Generation Interconnection System Impact Study Report

MPC01200

Queue Request Date: April 17, 2008
In-Service Date: December 31, 2010
Point of Interconnection: Maple River 230 kV bus
Size and Type: 200 MW, Wind Generation

MPC01900

Queue Request Date: April 17, 2008*
In-Service Date: March 1, 2012
Point of Interconnection: Maple River 230 kV bus
Size and Type: 199.8 MW, Wind Generation

*MPC01900 interconnection request date has been adjusted from Feb 20, 2009 to Apr 17, 2008 per a Settlement Agreement in FERC Docket EL08-086-000

Evaluation of Near-Term Interconnection of MPC01200 at 50 MW and MPC01900 at 50 MW

December 10, 2010

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Executive Summary

A System Impact Study has been completed for interconnection requests for two wind farm projects at the Maple River 230 kV bus.

MPC01200 is a 200 MW wind generation request to be developed using GE XLE 1.6 MW wind turbines. The request date for this project was April 17, 2008 and the scheduled in-service (IS) date is December 31, 2010. MPC01200 is called Ashtabula 3.

MPC01900 is a 199.8 MW wind generation request to be developed using Vestas V90 turbines. The effective request date for MPC01900 is April 17, 2008. The original request date of February 20, 2009 was changed to April 17, 2008 per a Settlement Agreement in FERC Docket EL08-086-000. The IS date is March 1, 2012.

There are two existing wind farms already in service at this location, Ashtabula 1 and 2. These existing farms were originally queued as MPC0500, which was a 358 MW interconnection request at the Maple River 230 kV bus. 358 MW delivered at Maple River equates to approximately 378 MW of nameplate generation at the wind farm location. There is a total of 366 MW of nameplate generation in service as of the date of this report. The 12 MW of generation that has not yet been installed will be included in the MPC01200 wind farm.

The 62 mile Pillsbury-Maple River 230 kV line provides a radial connection from the existing wind farms to the Maple River 230kV substation. Wind-adjusted ratings will be used to allow a summer continuous rating of 670 MVA when wind generation output is at maximum. During low wind conditions, the summer continuous rating will be 478 MVA.

The customer for MPC01200 has expressed interest in putting a 50 MW portion of the wind farm in service by December, 2010. Due to the requirement for equal priority of the two requests in the Settlement Agreement, a study was completed showing a 50 MW generation addition for each of the two requests. Further analysis was then completed to show the near-term requirements for just the 50 MW of generation associated with MPC01200.

MPC requires 0.95 power factor capability from the generation projects as measured at the Pillsbury 230 kV bus. The Vestas machines associated with MPC01900 will

require 16.5 MVAR of supplemental capacitors at the 34.5 kV collector bus to meet this requirement for a 50 MW wind farm.

Voltage stability analysis indicates the need for 15 MVAR of additional reactive compensation at the 34.5 kV collector bus of each wind farm to prevent voltage collapse at those locations and their adjacent 230 kV buses. If the total interconnected generation is less than approximately 80 MW, the additional reactive compensation is not needed.

Steady state contingency analysis points to the need for mitigation of a number of facilities, as summarized in the mitigation table below. The summer off-peak high transfer condition was the most limiting for all of the facility overloads that were observed.

Dynamic stability analysis indicates that no mitigation is needed for regional limiting faults. Two local slow-clearing single-line-to-ground faults at the Maple River 230 kV bus cause dynamic voltage violations at the Pillsbury 230 kV bus and other 230 kV buses adjacent to the wind farms. These violations occur for the 100 MW generation addition, but not for the first 50 MW addition associated with MPC01200. Replacing three 230 kV breakers and four 115 kV breakers at Maple River mitigates the violation.

Short circuit analysis indicates that fault currents at Maple River and the adjacent buses are not approaching any breaker limitations.

The following tables summarizes the required mitigations with preliminary good faith estimates of costs. The mitigation cost estimates for the 100 MW combined project are assumed to cover the upgrades for the 50 MW project as well.

Separate tables are used for NERC Category B and Category C mitigations because the requirements may be less stringent for Category C events.

Table E1. Mitigation Summary for NERC Category A and B Conditions

Performance Criteria	MPC01200 Near Term Mitigations 50 MW Project		MPC01200 / MPC01900 Mitigations 100 MW Combined Project	
	Upgrade	Cost	Upgrade	Cost
Power Factor Requirement	No mitigation required	N/A	MPC01900: 16.5 MVAR of capacitors at 34.5 kV collector bus	$0.3 M
Facility load limit: Maple River - Frontier 230 kV line (11 miles)	Temporary SPS mitigation; Raise structures to achieve summer emergency rating of 370 MVA	$0.1M	Temporary SPS mitigation; Raise structures to achieve summer emergency rating of 379 MVA	$0.1M
Facility load limit: Frontier - Wahpeton 230 kV line (44 miles)	Temporary SPS mitigation; Raise structures to achieve summer emergency rating of 337 MVA	$0.4M	Temporary SPS mitigation; Raise structures to achieve summer emergency rating of 345 MVA	$0.4M
Facility load limit: Maple River - Sheyenne 230 kV line (7 miles)	No mitigation required	N/A	Re-conductor to achieve summer emergency rating of 527 MVA	$4M
Facility load limit: Sheyenne - Audubon 230 kV line (44 miles)	Temporary mitigation by use of dynamic ratings. Summer emergency rating of 372 MVA is needed.	No est. avail.	Temporary mitigation by use of dynamic ratings. Summer emergency rating of 378 MVA is needed.	No est. avail.
Voltage Stability: Voltage collapse at the wind farm collector buses, and Pillsbury 230 kV and Maple River 230 kV buses **[See Note 1]**	No mitigation required	N/A	MPC01200: 15 MVAR of capacitors at 34.5 kV collector bus MPC01900: 15 MVAR of capacitors at 34.5 kV collector bus	$0.3M $0.3M
Dynamic stability: Voltage violations at Pillsbury 230 kV bus **[See Note 1]**	No mitigation required	N/A	Replace 230 kV breakers 64 and 66 with 2-cycle breakers	$0.5M

Note 1: Worst-case impacts were observed following NERC Category C events. Some impacts may have also been observed following Category B events. Mitigation requirements are the same for NERC Category B and C contingencies for this performance issue.

Table E2. Mitigation Summary for NERC Category C Conditions

Performance Criteria	MPC01200 Near Term Mitigations 50 MW Project		MPC01200 / MPC01900 Mitigations 100 MW Combined Project	
	Upgrade	Cost	Upgrade	Cost
Facility load limit: Maple River - Red River 115 kV line (6 miles)	No mitigation required	N/A	Re-conductor to achieve summer emergency rating of 348 MVA (following Category C event)	$2M
Facility load limit: Red River - Cass County 115 kV line (3 miles)	Raise structures or re-conductor to achieve summer emergency rating of 245 MVA	$0.3M to $1M	Re-conductor to achieve summer emergency rating of 256 MVA	$1M
Facility load limit: Sheyenne - Audubon 230 kV line (44 miles)	Temporary mitigation by use of dynamic ratings. Summer emergency rating of 392 MVA is needed.	No est. avail.	Temporary mitigation by use of dynamic ratings. Summer emergency rating of 398 MVA is needed.	No est. avail.
Steady state bus voltage: Low voltage at the Maple River 345 kV bus	No mitigation required	N/A	Mitigation will be established with the Transmission Owner.	No est. avail.
Facility load limit: Maple River 230/115 kV Transformer #5 and #6	No mitigation required	N/A	Mitigation will be established with the Transmission Owner	No est. avail.

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1. INTRODUCTION

1.1 Project Overview

Minnkota Power Cooperative, Inc. (MPC) commissioned ABB Electric Systems Consulting (ESC) to perform a technical study to evaluate generation interconnection requests for two wind farm projects, MPC01200 and MPC01900. The point of interconnection of these projects is the Maple River 230 kV substation, which is also the point of interconnection of the existing Maple River Wind Farm (MPC0500). MPC0500 consists of a 358 MW interconnection request at the Maple River bus, which is approximately 378 MW of nameplate generation at the wind farm location. There is a total of 366 MW of nameplate generation in service as of the date of this report. The Pillsbury – Maple River 230 kV line provides a radial connection from the wind farms to the Maple River 230kV substation.

MPC01200 is a 200 MW wind generation request to be developed using GE XLE 1.6 MW wind turbines. The request date for this project was April 17, 2008 and the scheduled in-service (IS) date is December 31, 2010. MPC01200 is also called Ashtabula 3.

MPC01900 is a 199.8 MW wind generation request to be developed using Vestas V90 turbines. The effective request date for MPC01900 is April 17, 2008. The original request date of February 20, 2009 was changed to April 17, 2008 per a Settlement Agreement in FERC Docket EL08-086-000. The IS date is March 1, 2012.

The customer for MPC01200 has expressed interest in putting a 50 MW portion of the wind farm in service by December, 2010. Due to the requirement for equal priority of the two requests in the Settlement Agreement, a study was completed showing a 50 MW generation addition for each of the two requests. Further analysis was then completed to show the near-term requirements for just the 50 MW of generation associated with MPC01200. The impact of higher injection levels will be determined in a subsequent study.

The system impact study is being submitted to the Mid-Continent Area Power Pool (MAPP) Design Review Subcommittee (DRS) to obtain approval for the proposed generation interconnection. The study considers effects of prior queued generation interconnection requests in the MPC, MISO and other MAPP members' generation interconnection queues.

The study was performed with guidance from a study ad hoc group and the wind developers. The ad hoc study group included representation from BEPC, GRE, MDU, MH, MISO, MP, MRES, OTP, WAPA, and Xcel.

1.2 Study Scope

The study evaluated impact of proposed wind farms on transmission system performance and comprises voltage stability analysis, steady-state, dynamic stability, constrained interface and short-circuit analyses.

The scope of this study is limited to identifying and resolving possible criteria violations that may limit the ability of the proposed generation to interconnect. Any results related to delivery of power from the projects are for informational purposes only.

Chapter 2 presents a brief description of the wind turbines and transmission additions for the projects. Chapter 3 describes the study methodology, criteria and assumptions used for the analyses while Chapter 4 discusses model development. Chapters 5, 6, 7 and 8 discuss results of voltage stability, steady-state, dynamic stability and short-circuit analyses.

2. DESCRIPTION AND MODELING OF THE PROPOSED PROJECTS

The following sections provide a brief description of the main characteristics of GE and Vestas generators relevant to this study.

2.1 Description of GE 1.6 MW Wind Turbine Generators

The proposed MPC01200 wind farm will comprise wind turbine-generators manufactured by GE (1.6 MW DFIG). The GE 1.6 MW wind turbine is variable speed turbine and employs a three-phase doubly-fed induction generator with a power converter interfacing the rotor to the grid. The voltage at the wind turbine generator terminals is 690 V and is stepped up to feed a 34.5 kV collector system, which is in turn connected to the Barnes County 230 kV substation via a 34.5/230 kV substation transformer. The Barnes County 230 kV substation is radially connected to the Pillsbury 230 kV substation through a 9 mile 230 kV transmission line.

The wind turbine is capable of supplying/drawing reactive power to/from the grid thus contributing to grid voltage support. The reactive power capability corresponds to a power factor range from 0.90 lagging to 0.90 leading at the wind turbine generator terminals. In addition, the wind turbine generators have the capability to regulate voltage at the point of interconnection through a closed-loop control system. This system is typically structured to measure the voltage at a particular bus, often the point of interconnection, and regulate this voltage by sending a reactive power command to all the wind turbine generators within the wind farm. Although GE DFIG wind turbines also have the ability to regulate power factor, it is our understanding that such a control is not generally used on wind farms in North America (see reference [5] for details). For the purposes of this study, the wind farm is assumed to be in voltage control mode and assumed to regulate the voltage at the Barnes County 230 kV bus to 1.05 pu.

2.2 Description of Vestas V90 Wind Turbine Generators

The proposed MPC01900 wind farm will comprise Vestas V90 wind turbine-generators. Each wind turbine-generator unit has a rated power output of 1.8 MW. The generator is a three-phase doubly-fed induction generator whose stator is connected to the grid (via a transformer) and the rotor is connected to the grid through a converter system (via a transformer).

The voltage at the wind turbine-generator terminals is 690 V and is stepped up to a collector system voltage of 34.5 kV through a generator step-up transformer. Each GSU is rated 690 V/34.5 kV with a power rating of 1.9 MVA. The wind farm will have a 34.5 kV collector system network to collect the power output from the individual wind turbine generators. The collector system network is connected to the wind farm 230 kV substation via a 34.5/230 kV substation transformer. This 230 kV substation is also connected radially to Pillsbury 230 kV.

Based on the available information, Vestas V90 1.8 MW WTGs are not individually capable of reactive power exchange with the grid. The power factor of the wind turbine generators is held at unity. Thus for the purposes of this study, wind turbines were modeled with Qmin and Qmax both set to zero.

2.3 Project Modeling Details

The existing Maple River Wind Farm (MPC0500) was approved by the MAPP DRS on May 30, 2008 for a net injection of 358 MW at the Maple River 230 kV substation. See reference [3]. As described in reference [3], the gross capacity of the wind farm was modeled as 378 MW. Subsequent to the study, the wind developer developed 366 MW of gross capacity and deferred the remaining 12 MW to a future phase. This future phase is being developed together with MPC01200.

