Interconnection Evaluation Study Report

98 MW Wind Generation in
Fond du Lac County, Wisconsin
MISO #G427 (#38121-01)

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 #G427, MISO Queue #38121-01. This study identifies potential system loading, voltage violations and stability problems that are caused by or aggravated by the connection of G427, a proposed wind farm to be located in Fond du Lac County, Wisconsin. The requested in-service date for this project is December 1, 2005.

The proposed G427 wind farm is located in Fond du Lac County, Wisconsin, utilizing 49 2.0 MW wind turbines. The wind farm will have a single collection bus at a voltage level of 34.5kV and will connect to the planned Cypress substation via a new 345/34.5kV transformer. The planned Cypress substation consists of a three-breaker 345kV ring-bus substation that interconnects to the 345kV line Arcadian – Forest Junction. The Cypress substation is planned for the interconnection of G353 and G354. The one-line diagram of the existing system after the G427 wind farm addition is shown in Figure 1.1. The figure includes the competing requests.

Point of Interconnection Power Factor Requirement

G427 is required to have a power factor no worse than 0.98 leading (absorbing VArs), as measured at the point of interconnection ("POI").

Required G427 Interconnection Equipment

The Generator is responsible for the 345kV high side circuit breaker, the 345/34.5kV transformer and 34.5kV facilities to connect the wind farm collection bus to the planned Cypress substation equipment.

Load Flow Impacts

For the Summer 2006 study case, the addition of G427 did not cause any thermal overloads for the intact system. However, for the single contingency of losing the N. Appleton – Kewaunee 345 kV line (R304), the thermal loading on N. Appleton – Fox River 345 kV line (6832; labeled L151b in Fig. 1.1) violates its existing emergency rating. Since there is an existing ATC project underway to remove this limitation before June 2006, the addition of G427 does not cause any thermal overloads. However, during several prior outage conditions identified in Table D.1, the G427 output will need to be curtailed to 0 MW due to thermal overloads during N-2 contingency conditions that are identified in Table C.2.

For the Winter 2005/2006 study case, the addition of G427 did not cause any intact or single contingency overloads. The N-2 contingency results are presented in Table C.1 and the related operating restrictions are shown in Table D.1.

This study did not identify any voltage violations during contingency conditions due to the addition of G427.

Stability Impacts

Results of the stability analysis are summarized in Tables A.1 and A.2 in Appendix A. Stability analysis identified that the G427 has no negative impact on system stability.

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 G427.

System Upgrades

Existing System Before G427

This study did not identify any upgrades for the existing system before G427 interconnection.

Required Upgrades After G427

Breaker Duty Related

None.

Stability Related

None.

