After the Addition of G421 Generation[1]

Item	Faulted Facilities	Failed Ckt. Brkr	Element(s) Cleared In Breaker Failure	MECT	Calculated CCT [4]	Voltage Recovery [5]	Transient Problems
1	FIN – G421 69 kV	R-44	J-10, L-64, F-32, U-47	19.5	> 22	acceptable	None
2	FIN – LUX 69 kV	J-10	R-44, L-64, F-32, U-47	21	> 22	acceptable	None
3	FIN – HEN 69 kV	L-64	J-10, R-44, F-32, U-47	19.5	> 22	acceptable	None
4	FIN – VBR 69 kV	F-32	U-47, R-44, J-10, L-64	19.5	> 22	acceptable	None
5	FIN – HWY 69 kV	U-47	R-44, J-10, L-64, F-32	19.5	> 22	acceptable	None
6	WES – G421 69 kV	88	77	44	> 45	acceptable	None
7	WES – MRP 69 kV	77	88	21	> 22	acceptable	None
8	MRP – WES 69 kV	R-44	C-55, 691, P-68	21	> 22	acceptable	None
9	MRP – SHO 69 kV	C-55	R-44, 691, P-68	21	> 22	acceptable	None
10	MRP – RPD 69 kV	691	R-44, C-55, P-68	20.5	> 22	acceptable	None
11	MRP – CUS 69 kV	P-68	691, R-44, C-55	19.5	> 22	acceptable	None

Table A.3 – Stability Analysis Results of Prior Outage Contingencies Utilizing 2005 System After the Addition of G421 Generation[1]

Prior Outage	Item	Faulted Facilities	MECT[4] close end	MECT[4] far end	Calculated CCT [4]	Voltage Recovery [5]	Comments
G421 to Wesmark Or Wesmark to Manrsp	1a	FIN – LUX 69 kV	8	N/A	> 8	acceptable	G 421 trips at 6 cycles
	1b	FIN – HEN 69 kV	6.5	N/A	> 8	acceptable	G 421 trips at 6 cycles
	1c	FIN – VBR 69 kV	6.5	N/A	> 8	acceptable	G 421 trips at 6 cycles
	1d	FIN – HWY 69 kV	6.5	N/A	> 8	acceptable	G 421 trips at 6 cycles
Finger Road to Luxemburg	2a	WES – G421 69 kV	6.5	4.5	> 8	acceptable	None
	2b	FIN – HEN 69 kV	6.5	N/A	> 8	acceptable	None
	2c	FIN – VBR 69 kV	6.5	N/A	> 8	acceptable	None
	2d	FIN – HWY 69 kV	6.5	N/A	> 8	acceptable	None
G421 to Bluestone	3a	WES – MRP 69 kV	8	8	> 8	acceptable	G 421 trips at 6 cycles
	3b	MRP – WES 69 kV	8	44	> 8	acceptable	G 421 trips at 6 cycles
	3c	MRP – SHO 69 kV	8	N/A	> 8	acceptable	G 421 trips at 6 cycles
	3d	MRP – RPD 69 kV	8	N/A	> 8	acceptable	G 421 trips at 6 cycles
	3e	MRP – CUS 69 kV	8	N/A	> 8	acceptable	G 421 trips at 6 cycles
Manrap to Shoto	4a	WES – MRP 69 kV	8	8	> 8	acceptable	None
	4b	MRP – WES 69 kV	8	44	> 44	acceptable	None
	4d	MRP – RPD 69 kV	8	N/A	> 8	acceptable	None
	4e	MRP – CUS 69 kV	8	N/A	> 8	acceptable	None

Appendix B

Short Circuit Analysis

Table B.1 – Maximum and minimum fault duties at the G421 point of interconnection without the contribution from G421.

Maximum Fault Duty		Minimum Fault Duty	
Single-phase	**Three-Phase**	**Single-phase**	**Three-Phase**
3526 Amps	**5347 Amps**	**1013 Amps**	**1550 Amps**

Note: Minimum fault duty was calculated with the G421 – Bluestone 69 kV line out of service.

Table B.2 – Thevenin Equivalent Impedances (in Ohms) in intact system at the G421 point of interconnection without the contribution from G421.

