System Impact Study Report

130 MW Wind Generation in Green County, Wisconsin
MISO #G281 (#37628-01)

99 MW Wind Generation in Lafayette County, Wisconsin
MISO #G282 (#37628-02)

August 29, 2003

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Stability and Special Studies

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Executive Summary

This report contains the System Impact Study (SIS) for Generation Interconnection Requests (GIR) MISO projects #G281 and #G282, MISO Queues #37628-01 and #37628-02. The purpose of this study is to evaluate the impact of the addition of 130 MW wind generation in Green County, Wisconsin, and/or, 99 MW wind generation in Lafayette County, Wisconsin. The requested in-service date for both of the projects is June 30, 2004.

The proposed G281 wind farm will have a single collection bus at a voltage level of 34.5kV. A 34.5kV cable and a 138/34.5kV transformer will connect the wind farm collection bus to a new three-breaker ring-bus switch station that interconnects G281 to the 138kV line North Monroe – Town Line Road. The generation facility will have a 138 kV breaker on the high side of the generator step up transformer.

The proposed G282 wind farm will have a single collection bus at a voltage level of 34.5kV. A 34.5kV cable and a 138/34.5kV transformer will connect the wind farm collection bus to a new three-breaker ring-bus switch station that interconnects G282 to the 138kV line Darlington – Hillman. The generation facility will have a 138 kV breaker on the high side of the generator step up transformer.

The one-line diagram of the existing system without either of the projects is shown in Figure 1.1. The one-line diagram of the system with the addition of G281 only is shown in Figure 1.2. The one-line diagram of the system with the addition of G282 only is shown in Figure 1.3. The one-line diagram of the system with the addition of both G281 and G282 is shown in Figure 1.4.

This study is to identify whether any stability, or power flow limits may be violated on the ATC transmission system by the addition of G281 only, or G282 only, or both G281 and G282. If any stability, or power flow related problems are found, possible solutions that might address these problems are suggested.

The resolution of possible thermal overloads problems is not required for interconnection service, since thermal overloading impacts may be significantly affected by the specific power delivery requests from the facility. A customer can only identify whether any specific power delivery can be accomplished without causing thermal overloading problems or whether specific system modifications necessary to allow a specific power delivery via a valid Transmission Service Request (TSR) submitted on the MISO OASIS. Nevertheless, the thermal limit violations identified in this impact study are local to the G281 and G282 wind farms and are likely to be a reasonable indication of some of the facilities that might need upgrading when power delivery service is requested.

Detailed short-circuit analysis including the wind farms short-circuit current contributions is not included in this report. Typically induction generators contribute significant short-circuit current only within the first 1 ~ 1.5 cycles after a fault. Because of this fast decay characteristic, short-circuit impact due to the addition of G281 and/or G282 is not included in the System Impact Study. This impact can be evaluated in detail in the Facility Study, if deemed necessary and one is performed. This System Impact Study does provide a summary of maximum short-circuit current and Thevenin equivalent impedance at the three-breaker ring-bus interconnection point and viewed by the G281 and G282 wind farm projects. Refer to the Appendix B for the results.

ATC determined in its sole judgment that two Generator Interconnection Requests (GIRs) with an earlier queue position may impact the G281 and G282 study results. These requests are GIC004 (or G035) and GIC020 (or G072). This System Impact Study included the GIC004 (or G035) and GIC020 (or G072) facilities and any required system modifications identified in these requests. If any of these requests are not actualized as planned, the G281 and G282 study results may change and the Requests may subject to restudy at the Generator's expense.

System Impacts

Stability

The Study found no unacceptable stability impact for the expected 2004 system before the addition of G281 and/or G282.

The Study identified a number of problems after the additions of G281 and/or G282. These problems can be categorized into two classes – tripping of wind turbines and post-contingency voltage violations in the rest of the system.

The Study identified that due to the under voltage tripping criterion associated with the wind turbines proposed for G281 and G282, these two projects trip off line for many of the contingencies studied – including contingencies up to five substations away from the wind farms.

The Study also identified that under certain contingencies and after the tripping of the wind turbines, the rest of the system may experience unacceptable post-contingency over voltage (≥ 1.1pu) at certain substations close to the wind farms.

Summary of the system stability impact due to the addition of G281, or G282, or G281 and G282 is in the following.

Wind Farm Interconnections	Number of contingencies that caused wind turbine tripping	Number of contingencies that caused post-contingency over voltage	Number of sub-/switch- stations that experienced post-contingency over voltage
G281 only	20	3	2
G282 only	19	2	4
G281 and G282	24	6	5

Refer to section 3.1 (Stability Analysis Results) for details of the stability study results.

Impact of tripping of wind turbines

As discussed above, the Study identified that the ride-through capability of the wind turbines proposed for G281 and G282 are not adequate for the turbines to survive many of the studied contingencies – including contingencies up to five substations away. Tripping of the wind turbines certainly has a negative impact on the wind farms – e.g., lost revenue, stress on turbines, etc. Further, it imposes negative impact on system operation, and it has a potential to cause unacceptable transient and post-contingency system frequency deviations after the wind generation penetration level becomes higher in the ATC and neighboring systems. To minimize system operation hazards and potential unacceptable system frequency deviations in the future, it is required that the ride-through capability of the wind turbines for G281 and G282 be improved, such that the wind turbines are able to survive the primary faults, prior outage faults and breaker-failure faults evaluated in this Study.

Wind gust impact

The effect of wind gust and wind turbulence was not simulated in this Study. However, it is known and understood that the wind gust and wind turbulence can cause not only MW output variations, but also voltage fluctuations (voltage flickers) for the type of the wind turbines proposed for G281 and G282. In severe cases of wind gust and wind turbulence, voltage fluctuations may lead to turbine tripping.

Suggested solutions

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

The unacceptable post-contingency voltage condition may be corrected using a properly sized, shunt connected, Static VAR Compensation device installed at a properly selected location local to the wind farms. Static VAR Compensation is also known to be able to minimize voltage fluctuations (flicker) in the wind farm applications.

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

Power Flow

Power flow analysis was performed for the expected 2004 summer peak system. The Study found no voltage violations after the addition of G281 and/or G282. The Study found no thermal overloads after the addition of G282. The Study found thermal overloads after the addition of G281 or G281 and G282. A summary of the thermal overloads is in the following.

Overloaded Element	Emergency/Normal Ratings, MVA	Worse Loading (%), "After"	Loading (%), "Before"	Contingency	Description of "After"
N. Monroe 138kV – N. Monroe 69kV	93.3	119	76	Darlington – N. Monroe 138kV	With G281
N. Monroe 138kV – N. Monroe 69kV	93.3	105	77	Normal	With G281 And G282
N. Monroe 138kV – N. Monroe 69kV	93.3	113	86	Paddock – Rockdale 345kV	With G281 And G282
Rock River 138kV – Rock River 69kV	58.3	105	98	Colley Road – B. Church 138kV	With G281 And G282

Possible solutions include a second 138/69 kV transformer at North Monroe and replacement of the 138/69 kV transformer at Rock River.

Further Study

The next step in the Generation Interconnection Request process is for the Generator to decide whether to proceed with a Facility Study. A Facility Study would investigate whether the selected System Upgrades and enhanced turbine ride-through characteristics will address all of the identified System Impact Study issues. The Facility Study would also include a budgetary cost estimate and schedule for any ATC transmission system modifications that are required to resolve the identified impact problems.