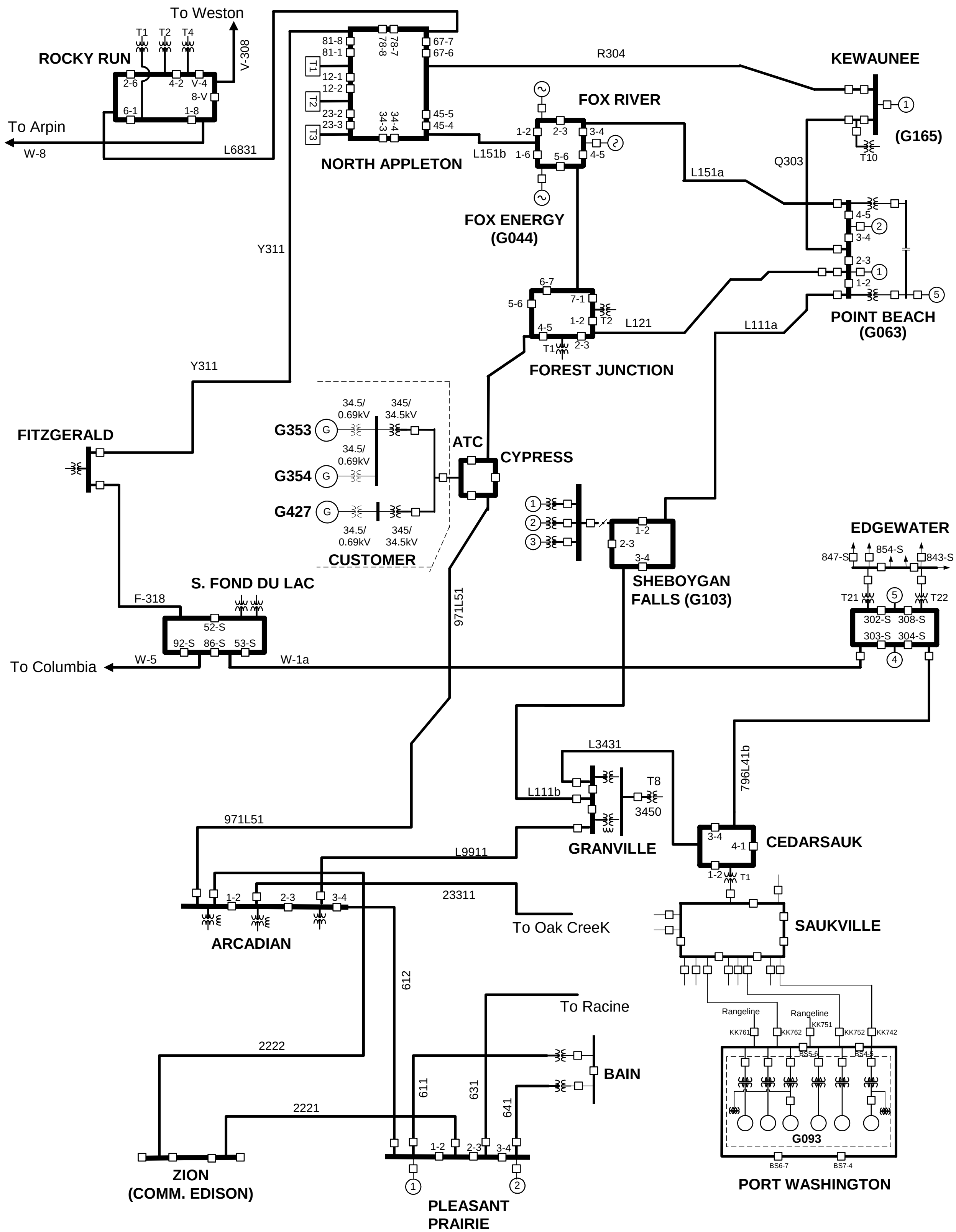
Proposed Upgrades After G427

None.

Operation Restrictions

Operation restrictions on the G427 generation are identified in Table D.1 in Appendix D for the thermal and stability constraints found for the double contingencies (N-2) studied.

Figure 1.1 – One Line Diagram of the Existing System After the Addition of G427



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 position 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 9 Generator Interconnection Requests (GIR) with an earlier queue position may impact the G427 study results. These requests are: G044, G063, G074, G103, G165, G225, G353, G354 and G383. All of these requests have signed interconnection agreements. This study included all of these facilities and any required system modifications identified in these requests.

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 G427 interconnection; two system conditions were examined - “Before” the addition of G427 and “After” the addition of G427. 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 G427.

Only those existing system violations that are made worse by the G427 wind farm are deemed relevant to the G427 interconnection request and are documented in this report. Any other identified existing system violations that are not made worse by the G427 wind farm are deemed unrelated to the G427 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, the 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-6.0 (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, the Summer 2006 power flow base case was developed using the ATC/MISO Summer 2006 model created from the 2002 Series NERC/MMWG model. All ATC projects expected to be completed and in-service by June 2006 were also added. For Winter 2005/2006, the existing ATC/MISO models used for transmission service were utilized. Full plant output (98 MW) of G427 was delivered to the NSP (25%) and ComEd (75%) control areas. Generation in these control areas was decreased 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.