Pos Seq.	Neg. Seq.	Zero Seq.
3.20964 + j 6.72265	**3.22353 + j 6.71845**	**6.93594 + j 17.7036**

Table B.3 – Thevenin equivalent impedances (in Ohms) measured at the G421 point of interconnection without the contribution from G421 and also with the G421 – Bluestone 69 kV Line out of service.

Pos Seq.	Neg. Seq.	Zero Seq.
11.4052 + j 23.0228	**11.3938 + j 22.9779**	**24.6686 + j 61.9887**

Appendix C

Power Flow Analysis

Table C.1 – Winter 2006/2007 Thermal Overloads Identified. 50 MW Generation Delivery from G421 to NSP(25%) and ComEd (75%)

Limiting Element	**Existing MVA Rating**	**Worst Contingency**	**MVA Flow without G421**	**MVA Flow G421 50 MW**	**Solution for Limiting Element**
		Base case			
		None			
		Single Contingencies			
		None			
		Double Contingencies			
Pulliam 69/138 kV Transformer	72	North Appleton – Fox Energy 345 kV Highway V - Preble 138 kV	74.5	80.6	No [1]
G410 – G384/410 138 kV	287	Point Beach – Kewaunee 345 kV North Appleton – Kewaunee 345 kV	325.6	327.5	No [1]
G410 – East Krok 138 kV	287	Point Beach – Kewaunee 345 kV North Appleton – Kewaunee 345 kV	324.6	326.3	No [1]

Note:
1- There is no previously identified project by ATC to solve the loading problem. G421 may be required to back down during prior outage events involving one of these two transmission elements. However, existing operating restrictions on the Point Beach and Kewaunee generating units for some of the prior outage events may mitigate the overloads listed. The impact of the existing operating restrictions can be reviewed in the ISIS

Table C.2 – Summer 2007 Thermal Overloads Identified. 50 MW Generation Delivery from G421 to NSP(25%) and ComEd (75%)

Limiting Element	Existing MVA Rating	Worst Contingency	MVA Flow without G421	MVA Flow G421 50 MW	Solution for Limiting Element
		Base Case			
		None			
		Single Contingencies			
		None			
		Double Contingencies			
North Appleton – Kewaunee 345 kV	1004	North Appleton – Fox Ener. 345 kV Point Beach – Forest Junct. 345 kV	1016	1019.5	No [1]

Note:
1- There is no previously identified project by ATC to solve the loading problem. G421 may be required to back down during prior outage events involving one of these two transmission elements. However, existing operating restrictions on the Point Beach generating units for either of the prior outage events may mitigate the overload listed. The impact of the existing operating restrictions can be reviewed in the ISIS.

