ELECTRIC SYSTEMS CONSULTING

DAKOTAS WIND TRANSMISSION STUDY

TASKS 3 and 4
System Impact Study and
Transfer Capability Study

TASKS 3 AND 4 FINAL REPORT

REPORT NO. 2005-10977-2 R3
June 28, 2005
(Revised October 19, 2005)

ABB Electric Systems Consulting
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ABB Electric Systems Consulting **Technical Report**

Dakotas Wind Transmission Study	No. 2002-10977-2 R3		
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Executive Summary

ABB Inc. was contracted to perform a Dakotas Wind Transmission Study for investigating transmission capacity for up to 500 MW of wind generation to be located at each of seven proposed sites. This report documents the status of results for Tasks 3 and 4 of the Dakotas Wind Transmission Study.

The seven wind generation sites in North and South Dakota would be connected to the following substations and buses: Garrison 230 kV, Pickert 230 kV, Ellendale (a new 345-kV tap on the Leland Olds-Groton line), New Underwood 230 kV, Mission 115 kV, Ft. Thompson 345 kV, and White 345 kV. These sites are shown in Figure 1-1 in Section 1 of this report.

<u>Objectives</u>

Task 3 is the interconnection studies for each of the seven sites. This task determined the local system requirements to connect the proposed wind generation to the existing system and identified any local enhancements needed to accommodate the new generation. Task 4 analyzes the transfer capability to ship power from the wind sites to markets. Regional stability performance and limitations were also analyzed and where limitations existed the study evaluated the potential for some transmission technologies such as FACTS to increase the transfer of power from the Dakotas.

<u>System Criteria</u>

In the steady-state analysis, Rate B in the database was used for determining the transmission branch loadings. Rate B for transmission lines is the continuous rating of the line without considering limitations of substation equipment. In the stability analysis, 6-cycle faults were simulated for local faults unless the faults were on the 345-kV system and the results were unstable. For those cases the simulations were rerun with 4-cycle faults. Regional stability was analyzed using the MAPP UIP package and modeled for summer off-peak 2003 condition with maximum simultaneous NDEX (≈1950MW), MHEX (≈2175MW), and MWSI (≈1480MW) transfers with additional cases modifying the transfers as described in the report.

Conclusions

Task 1 results indicated that for 500 MW installed at any one of the seven sites, there was non-firm transmission capacity across the critical interfaces to transfer almost all of the wind generated energy. Tasks 2 and 3 show some limitations in this non-firm capacity. Due to thermal limits, stability limits, and security considerations some of the sites are limited to less than 500 MW without additional system enhancements.

In the steady-state analysis for normal system conditions and for the N-1 contingency analysis, there were only a few overloaded transmission lines. For N-1 contingencies there were two outages. The steady-state analysis is summarized as follows:

- The Mission site can only support 250 MW with the existing transmission. Two new 230-kV lines will support 500 MW out of the Mission site.
- There are two sites with the normal system conditions which load one line to between 100-105%
- There are only a few contingencies that overload transmission lines.
- Most of the transformer overloads are also in the base case except for the New Underwood site which overloads the existing transformer at New Underwood
- Most of the wind sites results in a few low voltages in central North Dakota that will need some shunt capacitor support to maintain the system voltage.

All of the steady-state study results are summarized in the table below. Those cases with one or two lines loaded between 100 and 110% were listed as OK in the table. Alternatives for relieving these overloads are addressed in the Task 2 report.

Summary of Steady State Results for the Task 3 and Task 4 Analysis

The nomenclature for the case titles is explained on Page 2 of Section 1.

Case Name	System Intact Analysis	(N-1) Contingency Analysis	Constrained Interface Analysis	Transfer Capability Analysis
Case10	Ok	Ok	Ok	Ok
Case11	--	--	--	Ok
Case12	--	--	--	Ok
Case13	--	--	--	Ok
Case14	--	--	--	Ok
Case20	Ok	Ok	Ok	Ok
Case21	--	--	--	Ok
Case22	--	--	--	Ok
Case23	--	--	--	Ok
Case24	--	--	--	Ok
Case30	Ok	Ok	Ok	Ok
Case31	--	--	--	Ok
Case32	--	--	--	Ok
Case33	--	--	--	Ok
Case34	--	--	--	Ok
Case40	Ok	Ok	Ok	Ok
Case41	--	--	--	Ok
Case42	--	--	--	Ok
Case43	--	--	--	Ok
Case44	--	--	--	Ok
Case50	Failed*	Failed*	Ok	Failed*
Case51	Failed*	Failed*	Ok	Failed*
Case52	Ok	Ok	Ok	Ok
Case53	--	--	--	Ok
Case54	--	--	--	Ok
Case60	Ok	Ok	Ok	Ok
Case61	--	--	--	Ok
Case62	--	--	--	Ok
Case63	--	--	--	Ok
Case64	--	--	--	Ok
Case70	Ok	Ok	Ok	Ok
Case71	--	--	--	Ok
Case72	--	--	--	Ok
Case73	--	--	--	Ok
Case74	--	--	--	Ok
Case8	Ok	Ok	Ok	Ok