2.3 Assumptions

2.3.1 Generation Facility Modeling

The G427 wind farm is modeled by a lumped representation in this study. It is modeled as a single 98 MW, 690 V generator in the load flow case and represented by a user-written model in the dynamic simulations. For all analysis, G427 generation was modeled at 0.98 leading power factor (absorbing VArs) 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. "Before" and "After" scenarios were not analyzed because the "After" scenario was not deficient for any studied faults according to ATC stability criteria.

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.

Prior outage, primary fault contingency analysis determined that the lowest permissible leading power factor (i.e. absorbing MVAr) for G427 is 0.98 at the point of interconnection ("POI") with the ATC transmission system. This minimum permissible power factor value is required to maintain the voltage on the wind turbine 690 V bus above 0.90 pu. The customer provided dynamics model uses 0.90 pu as the highest voltage tripping point for the relay definitions.

3.1.1 Results of Intact System, Primary Fault Contingencies

Stability analysis was not performed for intact system, primary fault contingencies since the prior outage scenarios considered are more severe for this interconnection.

3.1.2 Results of Breaker Failure Contingencies

The breaker failure contingency results are summarized in Table A.1 in Appendix A. Stability analysis did not identify violations for any breaker failure contingencies when the G427 generation is at its full capacity of 98 MW. The G427 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.2 in Appendix A. Stability analysis did not identify violations for any prior outage, primary fault contingencies when the G427 generation is at its full capacity of 98 MW. The G427 wind farm did not trip for any of these contingencies.

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 G427.

The maximum and minimum short-circuit duties at the G427 Point of Interconnection (POI) and the Thevenin equivalent impedances at the G427 POI are provided in Tables B.1 through B.3 in the Appendix B. These values are provided to aid in the design of the customer's substation and harmonic and flicker compliance.

3.3 Thermal Analysis Results

Tables C.1 and C.2 in Appendix C list the thermal overloads caused by G427 or in which G427 contributes to the loading problem for the intact system and also for the system with single (N-1) and double (N-2) contingency conditions. No intact system violations and only one single contingency violation were identified. However, the single N-1 overload will be mitigated by a planned project for Summer 2005.

For the single (N-1) contingency condition of losing either one of the two G427 outlets, full output of G427 (98 MW) is diverted into the remaining 971L51 path with a summer emergency rating of 488 MVA. In order to meet the ATC voltage criteria for this single contingency condition, the G427 power factor at the Point of Interconnection (POI), that is, at Cypress 345 kV bus, is restricted between 0.95 leading (absorbing VArs) and 0.95 lagging (producing VArs). However, stability analysis results dictate a more stringent power factor requirement, as discussed in Section 3.1, and govern this request.

Several double (N-2) contingency conditions resulted in thermal overloads, which translate into operation restrictions for G427 during certain prior outage conditions, as listed in Table D.1 of Appendix D. This study did not identify any voltage violations during double contingency conditions due to the addition of G427.

Appendix A

Stability Analysis Results

Notes:

1. Table abbreviations: ADN – Arcadian, FIZ – Fitzgerald, FJT – Forest Junction, KEW – Kewaunee, NAP – N. Appleton, OCK – Oak Creek, POB – Point Beach, RRN – Rocky Run.
2. The fault is applied at the first named terminal of the faulted element. All faults modeled were 3-phase faults unless otherwise noted. Far end clearing assumed to be 5.0 cycles unless otherwise noted. IPO = Independent Pole Operated, IPO clearing assumed to be 3.5 cycles unless otherwise noted.
3. CCT = Critical Clearing Time (cycles). MECT = Actual Maximum Expected Clearing Time (cycles). New generation requires a 1.0 cycle margin between CCT and MECT.