For the purposes of this study, the gross capacities (MW) of the existing and proposed wind farms are modeled as follows. This study will determine the impact of adding 100 MW of wind above the interconnection approved for MPC0500.

	MPC00500		MPC01200 Ashtabula 3	MPC01900
	Ashtabula 1	Ashtabula 2		
Pre-project	208.5	169.5	OFF	OFF
Post-project	196.5	169.5	50.0 + 12.4	50.0

As noted previously, the proposed MPC01200 wind farm will comprise GE 1.6 MW wind turbine generators with reactive capability corresponding to ±0.9 power factor. Modeling details for this wind farm were provided by the developer. Based on voltage stability analysis results discussed in Section 5.3.2, a 15 MVAR capacitor bank was modeled on the low side of 230/34.5 kV transformer to maintain sufficient voltage stability margin. MPC01200 is connected to the existing Barnes County 230kV bus. Steady-state modeling data for this project is shown in Figure 2-1. It must be noted that for dynamic simulation purposes MPC01200 was modeled as GE 1.5 MW turbines for lack of data. Based on the available information, the electrical performance of GE 1.5 MW is the same as GE 1.6 MW.

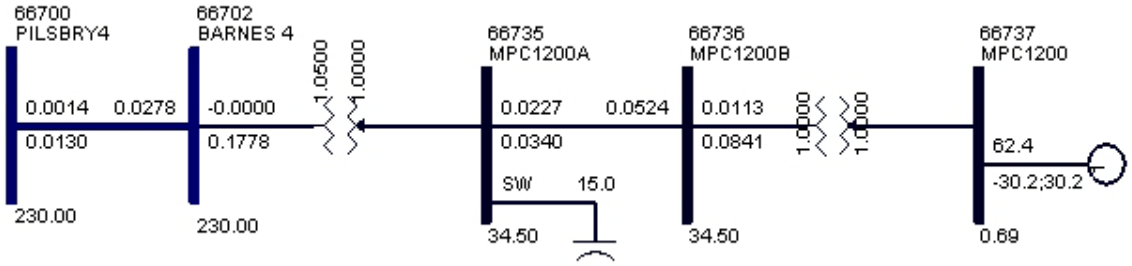

Figure 2-1: Impedance data of MPC01200

MPC01900 was modeled as Vestas V90 units with no reactive power capability. The modeling details can be found in Figure 2-2. A fixed capacitor was placed at the low side of 230/34.5 kV transformer to prevent the farm from leaning on the grid for reactive support. This shunt was sized for 0.95 power factor based on wind farm size at a voltage of 1.0 pu, resulting in a capacitor size of 16.5 MVAR. Based on voltage stability results, a second bank of 15 MVAR was added to this shunt for stability margin requirements. The wind farm was connected radially to the Pillsbury 230 kV substation using 6 miles of 954 kcmil conductor. Steady-state modeling data is shown in Figure 2-2.

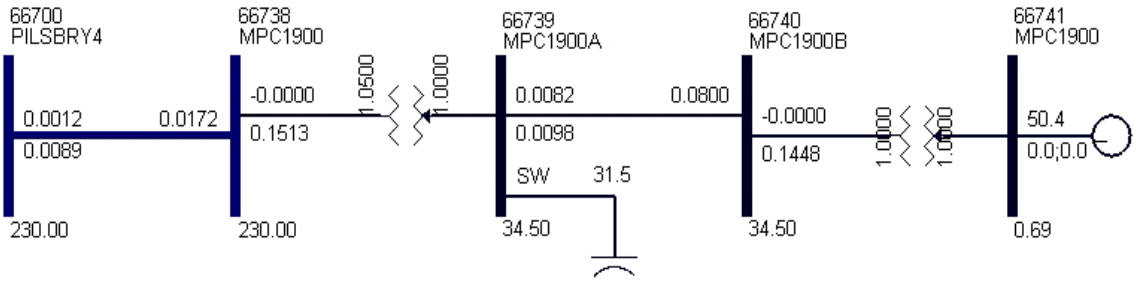

Figure 2-2: Impedance data of MPC01900

2.3.1 System Losses

It can be seen in Figure 2-1 and Figure 2-2 that the proposed projects are connected to Pillsbury 230 kV through the collector system, transformers and 230 kV lines. This section discusses losses in the Ashtabula 1, 2, MPC01200 and MPC01900 systems.

The one-line diagram of the winter peak pre-project case is shown in Figure 2-3. The net injection at Pillsbury 230 kV is 368 MW. On the Pillsbury – Maple River 230kV line, there are additional losses of 12 MW resulting in a net injection of 356 MW at the Maple River 230 kV substation.

The one-line diagram of the winter peak post-project case is shown in Figure 2-4. It can be seen that generation is 113 MW from the proposed projects. The gross generation including Ashtabula 1 and 2 is 479 MW. The net injection at Pillsbury 230 kV is 468 MW and at Maple River 230 kV is 448 MW.

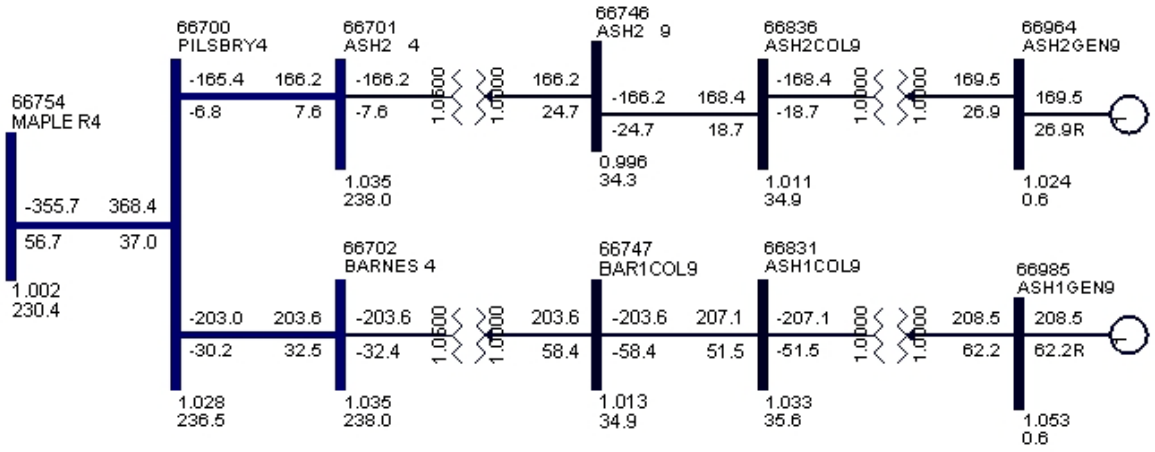

Figure 2-3: Pre-project power flow

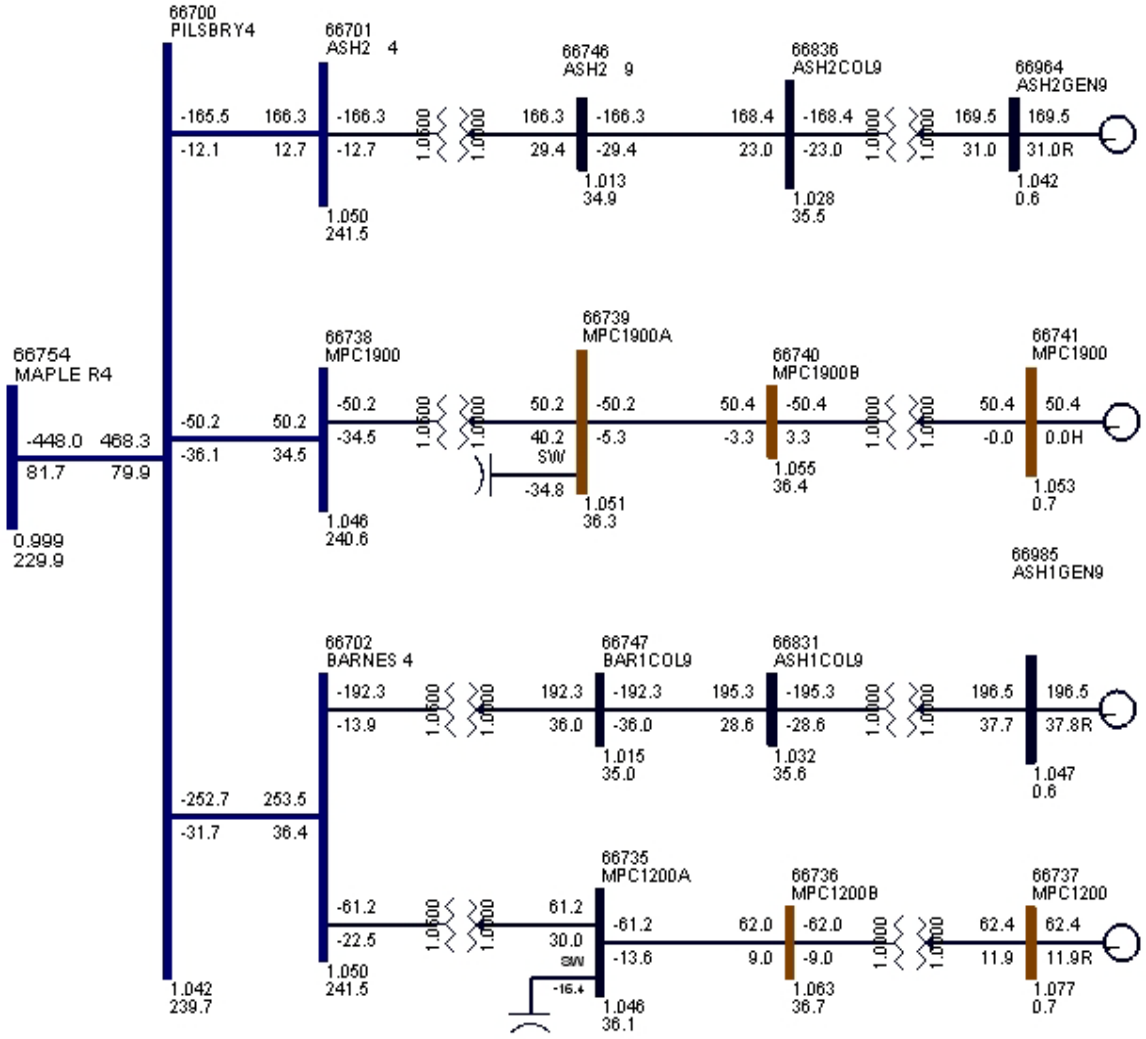

Figure 2-4: Post-project power flow

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3. CRITERIA, METHODOLOGY AND ASSUMPTIONS

3.1 Voltage Stability Analysis

See Chapter 5.

3.2 Steady-State Analysis

Steady-state performance was examined both under system intact and N-1 contingency conditions.

Transmission facilities rated 69 kV and above were monitored for loading and voltage impacts in the GRE, MH, MP, OTP, WAPA and Xcel control areas.

For the purposes of this analysis, Rate A is the continuous facility rating, Rate B is the conductor rating for transmission lines, and Rate C is the emergency facility rating.

System Intact Analysis:
The incremental impact of the proposed projects on thermal loading of transmission facilities under system intact conditions was evaluated by comparing transmission system power flows in the pre- and post-project cases. This was done using an AC power flow solution.

All thermal overloads above 100% of the continuous facility rating (Rate A) were recorded. Voltages that were outside the values shown in Section 1.1.1[1] of reference [2] were flagged.

N-1 Contingency Analysis:
Single branch AC outages as well as multiple-circuit and multi-terminal AC outages in Northern MAPP were simulated.

Contingency analysis was performed in two steps. First, a DC power flow analysis was performed using the PSS-MUST program in order to identify Significantly Affected Facilities (SAF) and limiting contingencies. Post-contingency power flows in excess of 95% of Rate A were recorded. Facilities whose post-contingency flow changed from their corresponding pre-contingency flow by less than 1 MW were not reported. Post-contingency facility loadings in the pre- and post-project cases were tabulated and compared.

Next, based on the results of the DC power flow analysis, limiting contingencies were selected for further evaluation with full AC power flow solution (activity ACCC in PSS/E). In addition, the following single branch contingencies were also simulated using ACCC:

[1] Pre-contingency Voltage Limitations.

- All 230 kV outlet lines and transformers connected to Maple River, Sheyenne, Audubon, Frontier, Wahpeton and Winger.
- All three winding transformers at Maple River, Audubon, Wahpeton and Winger.

In the AC power flow solution results, facilities loaded above 100% of the continuous facility rating (Rate A) were recorded. As in the DC analysis, facilities whose post-contingency flow changed from their corresponding pre-contingency flow by less than 1 MW were not reported.

For the purposes of the ACCC analysis, transformer taps, switched shunts and phase angle regulators were enabled.

Voltages outside the values specified in Section 1.1.3[2] of [2] were flagged if the difference in pre- and post-contingency voltages was greater than 0.01 pu.

Criteria for Identifying Impacts:

Significantly Affected Facilities (SAFs) were identified based on Attachment A[3] of MAPP Design Review Subcommittee Policies and Procedures document [1].