* With two new 230-kV lines, the Mission site will accomodate 500 MW
** Rapid City was tripped for the local faults at New Underwood

All sites provided good performance for the local stability analysis.

For the regional stability study, non-firm and firm transfer cases were set up based on the exports on the NDEX interface. Non-firm assumes that NDEX is 1450 MW with 500 MW of non-firm transfer capacity available on the systems. Firm assumes that NDEX is 1950 MW before 500 MW of wind generation is added.

The following are the conclusions for the regional stability analysis on the non-firm transfer cases:

For the eight scenarios using non-firm transmission, NDEX was readjusted to maintain a 1450 MW export leaving 500 MW for non-firm transfers. The maximum wind generation of 500 MW was added to a wind site and the regional stability simulations were run. The results of the regional stability are as listed below:

Garrison 230 kV	250 MW
Pickert 230 kV	500 MW
Ellendale 345 kV	250 MW
New Underwood 230 kV	500 MW
Mission 115 kV	375 MW
Ft. Thompson 345 kV	500 MW
White 345 kV	500 MW
Scenario 8, All Sites	500 MW

The following are the conclusions for the regional stability analysis on the firm transfer cases:

These are the results with NDEX at 1950 MW for the regional stability cases without any enhancements to the network and then the new wind generation is added for each site evaluation. If the wind generation is added to the existing firm commitments, the following generation can be added at each site without system enhancement to improve inter-regional transfers.

Garrison 230 kV	50 MW
Pickert 230 kV	50 MW
Ellendale 345 kV	50 MW
New Underwood 230 kV	50 MW
Mission 115 kV	150 MW
Ft. Thompson 345 kV	50 MW
White 345 kV	250 MW

Series compensation of 35% of the line reactance in the Leland Olds-Groton 345-kV line, the Leland Olds-Ft. Thompson 345-kV line, and the Antelope Valley-Broadland 345-kV line for the non-firm and firm transfer cases will raise the stability interconnection capacity of each site as follows:

Results of 35% series compensation on non-firm transfer cases:

Garrison 230 kV	500 MW
Ellendale 345 kV	500 MW

Results of 35% series compensation on firm transfer cases:

New Underwood 230kV	150 MW
Mission 115kV	250 MW
Ft. Thompson 345kV	150 MW
White 345kV	375 MW
Case 8	500 MW

Series compensation of 50% of the line reactance in the Leland Olds-Groton 345-kV line, the Leland Olds-Ft. Thompson 345-kV line, and the Antelope Valley-Broadland 345-kV line was tested for two sites and will raise the interconnection capacity of the following two sites:

Results of 50% series compensation on firm transfer cases:

Ft. Thompson 345kV	250 MW
White 345kV	500 MW

The series capacitor compensation was only tested for improving the stability. A complete analysis of this technology needs to include steady-state contingency analysis, stability, and special studies such as sub-synchronous resonance (SSR). These cases demonstrate the improved performance due to additional technologies that can be implemented to help eliminate system constraints. Further fine-tuning is required for the above values to design actual values, based on site selection.

A system upgrade case was developed by adding a new 345-kv transmission line from Maple River to Benton County for all the interconnection sites except for the interconnection at Mission. The results of the stability cases are indicated below.

Results of New Maple River-Benton County 345-kV Line on firm transfer cases:

Garrison 230 kV	375 MW
Ellendale 345 kV	500 MW
White 345kV	500 MW

Two new 230-kV lines were modeled connecting Mission to the Oahe and Ft. Randal Substation. With these two new lines, the steady-state performance indicated that 500 MW of wind could be accommodated, but the stability limits for inter-regional stability remain the same as reported above.

For 500 MW of wind generation at Garrison, three SVCs of 200 MVArs each installed at Arrowhead, Riverton, and Granite Falls eliminate the under-voltage violations that occur. These voltage violations occur for fault "nbz" even in the Base Case without new wind generation. This fault is defined in Section 4.3 on page 38.