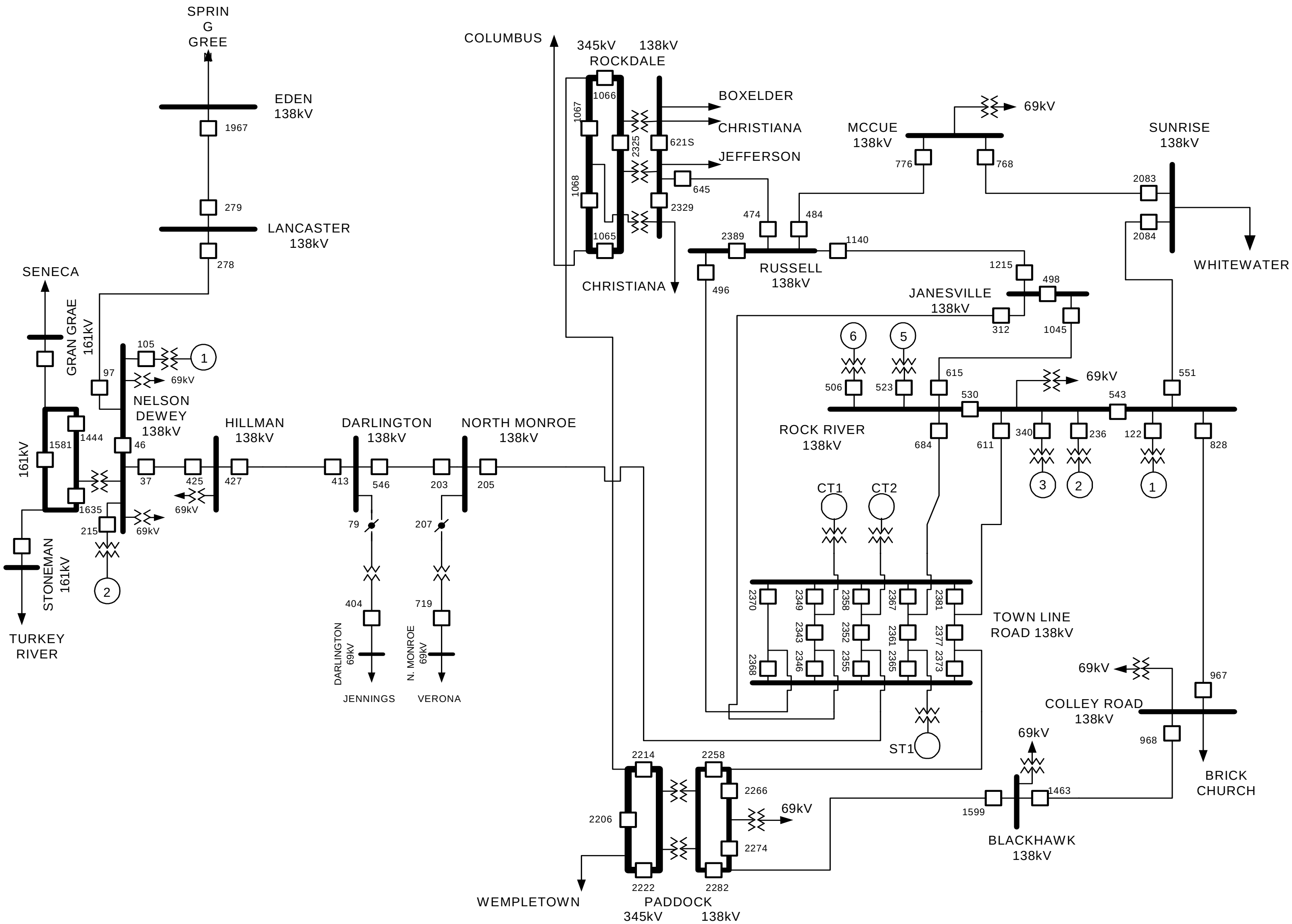

Figure 1.1 – One line diagram of the existing system before the addition of G281 or G282