All overloaded facilities that meet the following criteria were considered significantly affected, based on the 100 MW impact of MPC01200 and MPC01900 on the AC system:

- System Intact Conditions: Report all overloaded facilities (loaded above Rate A) that exhibit a MW increase in loading (pre-project to post-project) greater than 5% of 100 MW.
- Contingency Conditions: Report all overloaded facilities (loaded above Rate A) that exhibit a MW increase in loading (pre-project to post-project) greater than 3% of 100 MW.

Interconnection-related facility mitigations are required on those SAF's which are in the vicinity of the project, and on which the project has an impact of at least 10% to 20%, depending on engineering judgment.

For identifying voltage impacts, only buses that have a voltage change of more than 0.01 pu (pre- vs. post-project) are considered significantly affected.

[2] Post-contingency Voltage Limitations.
[3] Steady-State facility and Flowgate Impact Determination Requirements and Screening Guidelines for Study Submissions.

3.3 Stability Analysis

The purpose of the stability analysis is to determine whether the MAPP transmission system would meet stability criteria following commissioning of the proposed 100 MW wind farm at Maple River. Disturbances were simulated in Northern MAPP to assess the impact of the proposed project on transmission system stability performance. After identifying the impacts, reinforcements were proposed and tested for faults that resulted in stability criteria violations.

3.4 Short-Circuit Analysis

The purpose of the short-circuit analysis is to determine the impact of the proposed projects on substation fault current levels in the electrical vicinity. Three-phase and single-line-to-ground faults were simulated and the impact of the proposed projects on the fault currents was determined.

4. MODEL DEVELOPMENT

4.1 Summary of Models Developed

The study year chosen was 2012 prior to when major transmission additions, such as CAPX Group 1 projects and the Center – Grand Forks line are expected to come online. Pre- and post-project cases developed for the study are shown in Table 4-1.

Table 4-1: Pre- and Post-project Case Names

Condition	Pre-project Case	Post-project Case
Summer Peak	003-sp12aa.sav	b17-sp12aa.sav
Winter Peak	003-wp12aa.sav	b17-wp12aa.sav
Summer Off-peak (Steady-state)	005-so12aa.sav	b18-so12aa.sav
Summer Off-peak (Stability)	006-so12aa.sav	c21-so12aa.sav

Models were developed using the January 2010 release of NMORWG Study Package "pkg2010-1-05-2010." This package utilizes PTI PSS/E™ Rev 29.4 and Version 6.6B of the Digital FORTRAN Compiler. Cases in this package used in the model development are listed in Table 4-2 and are referred to as the 'base models.'

The NDEX limit for the pre- and post-project cases was assumed to be 2080MW.

Case summaries for all pre- and post-project cases are given in Appendix B.

4.2 Control Area Load

4.2.1 North Dakota

The estimates for 2010 ND load are recorded in the peakload.data file in the NMORWG package used for this study. The 2010 ND summer peak load value in the file is 3110 MW. The 2010 peak load was scaled up by 2.5% per year, resulting in a 2012 ND load value of 3267 MW. It was increased by 25 MW to account for the maximum usage by the five Keystone pipeline load deliveries in ND. This brought the total ND summer peak load to 3292 MW.

A reasonability check was done by MPC based on actual historic ND load. MPC observed an actual 2009 summer peak ND load and losses of 3000 MW. Assuming a ND loss value of 250 MW based on losses observed in operating models, the actual 2009 summer peak load was 2750 MW. With the assumption of general load growth from 2009 to 2012 plus the addition of the Keystone loads and western ND loads, the proposed ND load value of 3292 MW was found to be reasonable for the 2012 time frame.

The 2012/13 winter peak load was derived from 2009/10 historic loading in order to use the most current information possible. MPC observed an actual 2009/10 winter peak load and losses in ND of 3900 MW. Assuming a ND loss value of 360 MW based on losses observed in operating models, the actual 2009/10 winter peak load was 3540 MW. An increase of 2.5% per year for 2 years results in a 2012/13 ND load value of 3719 MW. It was increased by 75 MW to account for recent addition of five Keystone pipeline load deliveries in ND. These pipeline loads were just beginning to operate at low levels during the 2009/10 winter season, so would not have contributed appreciably to the historic measured peak load. The Keystone load addition brings the total ND winter peak load to 3794 MW.

For both summer and winter peak cases, only zone 90 load was scaled up to bring total ND load value to the peak value.

4.2.2 Manitoba Hydro and Xcel Energy

Xcel (Area 600) and MH (Area 667) loads were also adjusted to reflect the 2012 time frame. Estimates for 2010/11 Xcel and MH load are recorded in the peakload.data file in NMORWG study package. The 2010 peak load values from this file were used to derive 2012 model loads by scaling them up by 2.5% per year. The resulting 2012 Xcel load was 11312 MW for summer and 8566 MW for 2012/13 winter. The 2012 MH load was 3312 MW for the summer and 4424 MW for 2012/13 winter. No other loads were changed from the values in the 2010 base cases, based on the assumption that they are too far from the study region to impact the results.

4.3 Development of Pre-Project Cases

For purposes of developing pre-project cases, the study ad hoc group identified prior-queued generation plants to be added to the base models. Table 4-3 summarizes the MW output of these plants in the various cases.

Southwest Minnesota (SWMN) wind generation was modeled at 1200 MW in the cases. Table 4-4 summarizes SWMN wind projects with respective MW outputs. SWMN wind generation was dispatched against MISO footprint generation to the east of the Twin Cities.

The following changes were made to the original cases in the study package.

- Ashtabula 1 and 2 modeling: This included modeling changes based on data provided by the wind developer. The updated data can be found in Appendix A.
- Cass Lake caps addition: This was done using idev *OTP_100331_NMORWG_Topology.idv* provided by MPC.

- In the study package, the Rolla 115kV bus north of Agate was inadvertently given the same bus number as MPC's Helga bus. This was fixed using idevs provided by MPC.
- Increased reactive power capability of present Maple River wind generators, namely Ashtabula 1 and 2, corresponding to a power factor of ± 0.90.
- Updated line ratings to match MPC's revised facility rating methodology

In addition to the above-mentioned changes, several case-specific changes were implemented to develop final pre-project cases. The following sections discuss the specific changes for each system condition.

4.3.1 Pre-project 2012 Summer Peak Model

For development of the pre-project summer peak model, case *sp10aa.sav* from the NMORWG study package was used as the starting point. Generation adjustments were made as shown in Table 4-3 and Table 4-4 while load levels were updated as described in Section 4.2. In addition, following changes were made to get the pre-project summer peak case.

- Keystone loads were modeled at 75 MW.
- Existing Maple River wind was dispatched according to the same approach used in the GM00500 interconnection study: 56% to Coyote and Young 1, 27% to Big Stone, and 17% Cincinnati area generation.
- ND Coal Field base load generation was modeled at Cruise.

All prior-queued ND wind projects were dispatched at 100% of nameplate against MISO footprint generation to the east of the Twin Cities. Increase in SWMN wind generation was dispatched against Xcel energy load. The resulting pre-project summer peak case was named *003-sp12aa.sav.* The case summary and slider diagram of the Maple River region for this case is included in Appendix B.

4.3.2 Pre-project 2012 Winter Peak North Model

For development of pre-project winter peak model, case *nrt-wp10aa.sav* from the NMORWG study package was used as the starting point. Generation adjustments were made as shown in Table 4-3 and Table 4-4 while load levels were updated as described in Section 4.2. In addition, following changes were made to obtain the pre-project winter peak case.

- Keystone loads were modeled at 75 MW.
- Existing Maple River wind was dispatched according to the same approach used in the GM00500 interconnection study: 56% to Coyote and Young 1, 27% to Big Stone and 17% to Cincinnati area generation.
- ND Coal Field base load generation was modeled at Cruise.

All queued ND wind projects were dispatched at 100% of nameplate to MISO footprint. Increase in SWMN wind generation was dispatched partially against Xcel energy load and partially against generation to the east of Twin Cities in MISO footprint. MHEX was held at 700 MW north to obtain the resulting pre-project winter peak case, *003-wp12aa.sav.* The case summary and slider diagram of Maple River area for this case are included in Appendix B.

4.3.3 Pre-project 2012 Summer Off-Peak Model (Steady-state)

For development of the pre-project summer off-peak model, case *urg-so10aa.sav* from the NMORWG study package was used as the starting point. Generation adjustments were made as shown in Table 4-3 and Table 4-4 while load levels were updated as described in Section 4.2. In addition, following changes were made to derive the pre-project summer off-peak case.

- Existing Maple River wind (MPC0500) was dispatched against Big Stone and Hoot Lake. The net dispatches of Big Stone and Hoot Lake were made in the same way as in the MPC0500 interconnection study [3].
- ND Coal Field base load generation was modeled at URGE.

To keep ND load to around 70% of peak summer load, all ND wind except existing Maple River wind was dispatched at 30% of nameplate rating. Increase in SWMN wind generation was dispatched partially against Xcel energy load and partially against generation to the east of Twin Cities in MISO footprint. The resulting pre-project summer off-peak case was named *005-so12aa.sav.* The case summary and slider diagram of the Maple River area for this case are included in Appendix B.

4.3.4 Pre-project 2012 Summer Off-Peak Model (Dynamics)

The pre-project steady state case for summer off-peak was used as the starting point to develop the stability case. At the time of the study, a new version of NMORWG package dated May 11, 2010 had already been released. All updates from that package that were relevant to this Maple River area study were applied to the study case. Generation levels for various prior queued projects can be seen in Table 4-3. It can be seen from the table that Central ND wind was dispatched at 100%. Existing Maple River wind was dispatched 50% to Big Stone and 50% to ND load, the same as it was in the MPC0500 interconnection study [3].

In addition, the following changes were made to resolve initialization errors and develop a case suitable for stability simulation.

- The representation of Ashtabula 1 and 2 was changed to four machines as opposed to one machine in the steady-state. This was done to retain dynamic data from NMORWG snapshot ‘nmorwg08-pass7.snp’ used for stability analysis.

- Generator MBASE and/or ZSORCE were changed for many units to reflect wind turbine manufacturer's data specification. The data was changed for Oliver County 3, Bison 1, St. Joseph wind, and GI-0707A.
- A second 75 MVAR capacitor bank was turned on at Watertown.
- Hubbard 115 kV and 34.5 kV (61841, 61641), Pine River 115 kV (61657) and RDO 115 kV buses (62415, 62420) were moved from area 608 to 610 to reflect voltage criteria in Minnesota Power's Western Division (area 610).

Miles City DC line was modeled at 150 MW west. This was done to reduce ND load to around 70% of peak level. BEPC staff was consulted to confirm that this adjustment to Miles City DC was acceptable. The pre-project stability case was called *006-so12aa.sav*. The case summary and slider diagram of Maple River region for this case are included in Appendix B.

4.4 Development of Post-Project Cases

Post-project cases were developed from the corresponding pre-project cases by adding generators and interconnection facilities for proposed projects, MPC01200 and MPC01900. The total capacity studied is an additional 100 MW. An additional 12 MW of wind generation pre-approved for Ashtabula 1 was modeled as part of GM01200 according to data provided by the wind farm developer.

Modeling of proposed generation is discussed in greater detail in Section 2.3. MPC01200 and MPC01900 were dispatched to Cincinnati area generation in summer and winter peak cases. The respective cases are called *b17-sp12aa.sav* and *b17-wp12aa.sav*.

In the summer off-peak case for steady state analysis, the projects were dispatched to ND Load. There was a preference to dispatch the projects to base load generation, but the only base load generation available within the NDEX region would have produced countervailing system flow. Therefore, in keeping with the practice of establishing the most limiting high-export summer off-peak case possible, the projects were dispatched broadly to ND load. The case is called *b18-so12aa.sav*.

The slider diagrams of all post-project cases are included in Appendix B.

4.4.1 Post-project 2012 Summer Off-Peak Model (Dynamics)

The post-project summer off-peak case for dynamics analysis was developed with the pre-project dynamic summer off-peak case as the starting point. Dynamic data for GE 1.6 MW machines was not available. Therefore, MPC01200 was represented using 1.5 MW machines for dynamic simulation. Based on the available information, GE 1.6XLE turbines are electrically the

same as GE 1.5 MW turbines, but they have front-end turbine and drive improvements that increase mechanical efficiency.

MPC01200 and MPC01900 were dispatched 50% to Big Stone and 50% to ND load. The summer off-peak model for dynamics was named *c21-so12aa.sav*.

4.5 Development of Stability Model (Snapshot)

4.5.1 Pre-project Snapshot

The starting point for the pre-project stability model was update #7 of the dynamics data snapshot in the NMORWG package dated January 5, 2010 (nmorwg08-pass7.snp).

Stability data was added for some prior queued projects. In addition, the following changes were made to develop the pre-project snapshot based on updates included in the May 11, 2010 NMORWG package and input from study participants.

- Filter time constant of the Elbow Lake wind farm (G474) was fixed.
- Filter time constant of the Rugby wind farm (G380) was fixed.
- G82R DC reduction model parameters were updated.
- The correct NDEX tiesum model was added to the channel file.
- Old Acciona model for G132 was removed and Acciona model for AWG-1500 added.
- Dynamic data added for G531 after purging GENCLS model.
- St. Joseph wind and G288 were modeled as GE 1.5 MW machines. GE WTG model version 5.1.0 (compatible with gewt_p29_w51.lib) dated July 8, 2009 was used with wind inertia and Q droop control disabled.
- GI-0616 and GI-0707 were modeled as Seimens 2.3 MW machines. Model SMK203 version 1.2 dated June 18, 2006 was used.
- Transient voltage criteria for buses related to Oliver County and Bison Wind farms (bus numbers 61583 to 61599) was changed to 1.30 pu max and 0.7 pu min using model MAPPC1.