For 500 MW of wind generation at Garrison or Ellendale, one SVC of 200 MVAR installed at Groton eliminates the low voltage violations in the Groton area for faults "ei2" and "ag1". These faults are defined in Section 4.3 on page 38.

These cases demonstrate the improved performance due to additional technologies that can be implemented to help eliminate system constraints. Further fine-tuning is required for the above values to design actual values, based on site selection.

Additional sensitivity of new transmission lines on the firm transfer cases were performed by adding new transmission lines in the system to increase the power transfers. For NDEX set to 1950 MWs before the wind generation is connected, 375 MW of additional generation can be interconnected at Garrison and 500 MWs can be connected at the Ellendale and White sites without degrading the inter-regional transfers. Details of the new transmission lines and detailed stability results are described in section 4.3.4.10 of the report.

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1. INTRODUCTION

This report documents the status of results for Tasks 3 and 4 of the Dakotas Wind Transmission Study. Seven wind sites are being analyzed and from these seven sites eight scenarios have been developed. The scenarios are listed below.

Site 1: 500 MW at the Garrison 230-kV bus
Site 2: 500 MW at Pickert 230-kV bus
Site 3: 500 MW at a new substation on the Leland Olds-Groton 345-kV line near Ellendale
Site 4: 500 MW at the New Underwood 230-kV bus
Site 5: 500 MW at the Mission 115-kV bus (Without extensive upgrades to Ft. Randal this site will not accommodate 500 MW so a lower MW may be used)
Site 6: 500 MW at the Ft. Thompson 230-kV bus
Site 7: 500 MW at the White 345-kV bus
Site 8: 50 MW at each of the 4 previous sites in Scenarios 1 through 7 and 100 MW at 3 sites.

The locations of these seven sites are shown in Figure 1-1.

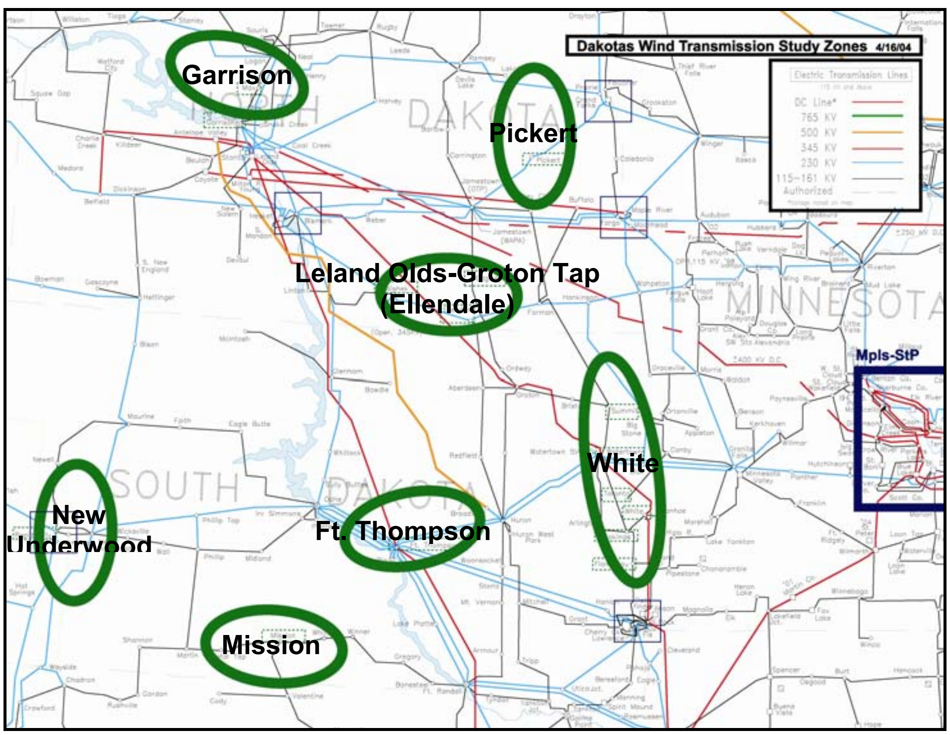

Figure 1-1 Interconnection Diagram for Dakotas Wind Transmission Project

Case Nomenclature Used In The Study

Steady state analysis case names are of the form “Case***AB***.sav”. Where in A can take values from 1-8 based on the interconnection site:

Site location	Value of “***A***”
Garrison	1
Pickert	2
Ellendale	3
New Underwood	4
Mission	5
Ft Thompson	6
White	7
All Sites	8

The letter “***B***” can take a value from 0-5 based on the generation level interconnected.