Appendix D

Summary of Operation Restrictions

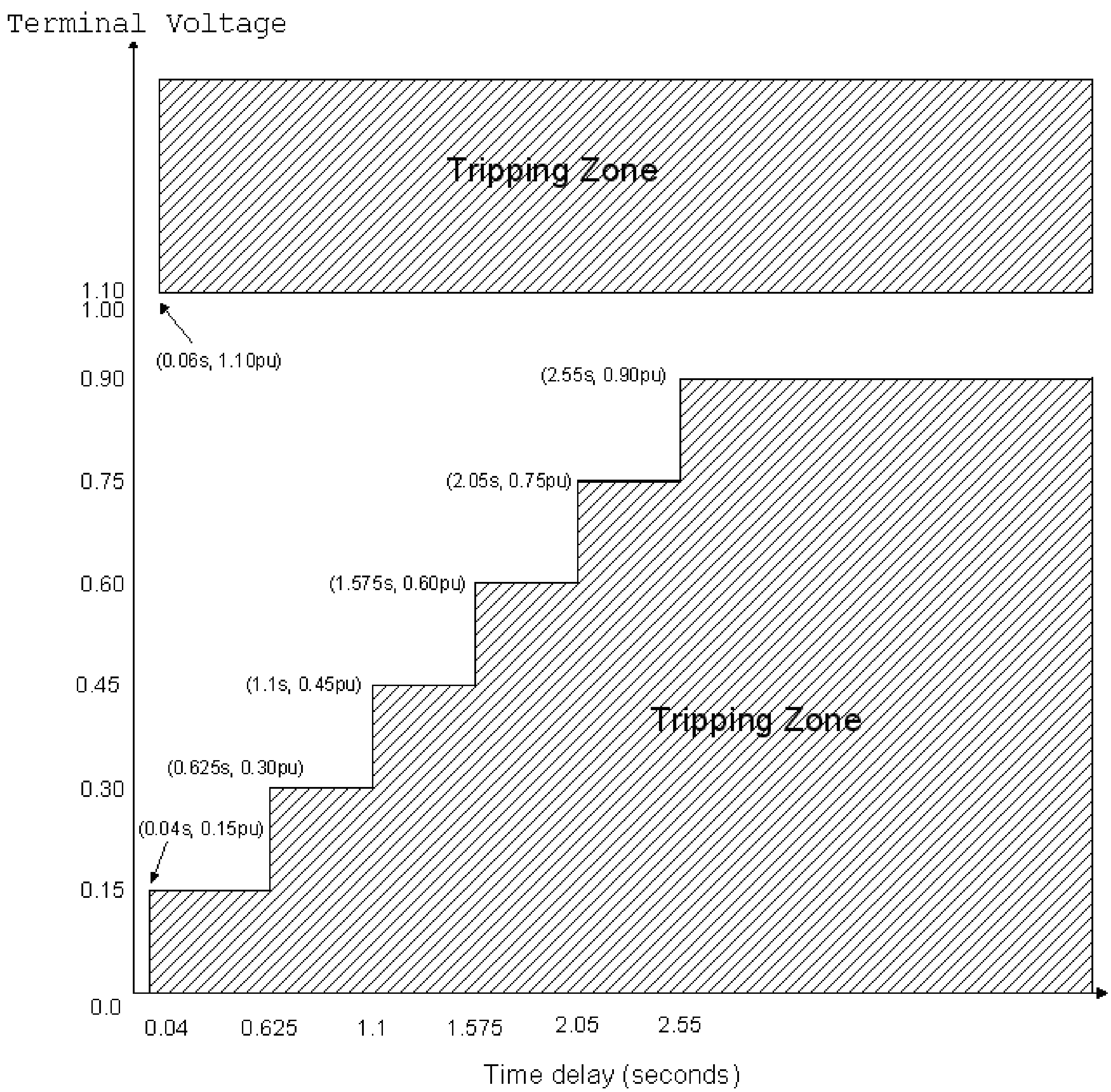
Table D.1 – Identified Operation Restrictions on the G421 Generation Under Prior Outage Scenarios

Prior Outage	G421 Max Allowable Output (MW)	Worst Next Contingency	Limiting Element[1]	MVA Rating	Reason	Season
Highway V - Preble 138 kV	0.0	North Appleton – Fox Energy 345 kV	Pulliam 69/138 kV Transformer	72	Thermal	Winter 2006/07
North Appleton – Fox Energy 345 kV	0.0	Point Beach – Forest Junct. 345 kV	North Appleton – Kewaunee 345 kV	925	Thermal	Summer 2007
North Appleton – Fox Energy 345 kV	0.0	Highway V – Preble 138 kV	Pulliam 69/138 kV Transformer	72	Thermal	Winter 2006/07
North Appleton – Kewaunee 345 kV	0.0	Point Beach – Kewaunee 345 kV	G410 – G384/410 138 kV	287	Thermal	Winter 2006/07
Point Beach – Forest Junct. 345 kV	0.0	North Appleton – Fox Energy 345 kV	North Appleton – Kewaunee 345 kV	925	Thermal	Summer 2007
Point Beach – Kewaunee 345 kV	0.0	North Appleton – Kewaunee 345 kV	G410 – G384/410 138 kV	287	Thermal	Winter 2006/07
G421 to Wesmark	0.0 [2]	Finger Road to Luxemburg 69 kV	G421 trips	N/A	Stability	Year round
Wesmark to Manrap	0.0 [2]	Finger Road to Luxemburg 69 kV	G421 trips	N/A	Stability	Year round
G421 to Bluestone	0.0 [2]	Manrap to Shoto 69 kV	G421 trips	N/A	Stability	Year round

1. The Facility Study can examine if minor upgrades to these limiting elements are possible, if desired.
2. Operating restrictions will be re-examined in ISIS taking into account the selected solution utilized to mitigate G421 tripping for the intact system, primary fault stability studies. Additionally, the ISIS can review the impact of existing operating restrictions on the Point Beach and Kewaunee generating units, where applicable.

Appendix E

Proposed Fault Ride-Through Characteristics For G421 Wind Turbines



Appendix F

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.