Table A.1 – Stability Analysis Results of Breaker Failure Contingencies at 345kV Buses For the Expected 2005 System After the Addition of G427 Generation

Item	Faulted Facilities	Failed Circuit Breaker	Element(s) Cleared In Breaker Failure	MECT[3]	With G427 Including Competes
					CCT[3]
1	ADN-OCK	ADN-OCK @ADN	ADN-OCK, T2, BS1-2, BS2-3	12.0	≥14.0
2	FJT-POB	BS1-2 @FJT	FJ T BS7-1, T2	11.25 IPO (-18500)	≥12.5
3	FJT-G044	BS7-1 @FJT	FJT BS1-2, T2	11.25 IPO (-18500)	≥14.0
4	FJT-G353/354a	BS4-5 @FJT	FJT BS2-3, T1	11.25 IPO (-18500)	≥12.5
5	FJT-G353/354b	BS6-7 @FJT	FJT BS7-1, FJT-G044	11.25 IPO (-18500)	≥12.5
6	G044-NAPa	G044 BS1-6	G044 BS5-6, CT2	~9.0 IPO (-18500)	11.0
7	G044-NAPb	G044 BS1-2	G044 BS2-3, ST1	~9.0 IPO (-18500)	≥12.0
8	G044-POBa	G044 BS2-3	G044 BS1-2, ST1	~9.0 IPO (-18500)	12.0
9	G044-POBb	G044 BS3-4	G044 BS4-5, CT1	~9.0 IPO (-18500)	11.5
10	KEW-POB	KEW-POB @ KEW	KEW-POB CB#2, T10	Double CB = 5.0	9.0
11	NAP-FIZ	NAP 78-8	NAP 78-7	~5.0	≥7.0
12	NAP-KEW	NAP 67-6	NAP 67-7	~5.0	≥7.0
13	NAP-G044	NAP 34-4	NAP 34-3	~5.0	≥7.0
14	NAP-RRN	NAP 67-7	NAP 67-6	~5.0	≥7.0
15	POB-FJT	@POB	POB-FJT CB#2	Double CB = 5.0	≥8.5
16	POB-G044	@POB	POB BS4-5	9.1 IPO (-12000)	11.0
17	POB-G103	@POB	POB BS1-2	9.1 IPO (-12000)	10.5
18	POB-KEW	@POB	POB BS3-4, POB BS2-3	9.1 IPO (-12000)	10.5

Table A.2 – Stability Analysis Results of Prior Outage Contingencies For the Expected 2005 System After the Addition of G427 Generation

Item	Faulted Facilities	Prior Outage	MECT[3]	With G353/354 Including Competes Facility Update CCT[3]
1	ADN-OCK	G353/354-FJT	~5.0	≥7.0
2	FJT-G044	G353/354-ADN	~5.0	≥7.0
3	G044-NAP	POB-KEW	~5.0	≥7.0
4	POB-G103	POB-KEW	~5.0	≥7.0
5	G044-NAP	FJT-G044	~5.0	≥7.0
6	NAP-FIZ	NAP-G044	~5.0	≥7.0
7	NAP-RRN	NAP-G044	~5.0	≥7.0
8	NAP-KEW	NAP-G044	~5.0	≥7.0
9	NAP-FIZ	NAP-KEW	~5.0	≥7.0
10	NAP-RRN	NAP-KEW	~5.0	≥7.0
11	NAP-G044	NAP-KEW	~5.0	6.0

Appendix B

Short Circuit Analysis

Table B.1 – Maximum and Minimum Fault Duties
At the G427 Point of Interconnection without the Contribution from G353/354 or G427

Maximum Fault Duty		**Minimum Fault Duty**	
Single-phase	**Three-Phase**	**Single-phase**	**Three-Phase**
6500 Amps	8800 Amps	2000 Amps	2800 Amps

Note: Minimum fault duty was calculated with the Forest Junction – G427 345 kV line out of service.