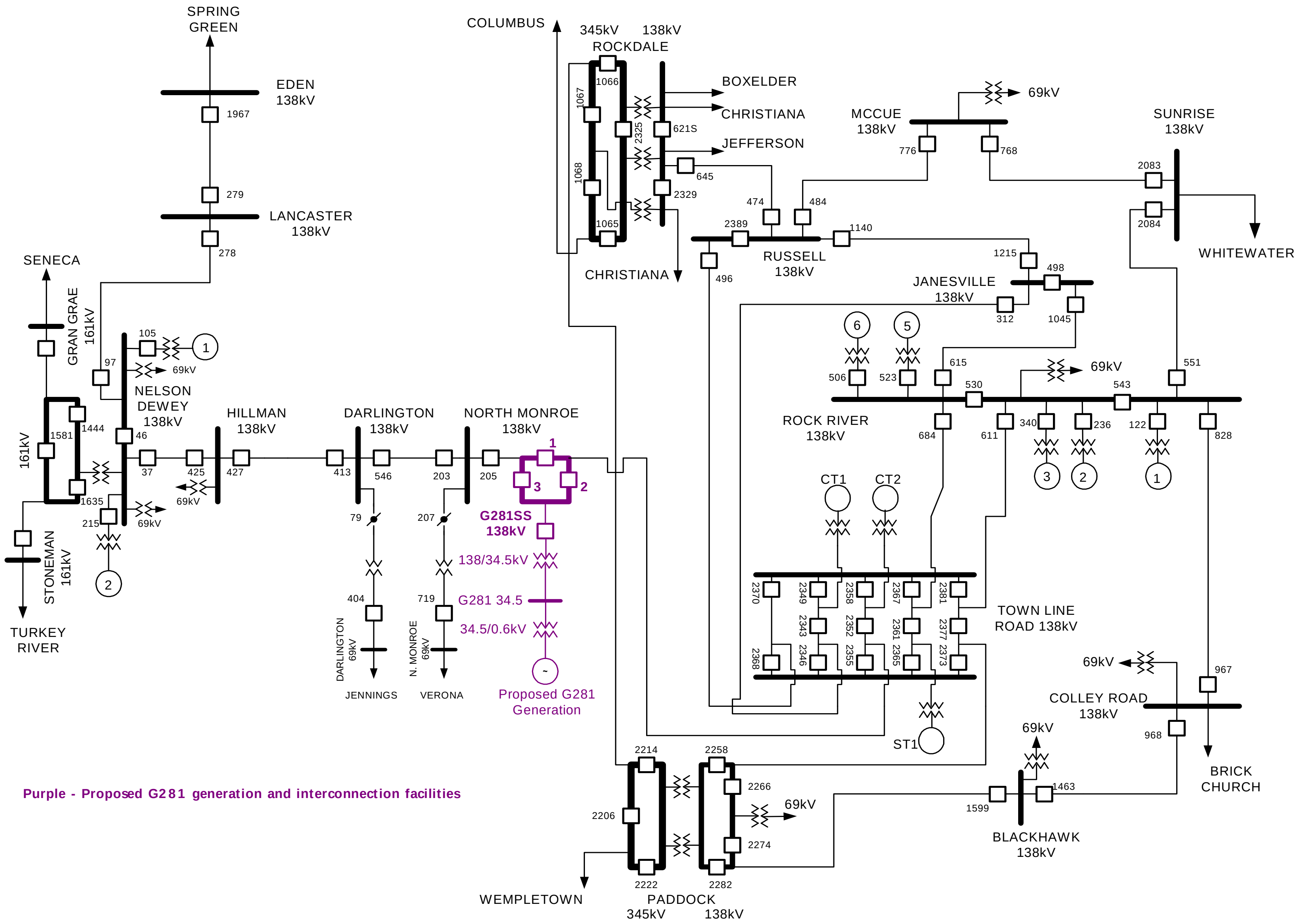

Figure 1.2 – One line diagram of the system after the addition of G281

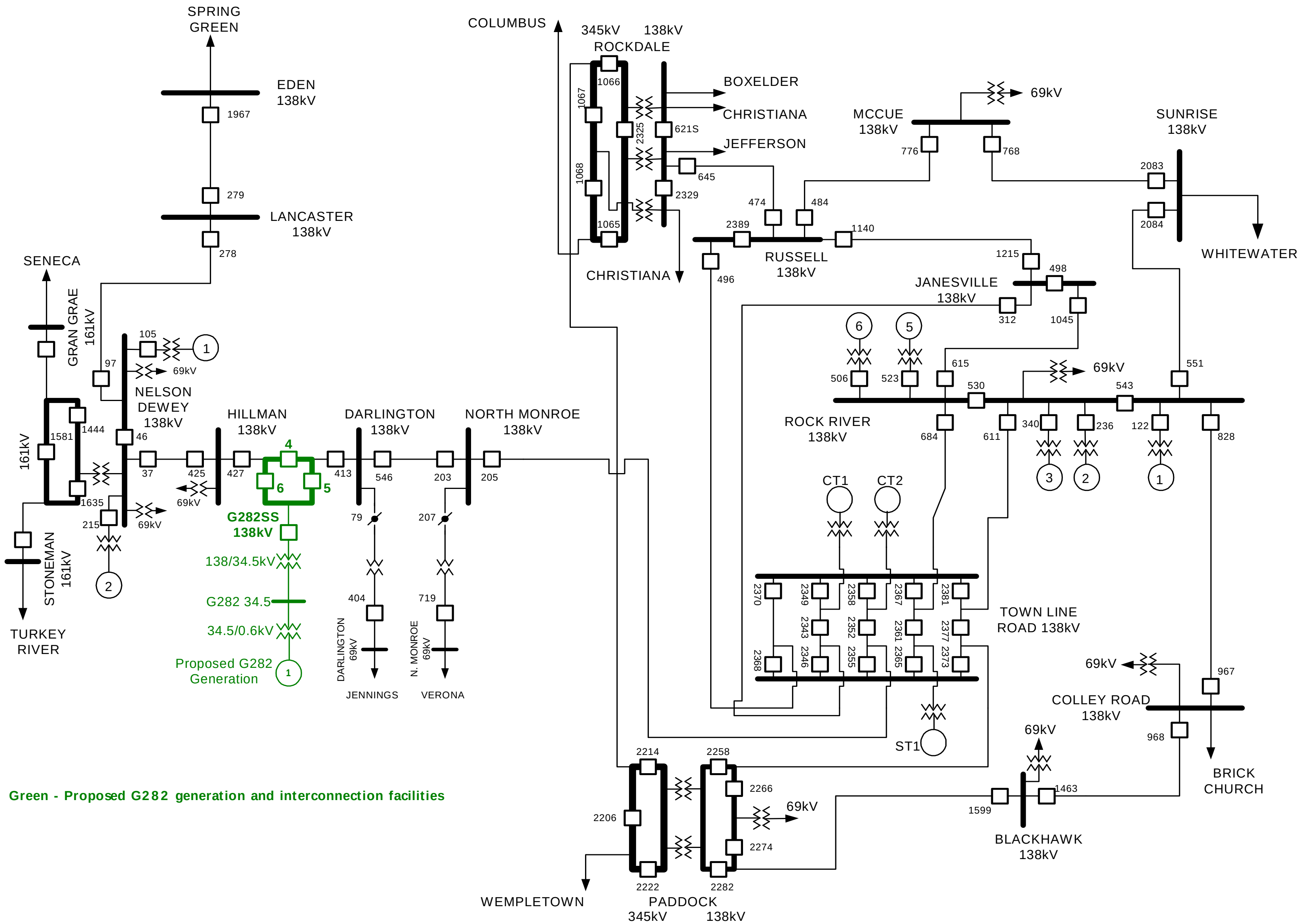

Figure 1.3 – One line diagram of the system after the addition of G282

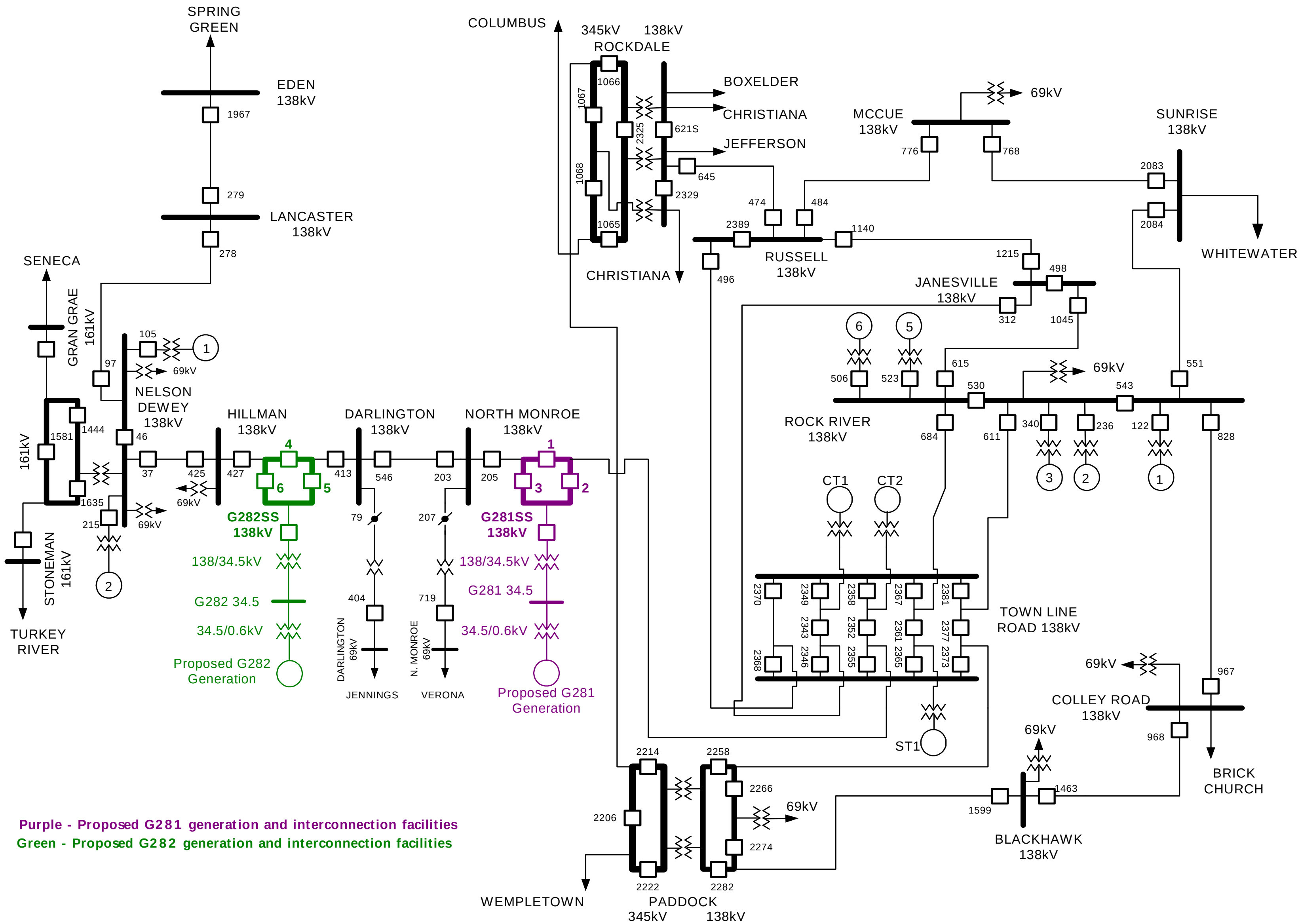

Figure 1.4 – One line diagram of the system after the addition of G281 and G282

1. Introduction and Project Description

This report contains the System Impact Study (SIS) for Generation Interconnection Requests (GIR) MISO projects #G281 and #G282, MISO Queues #37628-01 and #37628-02. The purpose of this study is to evaluate the impact of the addition of 130 MW wind generation in Green County, Wisconsin, and/or, 99 MW wind generation in Lafayette County, Wisconsin. The requested in-service date for both of the projects is June 30, 2004.

The proposed G281 wind farm will have a single collection bus at a voltage level of 34.5kV. A 34.5kV cable and a 138/34.5kV transformer will connect the wind farm collection bus to a new three-breaker ring-bus switch station that interconnects G281 to the 138kV line North Monroe – Town Line Road. The generation facility will have a 138 kV breaker on the high side of the generator step up transformer.

The proposed G282 wind farm will have a single collection bus at a voltage level of 34.5kV. A 34.5kV cable and a 138/34.5kV transformer will connect the wind farm collection bus to a new three-breaker ring-bus switch station that interconnects G282 to the 138kV line Darlington – Hillman. The generation facility will have a 138 kV breaker on the high side of the generator step up transformer.

The one-line diagram of the existing system without either of the projects is shown in Figure 1.1. The one-line diagram of the system with the addition of G281 only is shown in Figure 1.2. The one-line diagram of the system with the addition of G282 only is shown in Figure 1.3. The one-line diagram of the system with the addition of both G281 and G282 is shown in Figure 1.4.

This study is to identify whether any stability, or power flow limits may be violated on the ATC transmission system by the addition of G281 only, or G282 only, or both G281 and G282. If any stability, or power flow related problems are found, possible solutions that might address these problems are suggested.

The resolution of possible thermal overloads problems is not required for interconnection service, since thermal overloading impacts may be significantly affected by the specific power delivery requests from the facility. A customer can only identify whether any specific power delivery can be accomplished without causing thermal overloading problems or whether specific system modifications necessary to allow a specific power delivery via a valid Transmission Service Request (TSR) submitted on the MISO OASIS. Nevertheless, the thermal limit violations identified in this impact study are local to the G281 and G282 wind farms and are likely to be a reasonable indication of some of the facilities that might need upgrading when power delivery service is requested.

Detailed short-circuit analysis including the wind farms short-circuit current contributions is not included in this report. Typically induction generators contribute significant short-circuit current only within the first 1 ~ 1.5 cycles after a fault. Because of this fast decay characteristic, short-circuit impact due to the addition of G281 and/or G282 is not included in the System Impact Study. This impact can be evaluated in detail in the Facility Study, if deemed necessary and one is performed. This System Impact Study does provide a summary of maximum short-circuit current and Thevenin equivalent impedance at the three-breaker ring-bus interconnection point and viewed by the G281 and G282 wind farm projects. Refer to the Appendix B for the results.

ATC determined in its sole judgment that two Generator Interconnection Requests (GIRs) with an earlier queue position may impact the G281 and G282 study results. These requests are GIC004 (or G035) and GIC020 (or G072). This Impact Study included the GIC004 (or G035) and GIC020 (or G072) facilities and any required system modifications identified in these requests. If any of these requests are not actualized as planned, the G281 and G282 study results may change and the Requests may subject to restudy at the Generator's expense.

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

The results of this study may be subject to change. The results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the generator and controls data, in earlier queue GIRs, in related TSRs, or subsequent 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. 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 power flow analysis. Details of the stability and power flow analysis criteria applied in this study can be found in Appendix D.

2.2 Study Methodology

2.2.1 Before and After Comparison

To identify what impacts should be attributed to the addition of G281 and/or G282, four system conditions were examined - "Before" the addition of either G281 or G282, "After" the addition of G281, "After" the addition of G282, and "After" the addition of G281 and G282. Any additional problems identified in the "After" states as compared to the "Before" state are to be attributed to the addition of G281, or G282, or G281 and G282.

2.2.2 Base Case Development

The Summer 2004 Peak base case from the Multi-Regional Modeling Working Group (MMWG) 2002 series was used as the starting point for the development of the various base cases for the power flow analysis and stability analysis.

The power flow analysis was performed using the 100% peak load base case and including the 600MW competing generation of GIC004 (or G035) and GIC020 (or G072) connected at the 138kV substation Town Line Road.

For stability analysis, four system dispatch conditions were evaluated, as listed in Table 2.1 in the follows.

Table 2.1 - Description of the four system dispatch conditions evaluated in the stability analysis

Dispatch-1	Dispatch-2	Dispatch-3	Dispatch-4
2004 summer peak load River Side Generation = 600 MW	2004 summer peak load River Side Generators Out of service	50% 2004 summer peak load River Side Generation = 600 MW	50% 2004 summer peak load River Side Generators Out of service

System dispatch condition #1 is identical to what was used in the power flow analysis.