The pre-project snapshot was called *nmorwg08-pre-project.snp.*

4.5.2 Post-project Snapshot

Starting from the pre-project snapshot, the post-project snapshot was developed with the following changes.

- Based on recommendation by Vestas data sheet for its V90 model [6**Error! Not a valid bookmark self-reference.**], changes were made to some solution settings. Frequency filter was changed to 0.04, Delta threshold Intermediate value was changed to 0.06 and island frequency was changed to 0.14.

- MPC01200 was modeled as GE 1.5 MW machines. GE WTG model version 5.1.0 (compatible with gewt_p29_w51.lib) dated July 8, 2009 was used.
- MPC01900 was modeled as Vestas V90 machines. The model is compatible with VESTAS_6_0_2_PSSE29.lib dated March 06, 2008.

The post-project snapshot was called *nmorwg08-post-project.snp.*

Table 4-2: Case Development

	2012 Summer Off-peak (Dynamics)	2012 Summer Off-peak (Steady-state)	2012 Summer Peak	2012 Winter Peak
Case Origin	from *urg-so10aa.sav* 01-05-2010 NMORWG pkg	from *urg-so10aa.sav* 01-05-2010 NMORWG pkg	from *sp10aa.sav* 01-05-2010 NMORWG pkg	from *nrt-wp10aa.sav* 01-05-2010 NMORWG pkg
Existing Maple River Generation	Dispatched 50% to Big Stone, 50% to ND Load	Dispatched to Big Stone and Hoot Lake	Dispatched by off-taker to Coyote, Young 1, Big Stone and Cincinnati area generation	Dispatched by off-taker to Coyote, Young 1, Big Stone, Cincinnati area generation
GM01200 / GM01900	Dispatched 50% to Big Stone, 50% to ND Load	Dispatched to ND Load	Dispatch to Cincinnati area generation	Dispatch to Cincinnati area generation
ND coal field base load generation	URGE	URGE	Cruise	Cruise
ND wind (in-service and queued projects)	Central ND = Max Maple River Wind = Max Langdon OFF; existing Edgeley (BEPC) wind OFF	Generally 20% dispatched to ND load, set as high as possible while maintaining ND load at approx 70% Reduce as a group or turn OFF some gens if necessary to maintain NDEX at or below limit	Generally 100% dispatched to swing bus Reduce as a group or turn OFF gens if necessary to maintain NDEX at or below limit	Generally 100% dispatched to swing bus Reduce as a group or turn OFF gens if necessary to maintain NDEX at or below limit
SW MN wind	100% of 1200 MW	100% of 1200 MW	100% of 1200 MW	100% of 1200 MW
Peaking Generation: Groton, Solway, Jamestown, Culbertson	OFF	OFF	100%	100%
MH wind	St. Leon = 100% St. Joseph = 100%	St. Leon = 100% St. Joseph = 100%	St. Leon = 100% St. Joseph = 100%	St. Leon = 100% St. Joseph = 100%
Other - Ladish 1	OFF	ON	ON	ON
Square Butte Wind / DC	Sq Butte DC = 500 MW, Oliver County 1 on DC, Oliver County 2, 3 and Bison 1 on AC	Same as suop dynamics, but reduced together with other ND gens	Same as suop dynamics, but reduced together with other ND gens	Same as suop dynamics, but reduced together with other ND gens
ND Load	Pre: 2318 MW, 70.4% of peak Post: 2360 MW, 71.7% of peak	Pre: 2287 MW, 69.5% of peak Post: 2378 MW, 72.2% of peak	Pre: 3295 MW, 100.1% of peak Post: 3295 MW, 100.1% of peak	Pre: 3794 MW, 100% of peak Post: 3794 MW, 100% of peak
NDEX	Pre: 2080 MW Post: 2080 MW	Pre: 2080 MW Post: 2081 MW	Pre: 1667 MW Post: 1755 MW	Pre: 822 MW Post: 911 MW
MWEX	Pre: 1522 MW Post: 1524 MW	Pre: 1525 MW Post: 1523 MW	Pre: 739 MW Post: 756 MW	Pre: 436 MW Post: 453 MW
MHEX	Pre: 2170 MW Post: 2172 MW	Pre: 2176 MW Post: 2172 MW	Pre: 1237 MW Post: 1236 MW	Pre: 699 MW north Post: 700 MW north

Table 4-3: Prior Queued Projects

Project Name/Queue #	Location/Description	Queue	Nameplate (MW)	Fuel Type	Within NDEX	Include for study	Bus Number	003-sp12aa.sav	003-wp12aa.sav	005-so12aa.sav	006-so12aa.sav
G059 (in-service)	Solway	MISO	50.0	Gas Peaker	Y	Y	63385	50	50	Offline	Offline
G132	Tatanka	MISO	180.0	Wind	Y	Y	67399	180	180	54	Offline
G291	Edgeley OTP	MISO	21.0	Wind	Y	Y	63161 (63165 in su op)	21	21	6.3	Offline
G380	Rugby 1 (Rugby 230)	MISO	150.0	Wind	Y	Y	68378	150	150	45	150
G408	Velva Wind	MISO	12.0	Wind	Y	Y	63087	12	12	3.6	12
G474	Grant County	MISO	20.0	Wind	Y	Y	63220	20	20	6	Offline
G502	Oliver County 1		50.6	Wind	Y	Y	61603	50.6	50.6	50.6	50.6
G531	Stanton 230		75.0	Coal	Y	Y	63003	68	68	68	68
G619	Tamarac	MISO	50.0	Wind	Y	Y	62525	49.5	49.5	14.8	Offline
G645	Ladish 1 (Ladish 115)		50.0	Coal	Y	Y	63645	50	50	50	Offline
G767	Diamond Willow	MISO	19.5	Wind	Y	Y	67393	19.5	19.5	5.8	19.5
GI-0208	Edgeley BEPC	IS	40.5	Wind	Y	Y	67292	40.5	40.5	12.2	Offline
GI-0503	Minot 1 (Max-Mallard 115kV line)	IS	100.0	Wind	Y	Y	67157	115.5	115.5	34.6	116
GI-0720	Minot 2 (combined with Minot 1)	IS	16.0	Wind	Y	Y	67157				
GI-0508	Wilton 1	IS	49.5	Wind	Y	Y	67295	49.5	49.5	14.8	49.5
GI-0512	Edgeley 115	IS	50.0	Wind	Y	Y	99015	49.5	49.5	14.85	Offline
GI-0614A	Culbertson Waste Heat	IS	8.0	Gas Peaker	Y	Y	67300	8	8	Offline	Offline
GI-0615	Wilton 2	IS	50.0	Wind	Y	Y	67255	49.5	49.5	14.8	50
GI-0616	Leland Olds-Groton 345	IS	81.0	Wind	Y	Y	90616	100	100	30	30
GI-0707A	Leland Olds-Groton 345	IS	286.0	Wind	Y	Y	90707				
GI-0708	Culbertson Gas Peaker	IS	120.0	Gas Peaker	Y	Y	67300	120	120	Offline	Offline
GS659	Oliver County 2		49.5	Wind	Y	Y	61606	49.5	49.5	14.8	49.5
GS660	Bison 1	Square	75.0	Wind	Y	Y	61594	75	75	22.5	75
GS661	Oliver County 3	Square	48.0	Wind	Y	Y	61585	48	48	14.4	48
MPC0100/0200 (in-service)	Langdon 1	MPC	159.0	Wind	Y	Y	66881	159	159	47.7	Offline
MPC0300 (in-service)	Langdon 2	MPC	40.5	Wind	Y	Y	66883	40.5	40.5	12.15	Offline

Project Name/Queue #	Location/Description	Queue	Nameplate (MW)	Fuel Type	Within NDEX	Include for study	Bus Number	003-sp12aa.sav	003-wp12aa.sav	005-so12aa.sav	006-so12aa.sav
MPC0500 (in-service)	Maple River Wind	MPC	352.5	Wind	Y	Y	66964 66985	377.5	377.5	377.5	377.5
N/A	Letellier	MH	300.0	Wind	N	Y	67825	300	300	300	300
St. Leon wind farm		MH	99.0	Wind	N	Y	67816	99	99	99	99
Casselton ethanol plant					Y	Y	63180	8	8	7.3	7.7
Groton 1 and 2	Groton 1 and 2	IS	240.0	Gas Peaker	N	Y	67274	240	240	Offline	Offline
Jamestown Peakers	Jamestown Peakers	MISO	44.6	Gas Peaker	Y	Y	63172	42.5	57.6	Offline	Offline

Table 4-4: South-West Minnesota Wind Projects

Bus #	Bus Name	Pmax	Pgen
60065	West Pipestone	8.0	8.0
60066	Fenton 3	61.5	61.5
60067	Fenton 2	40.5	40.5
60068	Fenton 1	21.0	21.0
60069	Fenton 4	82.5	82.5
60071	Yankee 3	60.0	60.0
60072	Yankee 2	39.0	39.0
60073	Yankee 1	19.5	19.5
60074	Yankee 4	81.0	81.0
60075	Chanarambie GE 1	21.0	21.0
60076	Chanarambie GE 2	30.0	30.0
60077	Chanarambie GE 4	60.0	60.0
60078	Chanarambie GE 3	37.5	37.5
60084	Community Wind North 1	16.8	16.8
60085	Community Wind North 2	14.7	14.7
60395	East Ridge	10.0	10.0
60614	Chanarambie 9	54.7	54.7
60615	Chanarambie 2	24.0	24.0
60616	Buffalo Ridge 9	123.5	122.0
60617	Buffalo Ridge 2	123.5	122.0
60619	Chanarambie 4	112.0	112.0
60856	West Ridge	10.4	10.4
61190	Woodstock	10.4	10.4
61191	South Ridge	10.0	10.0
62710	Chandler	6.0	6.0
90187	Nobles 115kV	100.5	62.5
90188	Nobles 115kV	100.5	62.5
34901	Rock County Generator	12.0	12.0
	Total		1211.5

5. VOLTAGE STABILITY ANALYSIS

Voltage stability analysis was performed to determine the maximum power transfer on the Pillsbury – Maple River 230 kV line over and above the 358 MW of wind already approved for interconnection at the Maple River 230 kV bus.

5.1 Methodology

Voltage stability analysis was performed using PV methods. The built-in voltage stability toolbox in PSS/E version 32.0.2 was used for these analyses.

The main objective of the PV analysis was to determine the maximum power transfer on the Pillsbury – Maple River 230 kV line while maintaining a voltage stable solution (i.e. convergent) within criteria voltages. The analysis focused on voltage performance at the Pillsbury and Maple River 230 kV substations. The thermal rating of the Pillsbury - Maple River 230 kV line was ignored for this analysis. Typically PV curves are plots of post-contingent voltage versus pre-contingency line flow. In this study, however, Maple River generation had a TDF of 100%. As a result, post-contingency flows were approximately equal to pre-contingency flows and were used for plotting purposes.

The proposed wind farms, MPC01200 and MPC01900, were modeled and dispatched initially at zero output. The analysis was performed by incrementally increasing the dispatch of proposed wind farms in a 1:1 ratio and subjecting the resulting cases to the most limiting contingencies. Voltages were monitored at the Maple River 230 kV bus and plotted against the MW flow on Pillsbury – Maple River 230 kV line (as measured at Pillsbury).

The project output was dispatched to Cincinnati area generation in summer and winter peak cases and to Big Stone and Hoot Lake for summer off-peak. For PV analysis, transformer taps, switched shunts, and phase shifters were allowed to regulate, the Full Newton-Raphson solution method was used, and generator reactive limits applied automatically. Switched shunts near Maple River, namely at Fargo, Sheyenne, and Prairie, were allowed to regulate. PV analysis was run for system intact conditions and the seven contingencies listed below.

1. Maple River – Sheyenne 230 kV and Maple River – Frontier 230 kV double circuit (MRV-SHY-FRN)
2. Maple River – Sheyenne 230 kV line (MRV-SHY-230)
3. Maple River – Frontier 230 kV line (MRV-FRN-230)
4. Maple River – Winger 230 kV line (MRV-WNG-230)
5. Fargo – Sheyenne 230 kV line (FRG-SHY-230)
6. Sheyenne – Audubon 230 kV line (SHY-AUD-230)
7. Loss of Fargo SVC (FARGO SVC)

All base cases for voltage stability analysis included a 16.5 MVAR capacitor at the MPC01900 collector bus to meet power factor requirements, as discussed in Section 2.3. Any mention of additional capacitors for reactive support is with the assumption that this 16.5 MVAR of capacitance is already present at the MPC01900 collector bus.

5.2 Limiting Cases and Contingencies for Voltage Stability

Initial analysis on the preliminary summer peak, summer off-peak and winter peak cases demonstrated that the winter peak case is the most limiting from a voltage stability standpoint. Contingencies listed in Section 5.1 were run and the most limiting contingency was found to be the double contingency involving the loss of the Maple River – Sheyenne 230 kV and Maple River – Frontier 230 kV double circuit (MRV-SHY-FRN). The voltage stability performance was followed closely by the Maple River – Sheyenne 230 kV line single contingency (MRV-SHY). From a voltage stability perspective, these two contingencies weaken the Maple River 230 kV bus by cutting off the reactive power support available from the switched capacitor banks at Sheyenne. All further voltage stability analysis was therefore performed on the winter peak case and was limited to the base case and these two contingencies.