Table B.2 – Thevenin Equivalent Impedances in Ohms in Intact System
At the G427 Point of Interconnection without the Contribution from G353/354 or G427

Pos Seq.	**Neg. Seq.**	**Zero Seq.**
1.44097 + j22.8336	1.45472 + j22.8340	10.5045 + j46.5450

Table B.3 – Thevenin Equivalent Impedances in Ohms
In the System with outage of the Forest Junction – G427 345kV line
At the G427 Point of Interconnection without the Contribution from G353/354 or G427

Pos Seq.	**Neg. Seq.**	**Zero Seq.**
4.376 + j72.9625	4.3890 + j72.9758	36.9979 + j160.6530

Appendix C

Power Flow Analysis

Table C.1 – Winter 2005/2006 Thermal Overloads Identified.
98 MW Generation Delivery from G427 to NSP (25%) and ComEd (75%)

Limiting Element	Existing MVA Rating	Worst Contingency	MW Flow without G427	MW Flow with G427 at 98 MW	Solution for Limiting Element
		Base Case: None			
		Single Contingencies: None			
		Double Contingencies			
Granville T1 345/138 kV Xfmr	478	Granville T3 345/138 kV Xfmr Cedarsauk T1 345/138 kV Xfmr	571.6	574.8	No [1]
Granville T3 345/138 kV Xfmr	478	Granville T1 345/138 kV Xfmr Cedarsauk T1 345/138 kV Xfmr	570.0	573.2	No [1]
Lake Park – City Limits 138 kV	199	North Appleton – Fox River 345 kV North Appleton – Kewaunee 345 kV	242.2	253.5	No [1]
Kaukauna Central Tap – Melissa 138 kV	96	North Appleton – Fox River 345 kV North Appleton – Kewaunee 345 kV	139.0	144.2	No [1]

Notes:

1. There are no previously identified projects by ATC to solve the loading problem. G427 would likely be required to back down during prior outage events involving one of these two transmission elements.

Table C.2 – Summer 2006 Thermal Overloads Identified.
98 MW Generation Delivery from G427 to NSP (25%) and ComEd (75%)

Limiting Element	Existing MVA Rating	Worst Contingency	MW Flow without G427	MW Flow with G427 at 98 MW	Solution for Limiting Element
		Base Case: None			
		Single Contingencies			
North Appleton – Fox River 345 kV	926	North Appleton – Kewaunee 345 kV	984.7	1019.7	Yes [1]
		Double Contingencies			
North Appleton – Fox River 345 kV	926	Granville – Sheboygan Energy 345 kV North Appleton – Kewaunee 345 kV	1120.6*	1160.0*	No [2]
Lake Park – City Limits 138 kV	199	North Appleton – Fox River 345 kV North Appleton – Kewaunee 345 kV	231.0*	239.5*	No [2]
Kewaunee T10 345/138 kV Xfmr	390	North Appleton – Fox River 345 kV North Appleton – Kewaunee 345 kV	390.0*	402.8*	No [2]
Highway V – Preble 138 kV	226	North Appleton – Fox River 345 kV North Appleton – Kewaunee 345 kV	270.6*	275.0*	Yes [3]
Tower Dr. – Preble 138 kV	209	North Appleton – Fox River 345 kV North Appleton – Kewaunee 345 kV	242.5*	247.0*	Yes [3]
Forest Junction T2 345/138 kV Xfmr	675	North Appleton – Fox River 345 kV Forest Junction T1 345/138 kV Xfmr	713.9	737.5	No [2]
Granville T1 345/138 kV Xfmr	478	Granville T3 345/138 kV Xfmr Cedarsauk T1 345/138 kV Xfmr	594.6	597.8	No [2]
Granville T1 345/138 kV Xfmr	478	Granville T3 345/138 kV Xfmr Arcadian – Granville 345kV	498.0	506.2	No [2]
Granville T3 345/138 kV Xfmr	478	Granville T1 345/138 kV Xfmr Cedarsauk T1 345/138 kV Xfmr	592.7	596.0	No [2]
Granville 138 kV Bus Tie 5-6	388	Granville T1 345/138 kV Xfmr Granville T9 138/27.6 kV Xfmr	426.2	432.0	No [2]
Arcadian T3 345/138 kV Xfmr	240	Forest Junction – Cypress 345 kV Arcadian T1 345/138 kV Xfmr	232.1[4]	236.7[4]	No [2]

Notes:
*- Flow after implementing the required generation reduction at Kewaunee as per Operating Guide for prior outage of Kewaunee — North Appleton 345 kV line.