For the peak load base cases used for both the power flow and stability analysis, the additional generation from G281, or G282, or G281 and G282 was delivered to the WEPCO load. For the 50% of peak load base cases used for stability analysis, the additional generation from G281, or G282, or G281 and G282 was delivered 25% west to the NSP area load and 75% south to the NI area load.

2.3 Assumptions

2.3.1 Generation Facility Modeling and Data

Each wind farm (G281, G282) is represented by a single generator at steady state and modeled as an induction generator in dynamics. The 138/34.5kV transformer associated with each wind farm is modeled explicitly. The 34.5kV/600V transformer is represented by an impedance connected in series with the generator in the generator model. The power factor correction capacitor banks are modeled explicitly as discretely adjusted shunt capacitors. Modeling of the 34.5kV cable was ignored. A user-written model was created to model the under/over voltage- and under/over frequency- tripping characteristic of the wind turbines.

More detailed modeling for stability analysis can include the 34.5kV cable and use more than one induction generators to model the wind turbine clusters within a wind farm. This more detailed modeling may be used in the Facility Study to verify the stability study results obtained in this Impact Study if deemed necessary and one is performed.

Data for generator, transformer, power factor correction capacitors, and voltage- and frequency-tripping characteristic of the wind turbines for the proposed G281 and G282 wind farms are listed in the Appendix E.

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 total of sixteen base scenarios were evaluated in the stability analysis, considering the existing system configuration and the three proposed wind farm interconnection configurations, as well as four system dispatch conditions. These sixteen studied base scenarios are listed in Table 3.1.

Table 3.1 – Sixteen base scenarios evaluated in the stability analysis

	Dispatch-1	Dispatch-2	Dispatch-3	Dispatch-4
W/o G281, G282	X	X	X	X
W/ G281 only	X	X	X	X
W/ G282 only	X	X	X	X
W/ G281 and G282	X	X	X	X

Refer to Table 2.1 for the definition of the dispatch conditions.

For each studied base scenario, a number of contingencies were evaluated, which can be categorized into three classes – primary faults, prior outage faults and breaker failure faults. For each studied contingency, system stability performance was evaluated in five aspects – transient stability, dynamic damping, transient and dynamic voltage recovery, post-contingency voltage condition and wind turbine tripping. Details of the stability analysis results are included in Tables A.1 through A.4 in the Appendix A.

The Study found no unacceptable stability impact for the expected 2004 system before the addition of G281 or G282. Refer to Table A.1 in the Appendix A for details.

The Study identified a number of problems after the additions of G281 and/or G282. These problems can be categorized into two classes – tripping of wind turbines and post-contingency voltage violations in the rest of the system.

The Study identified that due to the under voltage tripping criterion associated with the wind turbines proposed for G281 and G282, these two projects trip off line for many of the contingencies studied – including contingencies up to five substations away from the wind farms.

The Study also identified that under certain contingencies and after the tripping of the wind turbines, the rest of the system experienced unacceptable post-contingency over voltages (≥ 1.1pu) at certain substations close to the wind farms. Also, it was observed that post-contingency voltages at a number of 138kV substations settling in between 1.05pu to 1.1pu under many contingencies and various system conditions and for all three proposed wind farm interconnection configurations.

Further discussions of the stability study results for each of the three proposed wind farm interconnection configurations are in the following.

3.1.1 After the Addition of G281

The Study identified unacceptable post-contingency over voltages under three primary and prior outage contingencies - all involving loss of the 138kV line Town Line Road – G281SS. A summary is listed in Table 3.2.

Table 3.2 – Substations/Switch-stations with unacceptable post-contingency voltages

Contingency	G281 Tripped	138kV Buses – Post-Cont. Voltage ≥ 1.1pu			
		Dispatch - 1	Dispatch - 2	Dispatch - 3	Dispatch - 4
Fault cleared by opening G281SS – Town Line Road 138kV	Yes	None	G281SS N. Monroe	None	None
Fault cleared by opening Town Line Road – G281SS 138kV	Yes	None	G281SS N. Monroe	None	None
Prior outage Nelson Dewey – Hillman 138kV *Fault cleared by opening* G281SS – Town Line Road 138kV	Yes	None	None	G281SS N. Monroe	None

Refer to Table 2.1 for the definition of the dispatch conditions.

The Study also identified that the G281 wind project tripped off line for majority of the contingencies studied – including faults and contingencies up to five substations away.

Refer to Table A.2 in the Appendix A for more details regarding the system stability performance after the addition of G281.

3.1.2 After the Addition of G282

The Study identified unacceptable post-contingency over voltages under two prior outage contingencies, as summarized in Table 3.3.

Table 3.3 – Substations/Switch-stations with unacceptable post-contingency voltages

Contingency	G282 Tripped	138kV Buses – Post-Cont. Voltage ≥ 1.1pu			
		Dispatch - 1	Dispatch - 2	Dispatch - 3	Dispatch - 4
Prior outage Nelson Dewey - Hillman 138kV *Fault cleared by opening* G282SS – Darlington 138kV	Yes	G282SS Hillman	G282SS Hillman	G282SS Hillman	G282SS Hillman
Prior outage Town Line Road – N. Monroe 138kV *Fault cleared by opening* G282SS – Hillman 138kV	Yes	None	None	G281SS N. Monroe Darlington	G281SS N. Monroe Darlington

Refer to Table 2.1 for the definition of the dispatch conditions.

The Study also identified that the G282 wind project tripped off line for majority of the contingencies studied – including faults and contingencies up to three substations away.

Refer to Table A.3 in the Appendix A for more details regarding the system stability performance after the addition of G282.

3.1.3 After the Addition of G281 and G282

The Study identified unacceptable post-contingency over voltages under six primary and prior outage contingencies, as summarized in Table 3.4.

Table 3.4 – Substations/Switch-stations with unacceptable post-contingency voltages

Contingency	**G281, G282 Tripped**	**138kV Buses – Post-Cont. Voltage ≥ 1.1pu**			
		Dispatch - 1	**Dispatch - 2**	**Dispatch - 3**	**Dispatch - 4**
Fault cleared by opening G281SS – Town Line Rd 138kV	Yes	G281SS N. Monroe	G281SS N. Monroe	G281SS N. Monroe G282SS Darlington	G281SS N. Monroe G282SS Darlington
Fault cleared by opening Town Line Rd - G281SS 138kV	Yes	G281SS N. Monroe	G281SS N. Monroe	G281SS N. Monroe G282SS Darlington	G281SS N. Monroe G282SS Darlington
Fault cleared by opening G282SS - Hillman 138kV	Yes	None	None	G282SS Darlington	G282SS Darlington
Prior outage Nelson Dewey – Hillman 138kV *Fault cleared by opening* G281SS – N. Monroe 138kV	Yes	None	None	G282SS N. Monroe Darlington Hillman	G282SS N. Monroe Darlington Hillman
Prior outage Town Line Rd – G281SS 138kV *Fault cleared by opening* G282SS – Darlington 138kV	Yes	G281SS N. Monroe	G281SS N. Monroe	G281SS N. Monroe Darlington	G281SS N. Monroe Darlington
Prior outage Town Line Rd – G281SS 138kV *Fault cleared by opening* Eden – Lancaster 138kV	Yes	G281SS N. Monroe	G281SS N. Monroe	None	None

Refer to Table 2.1 for the definition of the dispatch conditions.

The Study also identified that the G281 wind project and G282 wind project tripped off line for majority of the contingencies studied – including faults and contingencies up to five substations away.

Refer to Table A.4 in the Appendix A for more details regarding the system stability performance after the addition of G281 and G282.

3.1.4 Discussion of the Stability Performance Violations and Suggested Solutions

The stability analysis identified that the ride-through capability of the wind turbines proposed for G281 and G282 is not adequate for the turbines to survive many of the studied contingencies – including contingencies up to five substations away. Tripping of the wind turbines certainly has a negative impact on the wind farms – e.g., lost revenue, stress on turbines, etc. Further, it imposes negative impact on system operation, and it has a potential to cause unacceptable transient and post-contingency system frequency deviations after the wind generation penetration level becomes higher in the ATC and neighboring systems. To minimize system operation hazards and potential unacceptable system frequency deviations in the future, it is required that the ride-through capability of the wind turbines for G281 and G282 be improved, such that the wind turbines are able to survive the primary faults, prior outage faults and breaker-failure faults evaluated in this Study.

The effect of wind gust and wind turbulence was not simulated in this Study. However, it is known and understood that the wind gust and wind turbulence can cause not only MW output variations, but also voltage fluctuations (voltage flickers) for the type of the wind turbines proposed for G281 and G282. In severe cases of wind gust and wind turbulence, voltage fluctuations may lead to turbine tripping.

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

The unacceptable post-contingency voltage condition may be corrected using a properly sized, shunt connected, Static VAR Compensation device installed at a properly selected location local to the wind farms. Static VAR Compensation is also known to be able to minimize voltage fluctuations (flicker) in the wind farm applications.