5.3 Voltage Stability Results

Results of voltage stability analysis are presented in this section. It must be noted that existing Maple River wind generation is modeled at 366 MW. This is because 12 MW from Ashtabula 1 was removed from the pre-project case and studied with MPC01200 and MPC01900 projects. The pre-project case was called *002-wp12aa.sav*. Power injected at Pillsbury in the pre-project case is 357 MW indicating that the losses in the collector system are about 9 MW.

5.3.1 Voltage Stability Without Additional VAR Support

PV analysis was performed on the pre-project case using procedures described in Section 5.1. Results for base case, MRV-SHY-230 single contingency and MRV-SHY-FRN double circuit contingency are shown in Figure 5-1.

It can be seen from Figure 5-1 that the nose of the PV curve occurs at an injection of 498 MW for the double contingency MRV-SHY-FRN. With a 10% voltage stability margin, the maximum allowable transfer on the Pillsbury-Maple River 230 kV line would be 448 MW. The corresponding nameplate generation addition is 93 MW as can be seen from Table 5-1. Allocating the first 12 MW to Ashtabula 1, the additional injection for the proposed projects is approximately 80 MW.

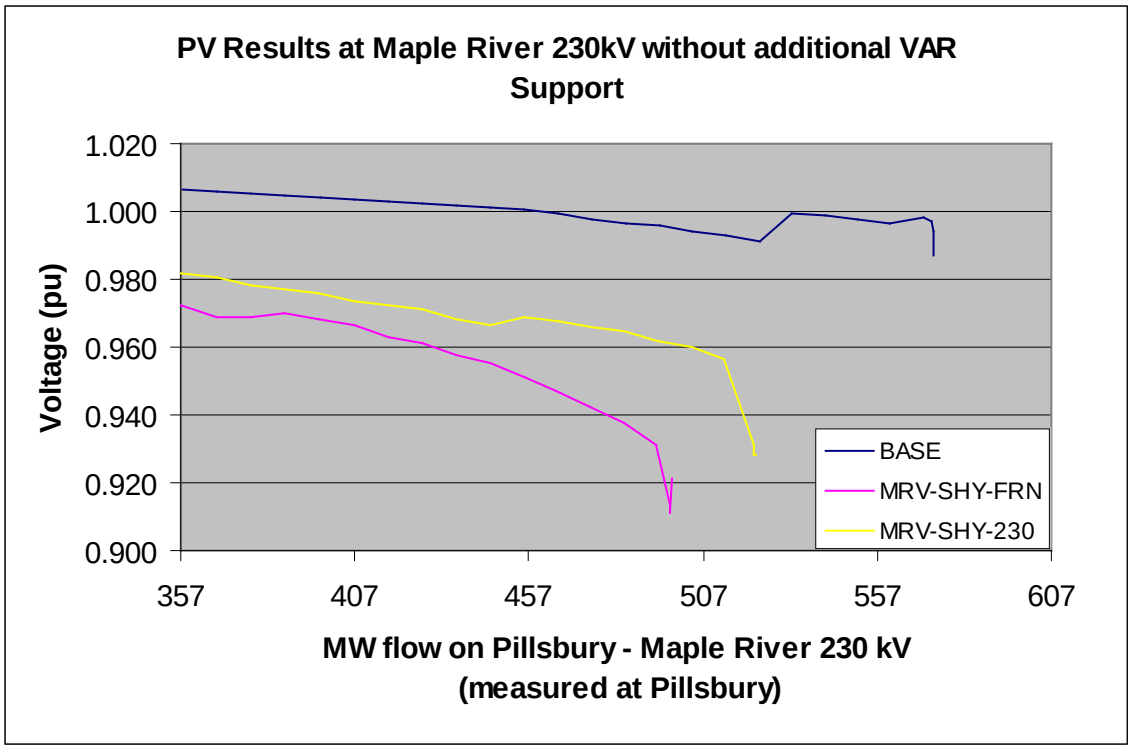

Figure 5-1: PV Results without additional VAR support.

5.3.2 Additional VAR Requirement to Support 100 MW Injection

Additional analysis was performed to quantify additional VAR support required to inject 100 MW from the new projects. For 100 MW of additional injection and the 12.4 MW of pre-approved capacity, the injection at Pillsbury 230kV would have to be 469 MW (357+12+100 = 469 MW). With a 10% margin, the injection would be 521 MW (469/0.9 = 521 MW).

The additional VAR requirement was determined using Optimal Power Flow (OPF). OPF minimizes the amount of shunt compensation required to get the post-contingency case to converge. OPF was setup to find the minimum VAR requirement for the case to converge following double contingency MRV-SHY-FRN. OPF also gives location of the VAR sources.

OPF analysis was performed to quantify the reactive requirements to support a total 521 MW of transfer on the Pillsbury – Maple River 230 kV line for the double circuit contingency. In this case, OPF placed a 30 MVAR of capacitor banks in the Maple River area. These 30 MVAR were pro-rated based on active power output of the two projects and installed at the low side of 230/34.5 kV transformers. Specifically, 17 MVAR were installed for the 12 MW build-out and MPC01200 and 13 MVAR for MPC01900. With 30 MVAR of compensation, there was no voltage collapse following the double contingency.

PV analysis was repeated on the post-project case with 30 MVAR of shunt compensation to verify the OPF results. The results of this analysis are shown in Figure 5-2.

It can be seen from Figure 5-2 that the termination point for double circuit contingency MRV-SHY-FRN occurs at 519 MW. For operation at 10% before the termination point, injection at Pillsbury 230 kV is 467 MW giving a project generation of 112 MW. Hence, after the first 12 MW have been allocated to Ashtabula 1, the two projects generate about 50 MW each.

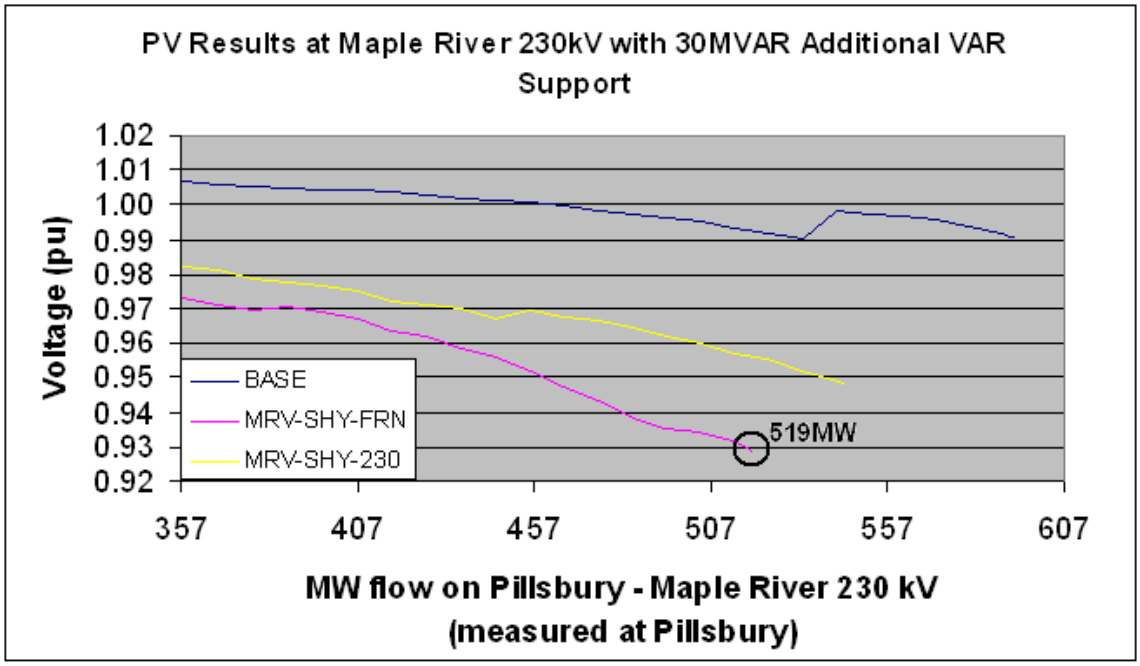

Figure 5-2: PV Results with 30 MVAR additional VAR support.

The voltage stability results are summarized in Table 5-1.

Table 5-1: Voltage Stability Summary

Outage Condition	Additional Reactive Support Required at the Collector Buses (MVAR) (Note 1)	Voltage Collapse Point (MW)	Voltage Stability Limit With 10% Margin (MW)	MPC01200/01900 Combined Project Size (MW) (Note 2)
System Intact	0	573	516	165
	30	593	534	180
Maple River – Sheyenne 230 kV line contingency (MRV-SHY-230)	0	522	470	115
	30	545	491	136
Maple River – Sheyenne / Maple River – Frontier 230 kV double circuit contingency (MRV-SHY-FRN)	0	498	448	93
	30	519	467	112

Note 1: To meet the 30 MVAR requirement, half was modeled at each collector bus; i.e.15 MVAR at the MPC01200 collector bus, and 15 MVAR at the MPC01900 collector bus. Additionally, at the MPC01900 collector bus, there are 16.5 MVAR of capacitors needed in all cases to meet the power factor requirement for the Vestas machines.

Note 2: Project Size includes 12 MW of the previously approved 378 MW nameplate for the existing Maple River Wind Farm (MPC0500).

6. STEADY-STATE ANALYSIS

The Pillsbury – Maple River 230 kV line is a radial generator lead line, so it is known that line loading will be directly proportional to wind generation output, and hence wind speed. Therefore, a dynamic (wind-adjusted) rating will be used on the line. The wind-adjusted summer continuous rating of the line is 478 MVA when generation output is low and 670 MVA when generation output is at maximum.

6.1 System Intact Analysis

Table 6-1 shows significantly affected facilities (SAFs) in the summer peak and summer off-peak powerflow cases. There were no SAFs in the winter peak case. Interconnection related SAFs are shown in Table 6-2, and described in detail below.

For each facility, the mitigation requirements are presented for a 50 MW interconnection by the MPC01200 customer alone, and for a 100 MW combined interconnection by the MPC01200 and MPC01900 customers. Mitigation requirements for MPC01200 are based on the anticipated loadings for 50 MW of interconnection calculated using the TDFs presented in Table 6-2.

- Sheyenne – Audubon 230 kV line
  - Existing generation projects have an upgrade obligation on this facility. The facility upgrade has not yet been completed. On an interim basis, dynamic ratings are being applied based on wind speed and ambient temperature. Final upgrades are scheduled to be in service in 2014.
  - MPC01200 (50 MW): No upgrade obligations are anticipated.
  - MPC01200/01900 (100 MW): A maximum pre-contingent flow of 309 MVA was observed in the summer peak case for this MPC01200/01900 study. It is assumed that the upgrade obligation of existing projects will be adequate to accommodate the pre-contingent flow observed in this study. Therefore, no further upgrade obligations are anticipated.
- Maple River – Frontier 230 kV line
  - Existing generation projects have an upgrade obligation on this facility. The facility upgrade has not yet been completed. On an interim basis, mitigation is by SPS. The final upgrade schedule has not been determined.
  - MPC01200 (50 MW): No upgrade obligations are anticipated.
  - MPC01200/01900 (100 MW): A maximum pre-contingent flow of 297 MVA was observed in the summer off-peak case for this MPC01200/01900 study. It is assumed that the upgrade obligation

of existing projects will be adequate to accommodate the pre-contingent flow observed in this study. Therefore, no further upgrade obligations are anticipated.

There are no significantly affected bus voltages for system intact conditions.

6.2 Contingency Analysis

Appendix C.1 lists the results of the DC power flow analysis. For the purposes of the DC screen, facilities loaded 95% above Rate A were identified.

AC contingency analysis results are tabulated in Table 6-3 through Table 6-5. These tables list SAF loadings for N-1 contingency conditions for summer peak, winter peak and summer off-peak conditions respectively. The tables list the limiting facilities and associated contingencies that cause overloads, along with a comparison of facility loadings expressed both in MVA and in percent on Rate C without and with the proposed projects.

A detailed set of AC power flow results showing facilities loaded above 100% of Rate A with TDF greater than 3% are given in Appendix C.2.

The results of the contingency analysis were consolidated in Table 6-6 to show the most limiting overloads. Interconnection related SAFs are shown in Table 6-7 and described in detail below.

For each facility, the mitigation requirements are presented for a 50 MW interconnection by the MPC01200 customer alone, and for a 100 MW combined interconnection by the MPC01200 and MPC01900 customers. Mitigation requirements for MPC01200 are based on the anticipated loadings for 50 MW of interconnection calculated using the TDFs presented in the Table 6-7.

Distinction is made between NERC Category B and C events in this section, because mitigation requirements may differ between the two types of event.