1. The North Appleton – Fox River 345 kV line (L151) will be uprated to 1096 MVA SN/SE after the planned conversion of N. Appleton 345kV switchyard to ring-bus configuration, scheduled for completion by 6/1/2005.
2. There are no previously identified projects by ATC to solve the loading problem. G427 would likely be required to back down during prior outage events involving one of these two transmission elements.
3. The planned installation of series reactor at Highway V will reduce the "with G427" flow on Highway V – Preble line to 214.2 MVA (below SE) and Tower Dr–Preble line to 185.8 MVA (below SN) before generation reduction at Kewaunee.
   After Kewaunee reduction, the flow on Highway V – Preble line falls below its SN rating.
4. Although lower than the rated MVA, these correspond to 101% and 102% thermal (current) loading on the transformer due to lower voltage.

Appendix D

Summary of Operation Restrictions

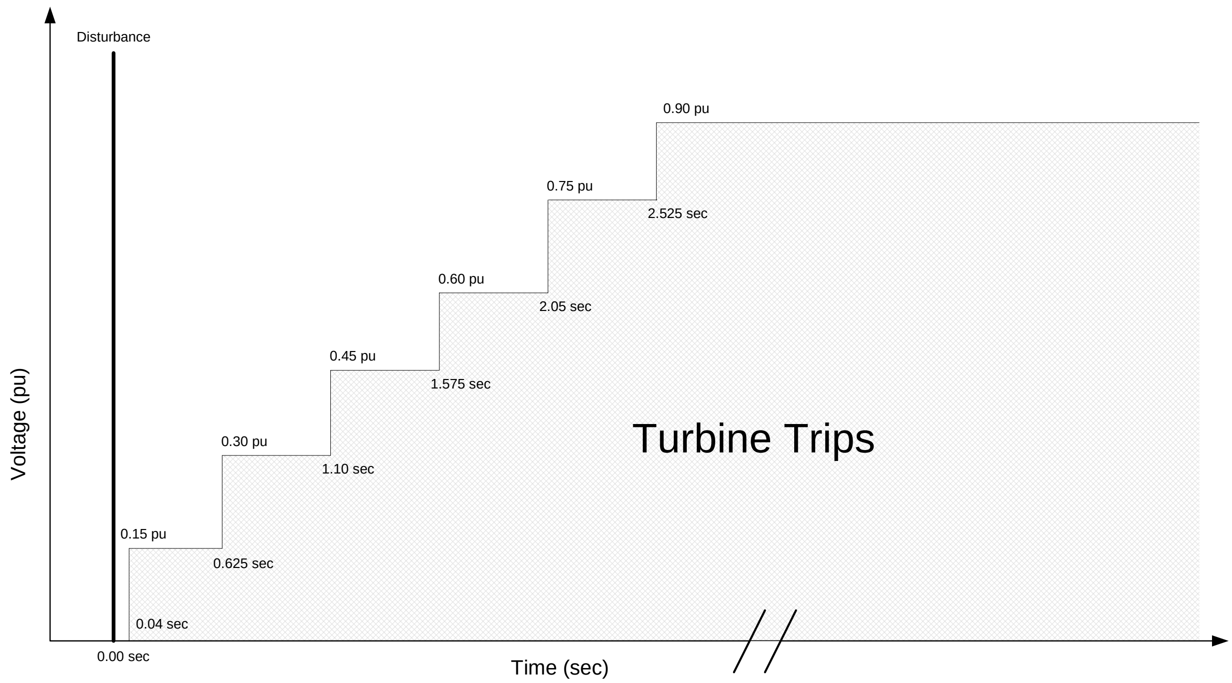
Table D.1 – Identified Operation Restrictions on G427 Under Prior Outage Scenarios