To illustrate how the Static VAR Compensation can help improve transient and post-contingency voltage performance, an example simulation was performed including a Static VAR Compensation device, the result of which is compared to its counterpart simulation without the application of the Static VAR Compensation. The results of the simulations and comparison are shown in Figure 3.1.

The contingency simulated was a primary fault at the 138kV switch station G281SS, which was cleared by opening the 138kV line G281SS – Town Line Road. Both G281 and G282 were included and were tripped off line after the fault.

Figure 3.1 shows that with the application of the Static VAR Compensation, the unacceptable post-contingency over voltage was eliminated. Also, the transient voltage over shoot right after the fault removal was reduced with the Static VAR Compensation.

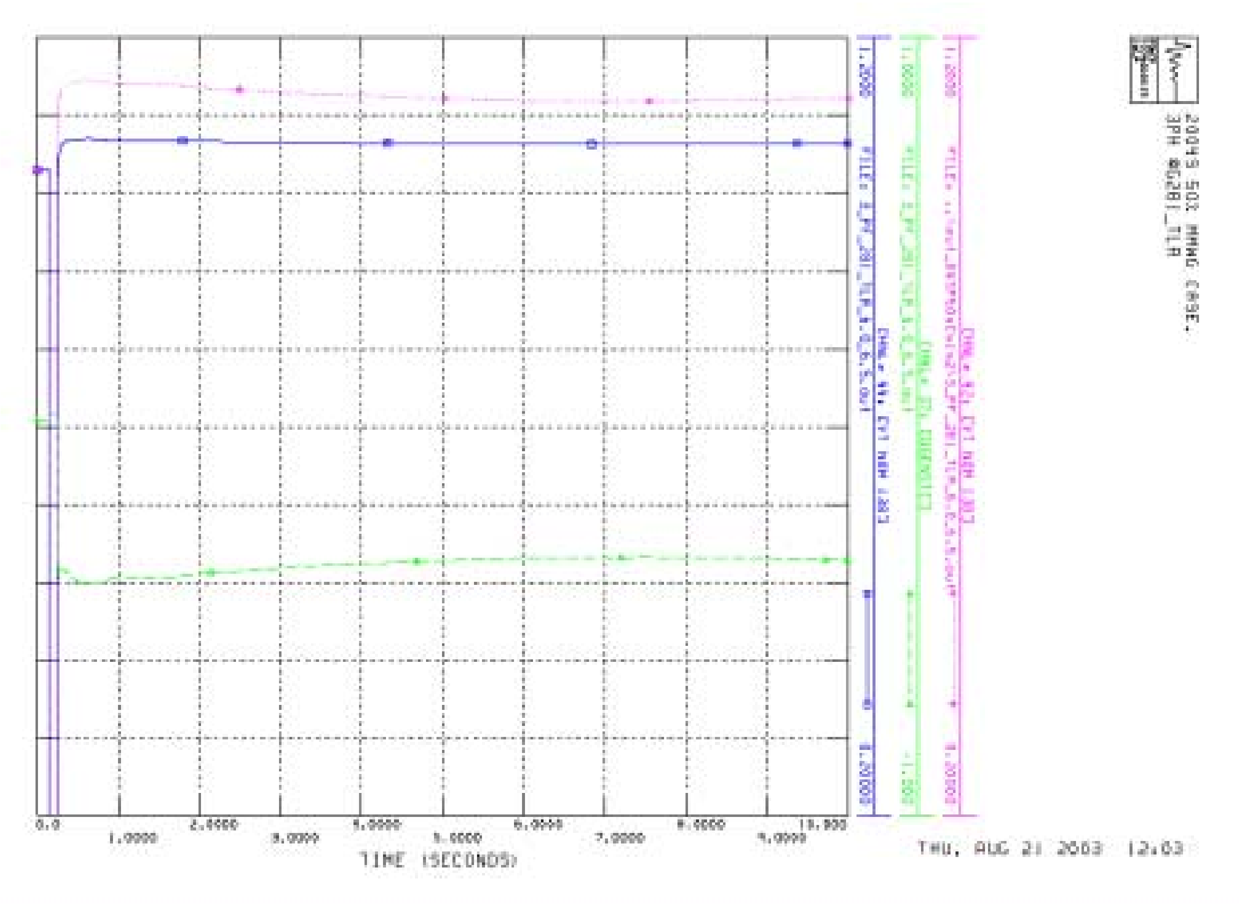

Figure 3.1 – Results of two dynamic simulations of a 3-phase fault and clearance
With and without an application of Static VAR Compensation
Pink – voltage at 138kV substation N. Monroe, without Static VAR Compensation
Blue – voltage at 138kV substation N. Monroe, with Static VAR Compensation
Green – reactive power output of the Static VAR Compensation device

Results of another pair of dynamic simulations are presented in the following to illustrate how the Static VAR Compensation has the potential to help improve the turbine ride-through under contingencies.

The contingency simulated was a primary fault at the 138kV switch substation G281SS, which was cleared by opening the 138kV line G281SS – Town Line Road. Both G281 and G282 were included and they were NOT tripped off line after the fault – the turbine tripping function was disabled artificially. The results of the simulations are shown in Figure 3.2.

Figure 3.2 shows that without the Static VAR Compensation, the recovery of the 138kV voltage at N. Monroe substation is unacceptably slow. This was caused by the recovery of the induction generator representing the G281 project. The power factor correction capacitors for the wind turbines will not be able to help the voltage recovery in the time frame concerning the transient and dynamic performance, because the associated time delay is relatively too long. Figure 3.2 also shows that with the application of the Static VAR Compensation, the voltage recovery at the N. Monroe 138kV substation is significantly improved. Since the turbine ride-through capability directly depends on how fast the voltage recovers, it is shown that the Static VAR Compensation has the potential to improve the turbine ride-through capability under contingencies. This pair of simulations also serves as another example showing how the Static VAR Compensation is able to help improve transient and dynamic voltage recovery after contingency.

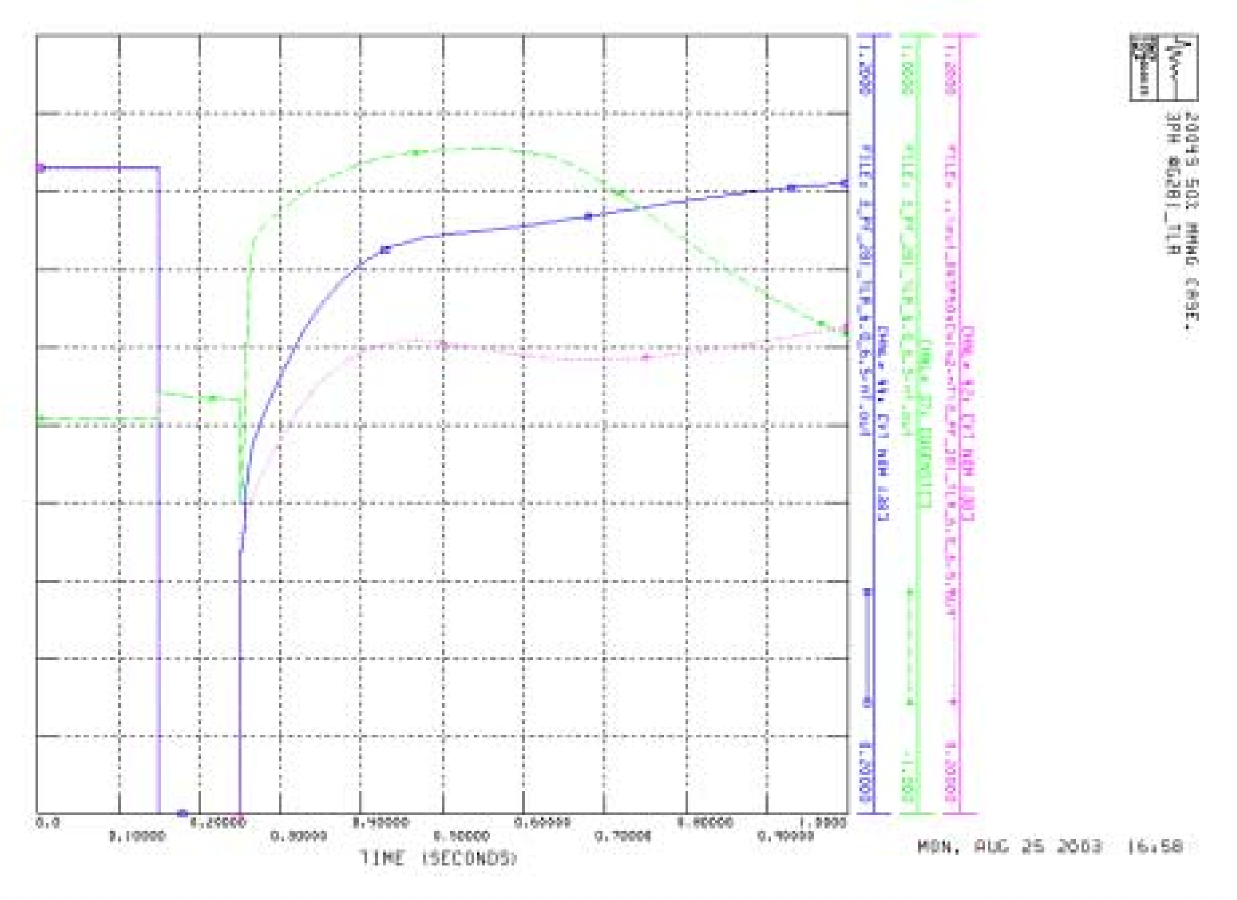

*Figure 3.2 – Results of two dynamic simulations of a 3-phase fault and clearance
With and without an application of Static VAR Compensation*

Pink – voltage at 138kV substation N. Monroe, without Static VAR Compensation
Blue – voltage at 138kV substation N. Monroe, with Static VAR Compensation
Green – reactive power output of the Static VAR Compensation device

3.2 Power Flow Analysis Results

The purpose of the power flow analysis was to identify the impact of the addition of the G281 and/or G282 on branch thermal loadings and system voltages at steady state. The approach was to compare branch thermal loading (MVA flows) and bus voltages in the "Before" and "After" states. Those thermal overloads worsened by at least 3% and those voltage violations worsened by at least 0.01pu in the "After" state are determined to be caused due to the addition of G281 and/or G282.