- <u>Sheyenne – Audubon 230kV line</u>
  - As described in Section 6.1, the existing Maple River Wind projects have an upgrade obligation on this facility. The facility upgrade has not yet been completed. On an interim basis, dynamic ratings are being applied based on wind speed and ambient temperature. Final upgrades are scheduled to be in service in 2014.
  - MPC01200 (50 MW): A maximum post-contingent flow of 372 MVA for Category B events, 392 MVA for Category C events, is anticipated in the summer off-peak case based on the TDFs. The proposed project is required to mitigate this overload.
  - MPC01200/01900 (100 MW): A maximum post-contingent flow of 378 MVA for Category B events, 398 MVA for Category C events,

was observed in the summer off-peak case. The proposed projects are required to mitigate this overload.

- Maple River – Sheyenne 230 kV line
  - This facility was upgraded in 2010. Following the upgrade, the summer emergency rating is 505 MVA.
  - MPC01200 (50 MW): A maximum post-contingent flow of 504 MVA is anticipated in the summer off-peak case based on the TDFs. This is lower than the new emergency rating, so no further upgrade is required.
  - MPC01200/01900 (100 MW): A maximum post-contingent flow of 527 MVA was observed in the summer off-peak case. This is higher than the emergency rating will be following the upgrades that are presently planned. The proposed projects are required to mitigate this overload.
- Maple River - Red River 115 kV line
  - MPC01200 (50 MW): A maximum post-contingent flow of 334 MVA following Category C events is anticipated in the summer off-peak case based on the TDFs. No upgrade is required.
  - MPC01200/01900 (100 MW): A maximum post-contingent flow of 348 MVA following Category C events was observed in the summer off-peak case. The proposed projects are required to mitigate this overload. No violations were observed following Category B events.
- Red River – Cass County 115 kV line:
  - This facility became overloaded in the pre- and post-project cases above its emergency rating of 199MVA following the Maple River – Sheyenne / Maple River – Frontier 230 kV double-contingency, MRV-SHY-FRN. A load-serving study is presently under way for the Fargo area, which is expected to address this pre-project facility overload.
  - MPC01200 (50 MW): A maximum post-contingent flow of 245 MVA is anticipated following Category C events in the summer off-peak case based on the TDFs. The proposed project is required to mitigate this overload.
  - MPC01200/01900 (100 MW): A maximum post-contingent flow of 256 MVA following Category C events was observed in the summer off-peak case. The proposed projects are required to mitigate this overload. No violations were observed following Category B events.
- Frontier – Wahpeton 230 kV line:

- Existing generation projects have an upgrade obligation on this facility, with an anticipated final emergency rating of 327 MVA. The facility upgrade has not yet been completed. A SPS is being used on an interim basis. The final upgrade schedule has not been determined.
- MPC01200 (50 MW): A maximum post-contingent flow of 337 MVA is anticipated in the summer off-peak case based on the TDFs. The proposed project is required to mitigate this overload.
- MPC01200/01900 (100 MW): A maximum post-contingent flow of 345 MVA was observed in the summer off-peak case. The proposed projects are required to mitigate this overload.

- Maple River – Frontier 230 kV line:
  - Existing generation projects have an upgrade obligation on this facility, with an anticipated final emergency rating of 359 MVA. The facility upgrade has not yet been completed. A SPS is being used on an interim basis. The final upgrade schedule has not been determined.
  - MPC01200 (50 MW): A maximum post-contingent flow of 370 MVA is anticipated in the summer off-peak case based on the TDFs. The proposed project is required to mitigate this overload.
  - MPC01200/01900 (100 MW): A maximum post-contingent flow of 379 MVA was observed in the summer off-peak case. The proposed projects are required to mitigate this overload.
- Maple River 230/115 Transformer #5 and #6:
  - Initial results showed no overload; however, due a rating discrepancy the summer emergency rating was reduced to 215 MVA which is violated by the Maple River – Sheyenne / Maple River – Frontier 230 kV double-contingency flow, MRV-SHY-FRN. A load-serving study is presently under way for the Fargo area, which is expected to address this pre-project facility overload.
  - MPC01200 (50 MW): A maximum post-contingent flow of 207 MVA is anticipated following Category C events in the summer peak case based on power flow analysis. No upgrade is required.
  - MPC01200/01900 (100 MW): A maximum post-contingent flow of 217 MVA following Category C events was observed in the summer peak case. The proposed projects are required to mitigate this overload. No violations were observed following Category B events.

Analysis of post-contingency voltages showed significant impacts on the Maple River 345 kV bus in the post-project winter peak case following the 230 kV double circuit contingency, MRV-SHY-FRN, which is a NERC Category C event. The pre- and post-project voltages are 0.9224 pu and 0.8997 pu,

whereas the criteria is 0.92 pu. The post-project voltage considering only MPC01200 (50 MW) is 0.9203 pu; therefore, no mitigation is required for the first 50 MW of the project. The results are also shown in Table 6-8. The voltage violation for the full 100 MW project will be addressed based on discussions with Otter Tail Power.

Note that the voltage at the Maple River 345 kV bus is highly contingent upon the tap settings of the Maple River 230/115 kV transformers. Several solution methods (Full Newton-Raphson and fixed slope decoupled Newton-Raphson, with Newton tolerances of 0.1 and 1.0) resulted in the same Maple River 345 kV bus voltage of 0.9203 following the MRV-SHY-FRN contingency with a 50 MW project addition.

6.3 Constrained Interface Analysis

The purpose of this task was to determine if the proposed MPC01200 and MPC01900 projects would adversely impact the regional constrained interfaces (PTDF and OTDF interfaces) of the MAPP and MISO systems. The emphasis here was not on the actual value of flows through those flowgates, but instead on the impact the proposed projects would have on those flowgates. Thus the results are less dependent on the assumptions used in developing the base cases, and more a consequence of the network topology between the proposed projects and the assumed sink (Cincinnati area generation).

The analysis was run on the pre- and post-project summer peak cases developed in this study (cases 003-sp12aa and b17-sp12aa) using the DFCALC program included in the 5/1/2010 NMORWG package. Results are attached in Appendix C.3. The constrained interfaces and flowgates evaluated in this analysis are based on definition file “ties-NMOR-pkg2010_sp10.txt”. Flows on some of the remote flowgates could not be monitored due to topology differences between the case and the interface definitions. These flowgates are remote from the area of interest and no further effort was made to reconcile these differences. See Appendix C.3 for a list of errors.

Impacted interfaces[4] based on the MAPP DRS Criteria of 5% PTDF and 3% OTDF are listed in Table 6-9. This table shows the interface impacts for the injection of 100 MW from the proposed wind farms to the Cincinnati area generation area. These impacts are for informational purposes only to identify potential flowgate issues for the requested delivery component of the transmission. Mitigation may be required if it is determined that there is insufficient or no available transfer capability (ATC) on the affected constrained interfaces. This is an issue that should be addressed in the delivery analysis.

[4] As per Attachment A of reference [2], the minimum PTDF threshold for MAPP PTDF Interfaces is 5% and the minimum MW impact threshold is 1 MW. PTDF Interfaces that have PTDFs >= 5% -and- a MW impact >= minimum MW impact threshold are considered significantly impacted.

For OTDF Interfaces, the minimum OTDF threshold is 3% and the minimum impact threshold is 1 MW. OTDF Interfaces that have OTDFs >= 3% -and- a MW impact >= minimum MW impact threshold are considered significantly impacted.

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Table 6-1: Significantly Affected Facilities – System Intact Conditions

(a) 2012 Summer Peak

MONITORED ELEMENT							RATEA	RATEB	RATEC	PRE-PROJECT		POST-PROJECT		TDF
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	MVA	MVA	MVA	MVA	% RATEA	MVA	%RATEA	%
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	266.2	102.8	280.6	108.6	14.4

(b) 2012 Summer Off-Peak

MONITORED ELEMENT							RATEA	RATEB	RATEC	PRE-PROJECT		POST-PROJECT		TDF
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	MVA	MVA	MVA	MVA	% RATEA	MVA	%RATEA	%
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	298.0	115.6	309.3	120.3	11.3
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	280.9	105.9	297.3	112.5	16.4

Table 6-2: Significantly Affected Facilities – System Intact Conditions Consolidated Interconnection Related

MONITORED ELEMENT							RATEA	RATEB	RATEC	PRE-PROJECT		POST-PROJECT		TDF	CASE
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	CKT	MVA	MVA	MVA	MVA	% RATEA	MVA	% RATEA	%	
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	298.0	115.6	309.3	120.3	11.3	Su Op
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	280.9	105.9	297.3	112.5	16.4	Su Op

Table 6-3: Significantly Affected Facilities – Contingency Case Conditions
2012 Summer Peak

MONITORED ELEMENT							RATEA	RATEB	RATEC	CONTINGENCY	PRE-PROJECT		POST-PROJECT		TDF
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	MVA	MVA	MVA		MVA	% RATEC	MVA	% RATEC	%
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	610 1	335.0	117.7	353.9	124.6	18.9
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	334.2	117.5	350.7	123.6	16.5
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	309.5	108.2	316.8	115.3	7.3
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63051 HENNING4 230 - 63331 FERGSFL4 230 ckt 1	297.8	108.6	311.7	114.4	13.9
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66754 MAPLE R4 230 - 66758 WINGER 4 230 ckt 1	293.8	103.0	310.8	109.3	17.0
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66750 FRONTIER 230 - 63329 WAHPETN4 230 ckt 1	301.4	105.4	309.5	112.4	8.1
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66758 WINGER 4 230 - 63345 WILTON 4 230 ckt 1	291.0	102.1	305.9	107.6	14.9
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	WINGER Y	278.2	97.2	292.9	102.8	14.7
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66758 WINGER 4 230 - 63187 WINGER Y 230 ckt 1	278.2	97.2	292.9	102.8	14.7
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	412.6	94.2	464.8	106.5	52.2
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	610 1	401.5	92.0	453.9	104.5	52.4
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66750 FRONTIER 230 - 63329 WAHPETN4 230 ckt 1	394.3	90.0	446.5	102.3	52.2
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	401.1	92.1	444.9	102.6	43.8
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66754 MAPLE R4 230 - 66758 WINGER 4 230 ckt 1	387.8	88.9	436.8	100.5	49.0
60137	REDRIVR7	115	60349	CASS TP7	115	1	191.0	191.0	199.0	MRV-SHY-FRN	187.1	93.2	213.0	106.2	25.9
61652	BRAINRD7	115	61653	RIVERTN7	115	1	90.0	90.0	99.0	61612 RIVERTN4 230 - 61617 MUDLAKE4 230 ckt 1	114.8	111.5	118.9	115.9	4.1
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	540	172.0	128.7	177.4	133.0	5.4
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	63336 AUDUBON4 230 - 63053 HUBBARD4 230 ckt 1	170.7	127.8	176.2	132.1	5.5
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	164.2	123.2	169.1	127.1	4.9
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	MRV-SHY-FRN	156.9	117.8	162.7	122.5	5.8
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	610 1	146.3	109.4	150.6	112.7	4.3
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	63051 HENNING4 230 - 63331 FERGSFL4 230 ckt 1	146.8	109.9	150.6	112.9	3.8
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	146.2	109.4	150.0	112.4	3.8
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	141.6	105.6	145.8	109.0	4.2
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	66754 MAPLE R4 230 - 60133 SHEYNNE4 230 ckt 1	141.4	105.9	145.5	109.2	4.1
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	66750 FRONTIER 230 - 63329 WAHPETN4 230 ckt 1	140.0	104.5	144.3	107.8	4.3
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	66758 WINGER 4 230 - 63187 WINGER Y 230 ckt 1	134.2	99.5	137.6	102.2	3.4
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	WINGER Y	134.2	99.5	137.6	102.2	3.4
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	67503 DORSEY 4 230 - 67574 PORTSOU4 230 ckt 1	132.0	98.5	135.5	101.2	3.5
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	105 01C.5	131.2	97.8	134.6	100.5	3.4
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	63336 AUDUBON4 230 - 63202 AUDUBONY 230 ckt 1	130.8	97.5	134.0	100.1	3.2
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63329 WAHPETN4 230 - 63327 HANKSON4 230 ckt 1	270.2	102.3	281.6	107.9	11.4
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	610 2	268.2	102.4	281.5	107.9	13.3
66754	MAPLE R4	230	60136	MAPLE R7	230	5	187	187	215	MRV-SHY-FRN	199.2	92.7	217.4	101.1	18.2
66754	MAPLE R4	230	60136	MAPLE R7	230	6	187	187	215	MRV-SHY-FRN	199.2	92.7	217.4	101.1	18.2

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Table 6-4: Significantly Affected Facilities – Contingency Case Conditions
2012 Winter Peak

MONITORED ELEMENT							RATEA	RATEB	RATEC	CONTINGENCY	PRE-PROJECT		POST-PROJECT		TDF
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	MVA	MVA	MVA		MVA	%RATEC	MVA	%RATEC	%
63187	WINGER Y	230	63238	WINGER 7	115	1	140.0	140.0	175.0	66758 WINGER 4 230 - 63345 WILTON 4 230 ckt 1	182.40	104.24	186.70	106.72	4.30
63187	WINGER Y	230	66758	WINGER 4	230	1	140.0	140.0	175.0	66758 WINGER 4 230 - 63345 WILTON 4 230 ckt 1	182.40	104.24	186.70	106.72	4.30

Table 6-5: Significantly Affected Facilities – Contingency Case Conditions
2012 Summer Off-Peak