Prior Outage	G427 Max. Allowable Output (MW)	Worst Next Contingency	Limiting Element[1]	MVA Rating	Reason	Season
Arcadian – Granville 345kV	0.0	Granville T3 345/138 kV Xfmr	Granville T1 345/138 kV Xfmr	478	Thermal	Summer
Arcadian T1 345/138 kV Xfmr	0.0	Forest Junction – Cypress 345 kV	Arcadian T3 345/138 kV Xfmr	240	Thermal	Summer
Cedarsauk T1 345/138 kV Xfmr	0.0	Granville T1 345/138 kV Xfmr	Granville T3 345/138 kV Xfmr	504	Thermal	Winter/ Summer
	0.0	Granville T3 345/138 kV Xfmr	Granville T1 345/138 kV Xfmr	504	Thermal	Winter/ Summer
Forest Junction – Cypress 345 kV	0.0	Arcadian T1 345/138 kV Xfmr	Arcadian T3 345/138 kV Xfmr	240	Thermal	Summer
Forest Junction T1 345/138 kV Xfmr	0.0	North Appleton – Fox River 345 kV	Forest Junction T2 345/138 kV Xfmr	675	Thermal	Summer
Granville T1 345/138 kV Xfmr	0.0	Cedarsauk T1 345/138 kV Xfmr	Granville T3 345/138 kV Xfmr	478	Thermal	Winter/ Summer
Granville T3 345/138 kV Xfmr	0.0	Arcadian – Granville 345kV	Granville T1 345/138 kV Xfmr	478	Thermal	Summer
	0.0	Cedarsauk T1 345/138 kV Xfmr	Granville T1 345/138 kV Xfmr	478	Thermal	Winter/ Summer
North Appleton – Fox River 345 kV	0.0	Forest Junction T1 345/138 kV Xfmr	Forest Junction T2 345/138 kV Xfmr	675	Thermal	Summer
	0.0	North Appleton – Kewaunee 345 kV	Highway V – Preble – Tower Dr 138 kV	226/209	Thermal	Summer
	0.0	North Appleton – Kewaunee 345 kV	Kaukauna Central Tap – Melissa 138 kV	96	Thermal	Winter
	0.0	North Appleton – Kewaunee 345 kV	Kewaunee T10 345/138 kV Xfmr	390	Thermal	Summer
	0.0	North Appleton – Kewaunee 345 kV	Lake Park – City Limits 138 kV	199	Thermal	Winter/ Summer
North Appleton – Kewaunee 345 kV	0.0	North Appleton – Fox River 345 kV	Highway V – Preble – Tower Dr 138 kV	226/209	Thermal	Summer
	0.0	North Appleton – Fox River 345 kV	Kaukauna Central Tap – Melissa 138 kV	96	Thermal	Winter
	0.0	North Appleton – Fox River 345 kV	Kewaunee T10 345/138 kV Xfmr	390	Thermal	Summer
	0.0	North Appleton – Fox River 345 kV	Lake Park – City Limits 138 kV	199	Thermal	Winter/ Summer
	0.0	Sheboygan Energy – Granville 345 kV	North Appleton – Fox River 345 kV	926 [2]	Thermal	Summer
Sheboygan Energy – Granville 345 kV	0.0	North Appleton – Kewaunee 345 kV	North Appleton – Fox River 345 kV	926 [2]	Thermal	Summer

Notes:
1. The Facility Study can examine if minor upgrades to these limiting elements are possible, if desired.
2. The operation restriction holds even after the expected uprate of North Appleton–Fox River 345 kV line (L151) to 1096 MVA SN/SE after the planned conversion of N. Appleton 345kV switchyard to ring-bus configuration.

Appendix E

Proposed Fault Ride-Through Characteristics For G427 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.