The base case used for power flow analysis was a 2004 summer peak load case developed based on the MMWG 2002 series 2004 summer peak load case. The competing generation of GIC004 (or G035) and GIC020 (or G072) at River Side connected to the 138kV substation Town Line Road was included in the base case.

A Transmission Service Request (TSR) has not been submitted that would identify key power flow impacts that are based on a specific, approved G281 and/or G282 power delivery. Therefore, power flow analysis was performed using a generic power dispatch scenario - the G281 and/or G282 generation delivered to the WEPCO load.

PTI MUST AC Contingency Analysis module was used for power flow analysis. This program is accepted industry-wide for power flow analysis.

The Study found no voltage violations after the addition of G281 and/or G282. The Study found no thermal overloads after the addition of G282. The Study found thermal overloads after the addition of G281 or G281 and G282. A summary of the thermal overloads is listed in Table 3.5.

Table 3.5 – Overloaded ATC facilities due to the addition of G281 or G281 and G282

Overloaded Element	**Emergency/Normal Ratings, MVA**	**Worse Loading (%), "After"**	**Loading (%), "Before"**	**Contingency**	**Description of "After"**
N. Monroe 138kV – N. Monroe 69kV	93.3	119	76	Darlington – N. Monroe 138kV	With G281
N. Monroe 138kV – N. Monroe 69kV	93.3	105	77	Normal	With G281 And G282
N. Monroe 138kV – N. Monroe 69kV	93.3	113	86	Paddock – Rockdale 345kV	With G281 And G282
Rock River 138kV – Rock River 69kV	58.3	105	98	Colley Road – B. Church 138kV	With G281 And G282

Possible solutions include a second 138/69 kV transformer at North Monroe and replacement of the 138/69 kV transformer at Rock River.

Appendix A

Stability Analysis Results

Table A.1 – Stability Impacts for the Expected 2004 System Before the Addition of the G281 or G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
Primary Faults (at from ends)							
F.1	N. Monroe – Town Line Rd 138kV	NOM 205 – 5 cy TLR 2352,2355 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.2	Town Line Rd – N. Monroe 138kV	TLR 2352,2355 – 5 cy NOM 205 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.3	Nelson Dewey – Hillman 138kV	NED 37 – 5 cy HLM 425 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.4	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.5	Town Line Rd – Rock River 138kV	TLR 2367,2361 – 5 cy ROR 684 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.6	Town Line Rd – Janesville 138kV	TLR 2343,2346 – 5 cy JAN 312 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.7	Town Line Rd – Russell 138kV	TLR 2368,2370 – 5 cy RUS 496 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.8	Town Line Rd – Paddock 138kV	TLR 2373,2377 – 5 cy PAD 2258,2266 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.9	Rock River – Town Line Rd 138kV	ROR 684 – 5.cy TLR 2367,2361 – 5.0 cy		**Good**	**Good**	**Good**	**Good**
F.10	Janesville – Town Line Rd 138kV	JAN 312 – 5 cy TLR 2343,2346 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.11	Russell – Town Line Rd 138kV	RUS 496 – 5 cy TLR 2368,2370 – 5.5 cy		**Good**	**Good**	**Good**	**Good**

Table A.1 (continued) – Stability Impacts for the Expected 2004 System Before the Addition of the G281 or G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
F.12	Paddock – Town Line Rd 138kV	PAD 2258,2266 – 5 cy TLR 2373,2377 – 5.5 cy		Good	Good	Good	Good
F.13	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy		Good	Good	Good	Good
F.14	Darlington 138 – 69kV	DAR 79 – 5 cy DAR 404 – 5.5 cy		Good	Good	Good	Good
F.15	N. Monroe 138 – 69kV	NOM 207 – 5 cy NOM 719 – 5.5 cy		Good	Good	Good	Good
Faults Involving Prior Outage							
F.16	Town Line Rd – N. Monroe 138kV	TLR 2352,2355 – 5 cy NOM 205 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	Good	Good	Good	Good
F.17	Town Line Rd – Rock River 138kV	TLR 2367,2361 – 5 cy ROR 684 – 5.5 cy	***Prior outage*** Town Line Rd – N. Monroe 138kV	Good	Good	Good	Good
F.18	Nelson Dewey – Lancaster 138kV	NED 97 – 5 cy LAN 278 – 5.5 cy	***Prior outage*** Town Line Rd – N. Monroe 138kV	Good	Good	Good	Good
Faults Involving Breaker Failure							
F.19	N. Monroe – Darlington 138kV	DAR 546 – 5.5 cy	***Breaker failure*** NOM 203 ***Backup clearing*** NOM 205 – 18 cy	Good	Good	Good	Good

Table A.1 (continued) – Stability Impacts for the Expected 2004 System Before the Addition of the G281 or G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
F.20	Hillman – Darlington 138kV	DAR 413 – 5.5 cy	***Breaker failure*** HLM 427 ***Backup clearing*** HLM 425 – 18 cy	Good	Good	Good	Good
Eau Claire - Arpin Operating Procedure							
F.21	Arpin – Eau Claire 345kV	ARP – 5 cy EAU – 5 cy	***Other lines opened after a time delay:*** WIEN – STRATFORD 115 KV COC 69 kV BUS TIE HILLTOP – MAUSTON 69 kV LUBIN – LAKEHEAD 69 KV	Good	Good	Good	Good

[1]Transient Performance annotation –
Good – system transient, dynamic and voltage stability performance satisfactory
HV - post-contingency voltage greater than or equal to 1.1pu
LV – post-contingency voltage less than or equal to 0.9pu
RV – unacceptable voltage recovery after fault
F – system transient angle stability performance not satisfactory
G – system dynamic damping performance not satisfactory
T1 – G281 tripped
T2 – G282 tripped
[2]Dispatches studied
1 – 2004 summer peak load; Riverside generators output = 600MW
2 – 2004 summer peak load; Riverside generators out of service
3 – 50% 2004 summer peak load; Riverside generators output = 600MW
4 – 50% 2004 summer peak load; Riverside generators out of service

Table A.2 (to be continued) – Stability Impacts for the Expected 2004 System After the Addition of the G281 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
Primary Faults (at from ends)							
F.1	G281Bus – Town Line Rd 138kV	G281 1 & 2 – 5 cy TLR 2352,2355 – 5.5 cy		**T1**	**HV - 281, NOM** **T1**	**T1**	**T1**
F.2	Town Line Rd – G281Bus 138kV	TLR 2352,2355 – 5 cy G281 1 & 2 – 5.5 cy		**T1**	**HV - 281, NOM** **T1**	**T1**	**T1**
F.3	G281Bus – N. Monroe 138kV	G281 1 & 3 – 5 cy NOM 205 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.4	Nelson Dewey – Hillman 138kV	NED 37 – 5 cy HLM 425 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.5	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.6	Town Line Rd – Rock River 138kV	TLR 2367,2361 – 5 cy ROR 684 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.7	Town Line Rd – Janesville 138kV	TLR 2343,2346 – 5 cy JAN 312 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.8	Town Line Rd – Russell 138kV	TLR 2368,2370 – 5 cy RUS 496 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.9	Town Line Rd – Paddock 138kV	TLR 2373,2377 – 5 cy PAD 2258,2266 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.10	Rock River – Town Line Rd 138kV	ROR 684 – 5.cy TLR 2367,2361 – 5.0 cy		**T1**	**T1**	**T1**	**T1**
F.11	Janesville – Town Line Rd 138kV	JAN 312 – 5 cy TLR 2343,2346 – 5.5 cy		**T1**	**T1**	**Good** **T1**	**Good** **T1**