MONITORED ELEMENT							RATEA	RATEB	RATEC	CONTINGENCY	PRE-PROJECT		POST-PROJECT		TDF
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	MVA	MVA	MVA		MVA	% RATEC	MVA	% RATEC	%
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	610 1	385.8	136.2	397.8	141.7	12.0
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	366.1	129.4	378.4	134.4	12.3
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	355.8	130.7	367.2	136.3	11.4
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66750 FRONTIER 230 - 63329 WAHPETN4 230 ckt 1	348.5	127.6	360.2	133.0	11.7
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63345 WILTON 4 230 - 66758 WINGER 4 230 ckt 1	324.4	114.4	334.8	118.6	10.4
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63051 HENNING4 230 - 63331 FERGSFL4 230 ckt 1	322.7	118.2	332.3	122.5	9.6
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66754 MAPLE R4 230 - 66758 WINGER 4 230 ckt 1	314.6	110.9	327.5	115.8	12.9
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66550 GRANITF4 230 - 66554 MORRIS 4 230 ckt 1	311.0	109.0	321.3	113.1	10.3
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66758 WINGER 4 230 - 63187 WINGER Y 230 ckt 1	308.5	108.4	320.3	112.8	11.8
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	WINGER Y	308.5	108.4	320.3	112.8	11.8
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	MRV-SHY-FRN	305.2	107.5	313.5	110.9	8.3
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	66758 WINGER 4 230 - 66755 PRAIRIE4 230 ckt 1	299.3	105.8	310.3	110.0	11.0
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	MAPLER2Y	295.7	104.1	307.1	108.4	11.4
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	MAPLER1Y	295.7	104.1	307.1	108.4	11.4
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63190 MAPLER2Y 345 - 66754 MAPLE R4 230 ckt 1	295.7	104.1	307.1	108.4	11.4
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63189 MAPLER1Y 345 - 66754 MAPLE R4 230 ckt 1	295.7	104.1	307.1	108.4	11.4
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	105 01C.5	292.6	102.9	303.9	107.1	11.3
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63336 AUDUBON4 230 - 63136 AUDUBON9 41.6 ckt 1	292.0	102.7	303.0	106.9	11.0
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	60133 SHEYNNE4 230 - 66435 FARGO 4 230 ckt 1	284.8	101.7	298.4	107.5	13.6
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63336 AUDUBON4 230 - 63202 AUDUBONY 230 ckt 1	277.2	97.4	287.2	101.2	10.0
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	480.4	110.1	527.3	121.8	46.9
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	610 1	466.1	107.1	511.3	118.6	45.2
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66750 FRONTIER 230 - 63329 WAHPETN4 230 ckt 1	461.5	105.8	508.5	117.1	47.0
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	400.0	92.1	440.8	102.1	40.8
60137	REDRIVR7	115	60349	CASS TP7	115	1	191.0	191.0	199.0	MRV-SHY-FRN	234.4	116.9	256.4	128.0	22.0
63223	HOOT LK7	115	63231	FERGSFL7	115	1	96.0	96.0	105.6	63051 HENNING4 230 - 63331 FERGSFL4 230 ckt 1	111.0	101.2	114.7	104.8	3.7
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	63336 AUDUBON4 230 - 63053 HUBBARD4 230 ckt 1	169.9	130.9	173.3	133.8	3.4
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	328.6	125.0	345.1	132.1	16.5
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	66754 MAPLE R4 230 - 60133 SHEYNNE4 230 ckt 1	299.5	115.8	319.0	124.7	19.5
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	63336 AUDUBON4 230 - 63053 HUBBARD4 230 ckt 1	288.5	109.8	304.3	116.4	15.8
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	63329 WAHPETN4 230 - 63327 HANKSON4 230 ckt 1	278.8	106.5	288.7	111.1	9.9
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	66754 MAPLE R4 230 - 66758 WINGER 4 230 ckt 1	259.3	98.6	276.2	105.5	16.9
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	66550 GRANITF4 230 - 66554 MORRIS 4 230 ckt 1	259.7	98.3	274.4	104.5	14.7
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	63345 WILTON 4 230 - 66758 WINGER 4 230 ckt 1	257.2	97.8	271.8	104.0	14.6
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	AUDUBON T1	254.9	96.7	270.2	103.0	15.3
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	63336 AUDUBON4 230 - 63202 AUDUBONY 230 ckt 1	252.9	96.0	268.1	102.2	15.2
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	66758 WINGER 4 230 - 63187 WINGER Y 230 ckt 1	251.9	95.4	266.9	101.6	15.0
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	WINGER Y	251.9	95.5	266.9	101.6	15.0
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	63336 AUDUBON4 230 - 63136 AUDUBON9 41.6 ckt 1	248.4	94.3	263.3	100.3	14.9
66554	MORRIS 4	230	66555	MORRIS 7	115	1	100.0	100.0	125.0	66550 GRANITF4 230 - 66554 MORRIS 4 230 ckt 1	131.9	105.5	136.0	108.8	4.1
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	361.2	137.4	379.1	145.2	17.9
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	66754 MAPLE R4 230 - 60133 SHEYNNE4 230 ckt 1	334.5	128.4	355.6	138.0	21.1
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63336 AUDUBON4 230 - 63053 HUBBARD4 230 ckt 1	321.1	122.2	338.3	129.4	17.2
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63329 WAHPETN4 230 - 63327 HANKSON4 230 ckt 1	311.4	119.0	322.7	124.2	11.3

ABB

MONITORED ELEMENT							RATEA	RATEB	RATEC	CONTINGENCY	PRE-PROJECT		POST-PROJECT		TDF
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	MVA	MVA	MVA		MVA	% RATEC	MVA	% RATEC	%
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	66754 MAPLE R4 230 - 66758 WINGER 4 230 ckt 1	293.8	111.0	312.4	118.5	18.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	66550 GRANITF4 230 - 66554 MORRIS 4 230 ckt 1	294.3	110.7	310.7	117.4	16.4
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63345 WILTON 4 230 - 66758 WINGER 4 230 ckt 1	291.7	110.2	308.0	117.0	16.3
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	AUDUBON T1	289.5	109.1	306.5	115.9	17.0
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63336 AUDUBON4 230 - 63202 AUDUBONY 230 ckt 1	287.5	108.4	304.3	115.1	16.8
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	WINGER Y	286.4	107.8	303.0	114.5	16.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	66758 WINGER 4 230 - 63187 WINGER Y 230 ckt 1	286.4	107.8	303.0	114.5	16.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63336 AUDUBON4 230 - 63136 AUDUBON9 41.6 ckt 1	282.8	106.6	299.3	113.3	16.5
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	105 01C.5	277.2	104.5	293.7	111.1	16.5
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	MAPLER2Y	277.0	104.6	293.6	111.2	16.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	MAPLER1Y	277.0	104.6	293.6	111.2	16.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63190 MAPLER2Y 345 - 66754 MAPLE R4 230 ckt 1	277.0	104.6	293.6	111.2	16.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	63189 MAPLER1Y 345 - 66754 MAPLE R4 230 ckt 1	277.0	104.6	293.6	111.2	16.6
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 66435 FARGO 4 230 ckt 1	268.2	102.4	289.1	111.4	20.9
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	66758 WINGER 4 230 - 66755 PRAIRIE4 230 ckt 1	269.9	102.4	287.0	109.3	17.1
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	110 2	268.4	102.4	284.6	109.3	16.2
60136	MAPLE R7	115	60137	REDRIVR7	115	1	310.0	310.0	341.0	MRV-SHY-FRN	320.1	91.9	348.3	99.7	28.2

Table 6-6: Significantly Affected Facilities – Contingency Case Conditions
Consolidated List of Most Limiting Overloads

MONITORED ELEMENT							RATE A	RATE B	RATE C	CONTINGENCY	PRE-PROJECT		POST-PROJECT		TDF	CASE
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	CKT	MVA	MVA	MVA		MVA	% RATEC	MVA	% RATEC	%	
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	610 1	385.8	136.2	397.8	141.7	12.0	Su Op
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	366.1	129.4	378.4	134.4	12.3	Su Op
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	480.4	110.1	527.3	121.8	46.9	Su Op
60137	REDRIVR7	115	60349	CASS TP7	115	1	191.0	191.0	199.0	MRV-SHY-FRN	234.4	116.9	256.4	128.0	22.0	Su Op
61652	BRAINRD7	115	61653	RIVERTN7	115	1	90.0	90.0	99.0	61612 RIVERTN4 230 - 61617 MUDLAKE4 230 ckt 1	114.8	111.5	118.9	115.9	4.1	Su Pk
63187	WINGER Y	230	66758	WINGER 4	230	1	140.0	140.0	175.0	66758 WINGER 4 230 - 63345 WILTON 4 230 ckt 1	182.4	104.2	186.7	106.7	4.3	Wi Pk
63223	HOOT LK7	115	63231	FERGSFL7	115	1	96.0	96.0	105.6	63051 HENNING4 230 - 63331 FERGSFL4 230 ckt 1	111.0	101.2	114.7	104.8	3.7	Su Op
63245	WILTON 7	115	63246	BEMIDJI7	115	1	120.0	157.0	132.0	540	172.0	128.7	177.4	133.0	5.4	Su Pk
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	328.6	125.0	345.1	132.1	16.5	Su Op
66554	MORRIS 4	230	66555	MORRIS 7	115	1	100.0	100.0	125.0	66550 GRANITF4 230 - 66554 MORRIS 4 230 ckt 1	131.9	105.5	136.0	108.8	4.1	Su Op
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	361.2	137.4	379.1	145.2	17.9	Su Op
60136	MAPLE R7	115	60137	REDRIVR7	115	1	310.0	310.0	341.0	MRV-SHY-FRN	320.1	91.9	348.3	99.7	28.2	Su Op
66754	MAPLE R4	230	60136	MAPLE R7	230	5	187	187	215	MRV-SHY-FRN	199.2	92.7	217.4	101.1	18.2	Su Pk
66754	MAPLE R4	230	60136	MAPLE R7	230	6	187	187	215	MRV-SHY-FRN	199.2	92.7	217.4	101.1	18.2	Su Pk

Table 6-7: Significantly Affected Facilities – Contingency Case Conditions
Consolidated Interconnection Related

MONITORED ELEMENT							RATE A	RATE B	RATE C	CONTINGENCY	PRE-PROJECT		POST-PROJECT		TDF	CASE
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	CKT	MVA	MVA	MVA		MVA	% RATEC	MVA	% RATEC	%	
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	610 1	385.8	136.2	397.8	141.7	12.0	Su Op
60133	SHEYNNE4	230	63336	AUDUBON4	230	1	254.0	254.0	280.0	63329 WAHPETN4 230 - 63331 FERGSFL4 230 ckt 1	366.1	129.4	378.4	134.4	12.3	Su Op
60133	SHEYNNE4	230	66754	MAPLE R4	230	1	391.0	391.0	430.0	66754 MAPLE R4 230 - 66750 FRONTIER 230 ckt 1	480.4	110.1	527.3	121.8	46.9	Su Op
60136	MAPLE R7	115	60137	REDRIVR7	115	1	310.0	310.0	341.0	MRV-SHY-FRN	320.1	91.9	348.3	99.7	28.2	Su Op
60137	REDRIVR7	115	60349	CASS TP7	115	1	191.0	191.0	199.0	MRV-SHY-FRN	234.4	116.9	256.4	128.0	22.0	Su Op
63329	WAHPETN4	230	66750	FRONTIER	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	328.6	125.0	345.1	132.1	16.5	Su Op
66750	FRONTIER	230	66754	MAPLE R4	230	1	262.0	262.0	262.0	60133 SHEYNNE4 230 - 63336 AUDUBON4 230 ckt 1	361.2	137.4	379.1	145.2	17.9	Su Op

ABB

Table 6-8: Significantly Affected Bus Voltages – Contingency Case Conditions

(a) 2012 Winter Peak

Bus			Contingency	Voltage (pu)		
#	Name	kV		Pre-project	Post-project	Impact
66792	MAPLE R3	345	MRV-SHY-FRN	0.9224	0.8992	0.0232

Table 6-9: List of Impacted Interfaces

INTERFACE	FLOW (MW)			TDF
	PRE-PROJECT	POST-PROJECT	CHANGE	
PTDF INTERFACES				
EAUARP__PTDF	149.9	160	10.1	10.1%
PPRZIO__PTDF	216.6	226.9	10.3	10.3%
NDEX	1667.6	1755.6	88.0	88.0%
GRIS_LNC	401.7	407.9	6.2	6.2%
COOPER_S	156.2	170.6	14.4	14.4%
PR_ISL_BYRON	-57.7	-44.2	13.5	13.5%
FTCAL_S	268.1	277.6	9.5	9.5%
AHDSTL__PTDF	343.9	350.7	6.8	6.8%
MWEX____PTDF	739.4	756.6	17.2	17.2%
OTDF INTERFACES				
LEEBYRNELELC	564.4	573.4	9	9.0%
CDVNELQUA471	678	692.4	14.4	14.4%
QUDCOR471QUD	306.7	311.4	4.6	4.6%
QUDCORNEL471	306.7	311.4	4.6	4.6%
ADNZIOPLPZIO	38.8	49.4	10.5	10.5%
EAUARPWMPPAD	181.2	191.1	9.9	9.9%
EAUARPPRIBYR	143.6	155.2	11.6	11.6%
QUA471CDVNEL	681.7	696.2	14.4	14.4%
QUACDVQUA471	962.3	981.9	19.6	19.6%
CHESILNELELC	1047.3	1056.9	9.6	9.6%
NELELCCHESIL	855.4	866.9	11.4	11.4%
PLPZIOCHESIL	337.4	348.7	11.3	11.3%
PLPZIOZIOARC	165.9	180.2	14.3	14.3%
NAPFOXNAPKEW	-918.7	-911.6	7.1	7.1%
WRWWRNWRWNAP	-106.2	-99.9	6.3	6.3%
SJHALKNAIASC	295	305.6	10.6	10.6%
IASCLKNASJHA	355.9	366	10.1	10.1%
BYRMLFBYRPVV	73.8	79.3	5.6	5.6%
BYRMLFPVVADM	175	178.6	3.6	3.6%

7. STABILITY ANALYSIS

7.1 Stability Methodology and Fault Definitions

System stability was evaluated by running regional faults as well as faults local to the Maple River region.