Table A.2 (continued) – Stability Impacts for the Expected 2004 System After the Addition of the G281 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
F.12	Russell – Town Line Rd 138kV	RUS 496 – 5 cy TLR 2368,2370 – 5.5 cy		T1	T1	T1	T1
F.13	Paddock – Town Line Rd 138kV	PAD 2258,2266 – 5 cy TLR 2373,2377 – 5.5 cy		T1	T1	T1	T1
F.14	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy		Good	T1	T1	T1
F.15	Darlington 138 – 69kV	DAR 79 – 5 cy DAR 404 – 5.5 cy		T1	T1	T1	T1
F.16	N. Monroe 138 – 69kV	NOM 207 – 5 cy NOM 719 – 5.5 cy		T1	T1	T1	T1
Faults Involving Prior Outage							
F.17	G281Bus – Town Line Rd 138kV	G281 1 & 2 – 5 cy TLR 2352,2355 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	T1	T1	HV - 281, NOM T1	T1
F.18	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	T1	T1	T1	T1
F.19	G281Bus – N. Monroe 138kV	G281 1 &3 – 5 cy NOM 205 – 5.5 cy	***Prior outage*** Town Line Rd – G281Bus 138kV	T1	T1	T1	T1
F.20	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy	***Prior outage*** Town Line Rd – G281Bus 138kV	Good	Good	T1	Good

Table A.2 (continued) – Stability Impacts for the Expected 2004 System After the Addition of the G281 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
Faults Involving Breaker Failure							
F.21	G281Bus – N. Monroe 138kV	G281 3 – 5 cy NOM 205 – 5.5 cy	***Breaker failure*** G281 1 ***Backup clearing*** G281 2 – 18 cy TLR 2352,2355 – 18 cy	**T1**	**T1**	**T1**	**T1**
F.22	G281Bus – Town Line Rd 138kV	G281 2 – 5 cy TLR 2352,2355 – 5.5 cy	***Breaker failure*** G281 1 ***Backup clearing*** G281 3 – 18 cy NOM 205 – 18 cy	**T1**	**T1**	**T1**	**T1**
Eau Claire - Arpin Operating Procedure							
F.23	Arpin – Eau Claire 345kV	ARP – 5 cy EAU– 5 cy	***Other lines opened after a time delay:*** WIEN – STRATFORD 115 KV COC 69 kV BUS TIE HILLTOP – MAUSTON 69 kV LUBIN – LAKEHEAD 69 KV	**Good**	**Good**	**Good**	**Good**

[1]Transient Performance annotation –
Good – system transient, dynamic and voltage stability performance satisfactory
HV - post-contingency voltage greater than or equal to 1.1pu
LV – post-contingency voltage less than or equal to 0.9pu
RV – unacceptable voltage recovery after fault
F – system transient angle stability performance not satisfactory
G – system dynamic damping performance not satisfactory
T1 – G281 tripped

T2 – G282 tripped
[2]Dispatches studied
1 – 2004 summer peak load; Riverside generators output = 600MW
2 – 2004 summer peak load; Riverside generators out of service
3 – 50% 2004 summer peak load; Riverside generators output = 600MW
4 – 50% 2004 summer peak load; Riverside generators out of service

Table A.3 (to be continued) – Stability Impacts for the Expected 2004 System After the Addition of the G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
Primary Faults (at from ends)							
F.1	G282Bus – Darlington 138kV	G282 4 & 5 – 5 cy DAR 413 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.2	G282Bus – Hillman 138kV	G282 4 &6 – 5 cy HLM 427 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.3	Nelson Dewey – Hillman 138kV	NED 37 – 5 cy HLM 425 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.4	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.5	Town Line Rd – Rock River 138kV	TLR 2367,2361 – 5 cy ROR 684 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.6	Town Line Rd – Janesville 138kV	TLR 2343,2346 – 5 cy JAN 312 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.7	Town Line Rd – Russell 138kV	TLR 2368,2370 – 5 cy RUS 496 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.8	Town Line Rd – Paddock 138kV	TLR 2373,2377 – 5 cy PAD 2258,2266 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.9	Rock River – Town Line Rd 138kV	ROR 684 – 5.cy TLR 2367,2361 – 5.0 cy		**T2**	**T2**	**T2**	**T2**
F.10	Janesville – Town Line Rd 138kV	JAN 312 – 5 cy TLR 2343,2346 – 5.5 cy		**Good**	**T2**	**Good**	**Good**
F.11	Russell – Town Line Rd 138kV	RUS 496 – 5 cy TLR 2368,2370 – 5.5 cy		**Good**	**Good**	**Good**	**Good**

Table A.3 (continued) – Stability Impacts for the Expected 2004 System After the Addition of the G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
F.12	Paddock – Town Line Rd 138kV	PAD 2258,2266 – 5 cy TLR 2373,2377 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.13	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy		**Good**	**Good**	**Good**	**Good**
F.14	Darlington 138 – 69kV	DAR 79 – 5 cy DAR 404 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
F.15	N. Monroe 138 – 69kV	NOM 207 – 5 cy NOM 719 – 5.5 cy		**T2**	**T2**	**T2**	**T2**
Faults Involving Prior Outage							
F.16	G282Bus – Darlington 138kV	G282 4 & 5 – 5 cy DAR 413 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	**HV - 282, HLM** **T2**	**HV - 282, HLM** **T2**	**HV - 282, HLM** **T2**	**HV - 282, HLM** **T2**
F.17	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	**T2**	**T2**	**T2**	**T2**
F.18	G282Bus – Hillman 138kV	G282 4 &6 – 5 cy HLM 427 – 5.5 cy	***Prior outage*** Town Line Rd – N. Monroe 138kV	**T2**	**T2**	**HV - 282, NOM, DAR** **T2**	**HV - 282, NOM, DAR** **T2**
F.19	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy	***Prior outage*** Town Line Rd – N. Monroe 138kV	**T2**	**T2**	**T2**	**T2**

Table A.3 (continued) – Stability Impacts for the Expected 2004 System After the Addition of the G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	**Simulated clearing: +1.0 cy primary +1.0 cy backup**	**Simulated clearing: +1.0 cy primary +1.0 cy backup**	**Simulated clearing: +1.0 cy primary +1.0 cy backup**
Faults Involving Breaker Failure							
F.20	G282Bus – Hillman 138kV	G282 6 – 5 cy HLM 427 – 5.5 cy	***Breaker failure*** G282 4 ***Backup clearing*** G282 5 – 18 cy DAR 413 – 18 cy	**T2**	**T2**	**T2**	**T2**
F.21	G282Bus – Darlington 138kV	G282 5 – 5 cy DAR 413 – 5.5 cy	***Breaker failure*** G282 4 ***Backup clearing*** G282 6 – 18 cy HLM 427 – 18 cy	**T2**	**T2**	**T2**	**T2**
F.22	Arpin – Eau Claire 345kV	ARP – 5 cy EAU – 5 cy	***Other lines opened after a time delay:*** WIEN – STRATFORD 115 KV COC 69 kV BUS TIE HILLTOP – MAUSTON 69 kV LUBIN – LAKEHEAD 69 KV	**Good**	**Good**	**Good**	**Good**

[1]Transient Performance annotation –
Good – system transient, dynamic and voltage stability performance satisfactory
HV - post-contingency voltage greater than or equal to 1.1pu
LV – post-contingency voltage less than or equal to 0.9pu
RV – unacceptable voltage recovery after fault
F – system transient angle stability performance not satisfactory
G – system dynamic damping performance not satisfactory
T1 – G281 tripped

T2 – G282 tripped
[2]Dispatches studied
1 – 2004 summer peak load; Riverside generators output = 600MW
2 – 2004 summer peak load; Riverside generators out of service
3 – 50% 2004 summer peak load; Riverside generators output = 600MW
4 – 50% 2004 summer peak load; Riverside generators out of service

Table A.4 (to be continued) – Stability Impacts for the Expected 2004 System After the Addition of the G281 and G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
Primary Faults (at from ends)							
F.1	G281Bus – Town Line Rd 138kV	G281 1 & 2 – 5 cy TLR 2352,2355 – 5.5 cy		**HV – 281, NOM** **T1 T2**	**HV – 281, NOM** **T1 T2**	**HV – 281, 282, NOM, DAR** **T1 T2**	**HV – 281, 282 NOM, DAR** **T1 T2**
F.2	Town Line Rd – G281Bus 138kV	TLR 2352,2355 – 5 cy G281 1 & 2 – 5.5 cy		**HV – 281, NOM** **T1 T2**	**HV – 281, NOM** **T1 T2**	**HV – 281, 282, NOM, DAR** **T1 T2**	**HV – 281, 282 NOM, DAR** **T1 T2**
F.3	G281Bus – N. Monroe 138kV	G281 1 &3 – 5 cy NOM 205 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.4	G282Bus – Darlington 138kV	G282 4 & 5 – 5 cy DAR 413 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.5	G282Bus – Hillman 138kV	G282 4 &6 – 5 cy HLM 427 – 5.5 cy		**T1 T2**	**T1 T2**	**HV – 282, DAR** **T1 T2**	**HV – 282, DAR** **T1 T2**
F.6	Nelson Dewey – Hillman 138kV	NED 37 – 5 cy HLM 425 – 5.5 cy		**T1 T2**	**T2**	**T2**	**T2**
F.7	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy		**T1 T2**	**T2**	**Good**	**T2**
F.8	Town Line Rd – Rock River 138kV	TLR 2367,2361 – 5 cy ROR 684 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.9	Town Line Rd – Janesville 138kV	TLR 2343,2346 – 5 cy JAN 312 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.10	Town Line Rd – Russell 138kV	TLR 2368,2370 – 5 cy RUS 496 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**