The faults evaluated were similar to those in the Maple River Interconnection study [3]. Table 7-1 and Table 7-2 summarize the regional and local faults respectively. The following comments are in order.

- Backup clearing time for all local faults was increased by 1 cycle compared to Maple River Interconnection study [3]. This was done to allow 9 ms for breaker failure relay processing and auxiliary delay and 7 ms for breaker failure lockout.
- Some faults from the Maple River Interconnection study [3] were renamed. Also, fault FD3 was not evaluated. Instead FDS was run which is the same as FD9 in the Maple River Interconnection study [3].

With the setup described above, pre- and post-project stability analyses were run. The following sections discuss results in greater detail.

7.2 Pre-project Performance

This section summarizes baseline stability performance, i.e. performance with MPC01200 and MPC01900 out-of-service. The power flow case used for this analysis was *006-so12aa.sav* and the snapshot used was *nmorwg08-pre-project.snp*.

All faults listed in Table 7-1 and Table 7-2 were run for baseline performance evaluation.

All regional and local faults resulted in acceptable system performance without any violations. Simulation summary tables for the faults are given in Appendix E.1 and plots for select simulations are shown in Appendix F.1.

7.3 Post-project Performance

This section summarizes stability performance with MPC01200 and MPC01900 in service. The power flow case used for this analysis was *c21-so12aa.sav* and the snapshot used was *nmorwg08-post-project.snp*.

All faults listed in Table 7-1 and Table 7-2 were run.

Transient voltage violations were observed for local area faults *asz* and *aws* during stability simulations. For fault *asz,* voltage in the vicinity of Pillsbury fell as low as 0.66 pu. For fault aws, voltage at Luverne 230 kV substation, where Ashtabula 2 is connected, dropped to 0.69 pu. The violations are shown in Table 7-3.

Simulation summary tables for the faults are given in Appendix E.2 and plots for select simulations are shown in Appendix F.2.

Mitigation of violations observed for faults *asz* and *aws* can be achieved by reducing the backup fault clearing time from 15 cycles to 14 cycles. The effect of reducing backup fault clearing time can be seen in Table 7-3.

Mitigation can be accomplished by replacing the backup breakers involved in the fault simulations. For fault *asz*, clearing time for breakers 61, 67, 5F1 and 5F2 needs to be reduced while for fault *aws*, breakers 63, 69, 5F6 and 5F7 are involved in backup clearing.

Alternatively, mitigation can be accomplished by replacement of the failed breakers in the fault simulations. Replacing breaker 64 for fault *asz* and breaker 66 for fault *aws* allows shorter breaker failure relay delay settings, which also achieves the desired reduction in clearing time. This is the recommended solution because it allows replacement of 2 breakers instead of 8. See Figure 7-1.

7.4 Sensitivity to Increased ND Load

As discussed in Section 4.3.4, the summer off-peak power flow cases for stability analysis were modeled to bring North Dakota load to about 70% of peak summer load. This necessitated dispatching Miles City DC at 150 MW west. A couple of sensitivity simulations were run with the Miles City DC tie restored to 150MW east. In the pre-project case, this increases ND load to 79.4% of summer peak while in the post-project case, this increases ND load to 80.6%. This was done to determine impact of higher ND load on performance of the worst regional fault, *ei2*. It was run for both pre- and post-project conditions. The corresponding power flow cases were called *007-so12aa.sav* and *c22-so12aa.sav*.

The sensitivity analysis showed acceptable performance without any violations. Simulation summary tables for the faults are given in Appendix E.3 and plots are shown in Appendix F.3.

7.5 Reduction in Backup Clearing Time

MPC requested a sensitivity analysis to determine whether the reduction in backup clearing time from 15 cycles to 14 cycles would be required prior to the in-service date of December 31, 2010 for MPC01200 or whether the upgrades could be deferred until the interconnection of MPC01900 in 2012. A sensitivity analysis was performed with MPC01200 online and project facilities corresponding to MPC01900 disconnected.

The sensitivity case developed for this analysis with MPC01900 turned off was called *c23-so12aa.sav.* Faults *asz* and *aws* were repeated with a breaker backup clearing time of 15 cycles.

This sensitivity analysis did not reveal any stability criteria violations. It was therefore concluded that faster breaker backup clearing time is required only when MPC01200 and MPC01900 are both in service with a combined output of 100 MW. The upgrades are not required for interconnection of MPC01200 in the near term with a size of 50 MW.

Table 7-1: Regional Fault List

Fault Name	Faulted Bus	Fault Type	Clearing Time (Cycles)	Initial Clearing	Backup Clearing (Cycles)	Backup Clearing
AG1	Leland Olds 345 kV	SLGBF	4	Leland Old - Ft Thompson 345 kV line	11	FLTD line
AG3	Leland Olds 345 kV	3-phase	4	Leland Old - Ft Thompson 345 kV line		
EI2	Coal Creek 230 kV	Fault	10	CU HVDC bipole	7	Coal Creek 1 & 2
EQ1	Coal Creek 230 kV	SLGBF	4.5	CU HVDC #1	11	Coal Creek #2
FDS	Square Butte 230 kV	3-phase	4	Square Butte - Stanton 230 kV line		
MAD	Dorsey 500 kV	3-phase	4	Dorsey - Forbes 500 kV line		
MQS	SherCo 345 kV	SLGBF	4	Sherco #3	9	SherCo - Benton Co
MTS	Monticello 345 kV	SLGBF	5	Monticello - Elm Creek 345 kV line	9	Monticello bus
NAD	Forbes 500 kV	3-phase	4	Forbes - Dorsey 500 kV line		100% DC reduction
NMZ	Chisago Co 500 kV	3-phase	4	Chisago Co - Forbes 500 kV line		100% DC reduction
PAS	Forbes 500 kV	SLGBF	4	Forbes - Dorsey 500 kV line	13	Forbes-Chisago Co
PCS	King 345 kV	SLGBF	4	King - Eau Claire 345 kV line	14	King-Chisago Co
PCT	King 345 kV	Trip		King - Eau Claire 345 kV line		
PYS	Prairie Island 345 kV	SLGBF	4	Prairie Island - Byron 345 kV line	14	Prairie Island 345/161 xfmr
PYT	Prairie Island 345 kV	Trip		Prairie Island - Byron 345 kV line		

Table 7-2: Local Fault List

Fault Name	Faulted Bus	Fault Type	Clearing Time (Cycles)	Initial Clearing	Backup Clearing (Cycles)	Backup Clearing	Fault Name in MRV Study
MF3	Maple River 230 kV	3-phase	5.0	Maple River-Frontier 230 kV line line			MF3
MPZ	Maple River 230 kV	3-phase	5.0	Maple River - Pillsbury 230 kV line			MP3
MS3	Maple River 230 kV	3-phase	5.0	Maple River-Sheyenne 230 kV line			MS3
MW3	Maple River 230 kV	3-phase	5.0	Maple River-Winger 230 kV line			MW3
SA3	Maple River 230 kV	3-phase	5.0	Sheyenne-Audubon 230 kV line			SA3
SF3	Maple River 230 kV	3-phase	5.0	Sheyenne-Fargo 230 kV line			SF3
MJZ	Maple River 345	3-phase	4.5	Maple River-Buffalo 345 kV line Buffalo-Jamestown 345 kV line Maple River 345/115 kV xfmrs Buffalo 345/115 kV line xfmr			MJZ
MWZ	Maple River 230 kV	3-phase	5.0	Maple River-Frontier 230 kV line Maple River-Sheyenne 230 kV line			MWZ
AFS	Maple River 230 kV	SLGBF	5.0	Maple River-Frontier 230 kV line	15.0	Maple River 230/115 xfmr 5	MFS
APZ	Maple River 230 kV	SLGBF	5.0	Maple River-Pillsbury 230 kV line	15.0	Maple River 230/115 xfmr 6	MPS
ASZ	Maple River 230 kV	SLGBF	5.0	Maple River-Sheyenne 230 kV line	15.0	Maple River 230/115 xfmr 5	MSS
AWS	Maple River 230 kV	SLGBF	5.0	Maple River-Winger 230 kV line	15.0	Maple River 230/115 xfmr 6	MWS
AJS	Maple River 345	SLGBF	4.5	Maple River-Buffalo 345 kV line Buffalo-Jamestown 345 kV line	13.5	Maple River 230/115 xfmr 5	MJS
ARS	Maple River 230 kV	SLGBF	5.0	Maple River-Winger 230 kV line	15.0	Maple River-Sheyenne 230 kV line	MRS
FSS	Fargo 230 kV	SLGBF	5.0	Fargo-Sheyenne 230 kV line	15.0	Fargo 230/115 xfmr Fargo-Jamestown 230 kV line #2 Fargo-Moorhead 230 kV line	FSS
FMS	Sheyenne 230 kV	SLGBF	5.0	Sheyenne-Maple River 230 kV line	15.0	Sheyenne-Audubon 230 kV line Sheyenne 230/115 xfmr	SMS
AQS	Maple River 230 kV	SLGBF	5.0	Sheyenne-Maple River 230 kV line	15.0	Maple River-Winger 230 kV line	Not run

Table 7-3: Dynamic Voltage Warnings for Stability Analysis

Fault	Fault Definition	Post-project Case c21-so12aa	Shorter bkr backup clearing time
ASZ	SLGBF AT MAPLE RIVER TRIP MPR-SHEYENNE LINE, MPR 230/115 Tx 5 MRV 230 bkr 64 stuck; open brk 61, 67, 5F1, 5F2 at backup clearing	66700 [PILLSBY4] 0.66 66701 [LUVERNE4] 0.66 66702 [ASHTABU4] 0.66 66738 [MPC1900] 0.66	66700 [PILLSBY4] 0.73 66701 [LUVERNE4] 0.73 66702 [ASHTABU4] 0.73 66738 [MPC1900] 0.73
AWS	SLGBF AT MAPLE RIVER TRIP MPR-WINGER LINE, MPR 230/115 Tx 6 MRV 230 bkr 66 stuck; open brk 63, 69, 5F6, 5F7 at backup clearing	66701 [LUVERNE4] 0.69	66701 [LUVERNE4] 0.77

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8. SHORT-CIRCUIT ANALYSIS

Short circuit calculations of fault currents were performed using the ASPEN program for the Maple River area. Single line-to-ground and three-phase fault currents were determined at multiple substations in the vicinity of Maple River. Short circuit currents without the fault current contribution from the MPC01200/01900 wind farms are tabulated as follows:

Table 8-1: Post-Project Short Circuit Currents near Maple River

BUS	Maximum Fault Current (MPC 1200/1900 Offline)		Maximum Fault Current (MPC 1200/1900 Online)		CB Rating
	1LG	3PH	1LG	3PH	
Maple River 230 kV	10845	9001	11029	9187	67 & 69 = 31.5 kA; all others = 37.5 kA
Sheyenne 230 kV	9619	8607	9727	8736	7F4 = 40 kA; all others = 31.5 kA
Frontier 230 kV	6185	6673	6233	6756	40 kA
Fargo 230 kV	8832	8181	8911	8283	382 & 782 = 13 kA; 182 = 31.5 kA; all others = 40 kA

A comparison of the post-project fault currents to the capability of the existing breakers at the local substations indicates that there is adequate interrupting capability following the addition of the new generation.

9. FACILITY UPGRADE COSTS

Refer to the Executive Summary for a good faith estimate of facility upgrade costs.

10. CONCLUSIONS

Refer to the Executive Summary for the Conclusions.

11. REFERENCES

[1] “MAPP Design Review Subcommittee Policies and Procedures”, Prepared by MAPP Design Review Subcommittee Members, Version 7.0, March 2009.

[2] “MAPP Members Reliability Criteria and Study Procedures Manual”, Prepared by MAPP, Version 1.4, April 2009.

[3] “Maple River Wind Generation Interconnection System Impact Study”. Prepared by Excel Engineering, Inc., May 10, 2008

[4] "Glacier Ridge Wind Farm Feasibility Study", Prepared by TranServ International, Inc., March 18, 2009.

[5] "PSS®E Wind Modeling Package for GE1.5/3.6/2.5 MW Wind Turbines – User Guide”, Issue 5.1.0, Prepared by Siemens Power Technologies, Inc., June 2009.

[6] ”Model User Manual – PSS/E Model for Vestas V90 1.8MW VCUS 60Hz”, Version 6.0.2 (Sales Release), Vestas Wind Systems A/S, Revision No. 0, 2008-03-05.