Table A.4 (continued) – Stability Impacts for the Expected 2004 System After the Addition of the G281 and G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup	Simulated clearing: +1.0 cy primary +1.0 cy backup
F.11	Town Line Rd – Paddock 138kV	TLR 2373,2377 – 5 cy PAD 2258,2266 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.12	Rock River – Town Line Rd 138kV	ROR 684 – 5.cy TLR 2367,2361 – 5.0 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.13	Janesville – Town Line Rd 138kV	JAN 312 – 5 cy TLR 2343,2346 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.14	Russell – Town Line Rd 138kV	RUS 496 – 5 cy TLR 2368,2370 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.15	Paddock – Town Line Rd 138kV	PAD 2258,2266 – 5 cy TLR 2373,2377 – 5.5 cy		**T1**	**T1**	**T1**	**T1**
F.16	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy		**Good**	**T1**	**Good**	**T1**
F.17	Darlington 138 – 69kV	DAR 79 – 5 cy DAR 404 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.18	N. Monroe 138 – 69kV	NOM 207 – 5 cy NOM 719 – 5.5 cy		**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
Faults Involving Prior Outage							
F.19	G281Bus – N. Monroe 138kV	G281 1 &3 – 5 cy NOM 205 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	**T1 T2**	**T1 T2**	**HV – 282 NOM, DAR, HLM** **T1 T2**	**HV – 282 NOM, DAR, HLM** **T1 T2**
F.20	Rockdale – Russell 138kV	ROE 645 – 5 cy RUS 474 – 5.5 cy	***Prior outage*** Nelson Dewey – Hillman 138kV	**T1 T2**	**T1 T2**	**T1**	**T1 T2**

Table A.4 (continued) – Stability Impacts for the Expected 2004 System After the Addition of the G281 and G282 Generation

ID	3-Phase Fault	Breaker # & Primary Clearing	Other Details	Transient Performance[1]			
				Dispatch -1[2]	Dispatch -2[2]	Dispatch -3[2]	Dispatch -4[2]
				Simulated clearing: +1.0 cy primary +1.0 cy backup	**Simulated clearing: +1.0 cy primary +1.0 cy backup**	**Simulated clearing: +1.0 cy primary +1.0 cy backup**	**Simulated clearing: +1.0 cy primary +1.0 cy backup**
F.21	G282Bus – Darlington 138kV	G282 4 & 5 – 5 cy DAR 413 – 5.5 cy	***Prior outage*** Town Line Rd – G281Bus 138kV	**HV – 281, NOM** **T1 T2**	**HV – 281, NOM** **T1 T2**	**HV – 281 NOM, DAR** **T1 T2**	**HV – 281 NOM, DAR** **T1 T2**
F.22	Eden – Lancaster 138kV	EDN 1967 – 5 cy LAN 279 – 5.5 cy	***Prior outage*** Town Line Rd – G281Bus 138kV	**HV – 281, NOM** **T1 T2**	**HV – 281, NOM** **T1 T2**	**T2**	**T2**
Faults Involving Breaker Failure							
F.23	G281Bus – N. Monroe 138Kv	G281 3 – 5 cy NOM 205 – 5.5 cy	***Breaker failure*** G281 1 ***Backup clearing*** G281 2 – 18 cy TLR 2352,2355 – 18 cy	**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
F.24	G282Bus – Darlington 138kV	G282 5 – 5 cy DAR 413 – 5.5 cy	***Breaker failure*** G282 4 ***Backup clearing*** G282 6 – 18 cy HLM 427 – 18 cy	**T1 T2**	**T1 T2**	**T1 T2**	**T1 T2**
Eau Claire - Arpin Operating Procedure							
F.25	Arpin – Eau Claire 345kV	ARP – 5 cy EAU – 5 cy	***Other lines opened after a time delay:*** WIEN – STRATFORD 115 KV COC 69 kV BUS TIE HILLTOP – MAUSTON 69 kV LUBIN – LAKEHEAD 69 KV	**Good**	**Good**	**Good**	**Good**

[1]Transient Performance annotation –
Good – system transient, dynamic and voltage stability performance satisfactory
HV - post-contingency voltage greater than or equal to 1.1pu
LV – post-contingency voltage less than or equal to 0.9pu
RV – unacceptable voltage recovery after fault
F – system transient angle stability performance not satisfactory
G – system dynamic damping performance not satisfactory
T1 – G281 tripped
T2 – G282 tripped
[2]Dispatches studied
1 – 2004 summer peak load; Riverside generators output = 600MW
2 – 2004 summer peak load; Riverside generators out of service
3 – 50% 2004 summer peak load; Riverside generators output = 600MW
4 – 50% 2004 summer peak load; Riverside generators out of service

Appendix B

Short Circuit Analysis

Table B.1 – Maximum Fault Duties Viewed at the Interconnection Points By G281 and G282, Without the Contributions from G281 or G282

	Single-phase	**Three-Phase**
G281SS	3825 Amps	4925 Amps
G282SS	3518 Amps	4242 Amps

Table B.2 – Thevenin Equivalent Impedances in Ohms Viewed at the Interconnection Points By G281 and G282, Without Considering the G281 and G282 Facilities

	Pos Seq.	**Neg. Seq.**	**Zero Seq.**
G281SS	5.47300+j 15.2213	5.48470+j 15.2208	6.37553+j 29.5885
G282SS	4.61839+j 18.2034	4.62176+j 18.2041	5.09817+j 30.0043

Appendix C

Power Flow Analysis

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Appendix D

Study Criteria

D.1 Study Criteria

D.1.1 Contingencies

For stability analysis, a set of branches in the vicinity of the generator/power plant of concern is selected as contingencies, based on engineering judgment. Fault analysis is performed for the following three categories of contingency conditions:

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

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

D.1.2 Monitored Elements

For power flow analysis, load carrying elements of voltage level above 100 kV in the ATC areas – Alliant East Control Area, Wisconsin Electric Power Co. Control area, Wisconsin Public Service Corp Control Area and Upper Peninsula Power Co. Control Area were monitored in this Study.

D.1.3 Thermal Loading Criteria

For the normal (intact) system conditions, the loading of all transmission system elements significantly affected by G281 and/or G282 must not exceed 100% of the summer normal rating (Rate A). For contingency system conditions, the loading of all transmission system elements significantly affected by the G281 and/or G282 must not exceed 100% of the summer emergency rating (Rate B).

D.1.4 Voltage Criteria

For normal (intact) system conditions, voltages of all buses significantly affected by G281 and/or G282 must be in the range of 95% to 105% of the nominal system voltages. For contingency system conditions (selected N-1 and multiple contingencies), voltages of all buses significantly affected by G281 and/or G282 must be in the range of 90% to 110% of the nominal system voltages.

In the context of stability analysis, voltages of all transmission system buses significantly affected by G281 and/or G282 must recover to be at least 80% of the nominal system voltages in 0.5 second after fault removal.

D.1.5 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.

Appendix E

Generator Facility Data

E.1 Data in Power Flow Representation

E.1.1 Wind Turbines

The G281 wind farm is rated at 130MW and the G282 wind farm is rated at 99MW. Each wind farm contains a number of wind turbines, each rated at 1.65MW. An equivalent induction generator model is used to represent the wind turbines in each wind farm. The power factor of each induction generator at rated MW output is 0.91.

E.1.2 Power Factor Correction Capacitors

Each wind turbine rated at 1.65MW is equipped with power factor correction capacitor banks. The shunt capacitors for all turbines in each wind farm are modeled using an equivalent shunt capacitor connected at the terminal of the equivalent induction generator. The shunt capacitor can be adjusted discretely for power factor or voltage control. The step size for the adjustment is 1.79MVar for G281 and 1.38Mvar for G282. The time delay for the adjustment is 120 seconds. The total capacitive shunt compensation is 39.34MVar for G281 and 30.36MVar for G282.

E.1.3 Transformers

The impedance of the 138/34.5kV transformer for G281 is 0.09pu on 142MVA base.
The impedance of the 34.5/0.6kV transformer for G281 is 0.0575pu on 142MVA base.
The impedance of the 138/34.5kV transformer for G282 is 0.09pu on 109MVA base.
The impedance of the 34.5/0.6kV transformer for G282 is 0.0575pu on 109MVA base.

E.2 Data in Dynamic Representation

E.2.1 Induction Generator Data

The induction generators modeling G281 and G282 are represented by CIMTR3 model in PSS/E. Data used is listed below.

Table E.1 – Induction generator data

Description	T'	T''	H	X	X'	X''	E_1
Value	0.975	0.0	4.87	3.65	0.089	0.0	1.0

Table E.1 (cont.) – Induction generator data

Description	$S(E_1)$	E_2	$S(E_2)$
Value	0.06	1.15	0.15

E.2.2 Turbine Tripping Data

The under/over voltage- and under/over frequency- tripping characteristics of the wind turbines are modeled using a user-written model. Data description is shown in Table E.2.

Table E.2 – Wind turbine tripping data

Maximum voltage (1)	+10 % (60 sec)
Minimum voltage (1)	-10 % (60 sec)
Maximum voltage (2)	+12.5 % (0.1 sec)
Minimum voltage (2)	-15 % (0.1 sec)
High frequency	+1 Hz (0.2 sec)
Low frequency	-2 Hz (0.2 sec)