MW Interconnected	Value of “***B***”
500 MW	0
375 MW	1
250 MW	2
150 MW	3
50 MW	4

A similar case nomenclature is used during the naming of the stability cases using the MAPP package.

The typical case format used for stability is “c***AB***-so03.abcXXXX.sav”. Where the values of “***A***” and “***B***” are as described above and the values of “abcXXXX” in the case name are assigned by the MAPP package based on the MAPP defined interface flows.

The study scope is mainly divided into following tasks as below stated:

The following tasks will be performed as a part of the study:

Task 3 - Proposed Site Interconnection Studies
- Develop Base Cases
- Wind farm Models
- Steady-State Power flow and Contingency Analysis
- Short Circuit Study
- Stability Studies
- Constrained Interface Impact Studies

Task 4 - Transfer Capability for Wind Power to the Markets
- Develop Base Case
- Steady-State Power flow and Contingency Analysis
- Stability Studies
- Identification of Enhancements

2. STUDY METHODOLOGY

Methodology for the these tasks has been developed based on two kinds of system fundamental behaviors, steady state and transient stability as are described in the following subsections.

2.1 Steady State Analysis

The purpose of steady-state analysis is to analyze the impact of the proposed project on transmission system facilities under steady-state conditions. It involves two distinct analyses: thermal analysis and voltage analysis.

2.1.1 Thermal Analysis

System Intact Analysis:

The incremental impact of the Dakotas Wind Transmission Study project on thermal loading of transmission facilities under system intact conditions was evaluated by comparing the transmission system power flows for 2013 winter peak condition (see Section 3.1) with and without proposed wind generation. For this purpose, full ac power flow solutions were used. Each site was modeled from 500 MW to 50 MW or to the level that system enhancements are not required.

All facilities rated from 115-kV to 345-kV were monitored in XEL-NSP, MP, SMMPA, GRE, OTP, MPW, MEC, NPPD, OPPD, LES, WAPA, MH, SPC and DPC areas. The criteria used to flag thermal overloads is Rate B in the database. For transmission lines this is 100% of continuous line rating and excludes any limitation due to substation equipment.

N-1 Contingency Analysis:

N-1 contingency analyses were done for single branch contingencies on 2013 winter peak conditions with and without proposed wind generation. All facilities rated 230-kV and 345-kV were monitored in XEL-NSP, MP, SMMPA, GRE, OTP, MPW, MEC, NPPD, OPPD, LES, WAPA, MH, SPC and DPC. In case of new wind generation interconnection at Mission 115-kV, all facilities at 115-kV were also monitored along with 230-kV and 345-kV.

Contingency analysis was performed using activity ACCC of PSS/E. The contingencies were solved with phase shifters and tap changers enabled. Thermal violations were flagged based on 100% of Rate B data for facilities (from PSS/E). Non-convergent contingencies from these analyses (primarily due to switching back and forth of the transformer taps and switched shunts) were solved manually and their violations were appended to the ACCC results.

In order to assess transfer capability to potential markets, the First Contingency Incremental Transfer Capability (FCITC) were calculated. A DC-power flow based analysis was performed using the MUST program (functionally equivalent to the TLTG Activity in the PSS/E Program) in Task 4. MUST was instructed to study power transfer from four favorable sites to the respective sink defined with appropriate participation factors. The MUST output provides a list of all post-contingency thermal overloads as a function of the study transfer (based on the FCITC computed).

2.1.2 Voltage Analysis

For system intact conditions, bus voltages that fall outside the band of 0.95pu - 1.05pu were flagged as violations in XEL-NSP, MP, SMMPA, GRE, OTP, MPW, MEC, NPPD, OPPD, LES, WAPA, MH, SPC and DPC areas from 115-kV to 345-kV. For N-1 contingency conditions, bus voltages outside the range 0.92pu -1.08pu with a change in voltage of 0.01pu were flagged as violations for all above areas from 230-kV to 345-kV. For the Base Case and the Mission Site, the 115-kV lines are also included in the results.

2.2 Constrained Interface Analysis

The purpose of the constrained interface analysis is to calculate the impact of the proposed project on specified constrained interfaces in the MAPP transmission system. The MAPP DFCALC constrained interface analysis program is used for this purpose. Using DFCALC program, the impact of wind generation at each of the seven alternative sites on constrained interfaces was assessed for Winter Peak condition of Task 3.

2.3 Stability Analysis

The purpose of these analyses was to determine whether the MAPP system would meet stability criteria following commissioning of the proposed wind generation. To that end, important “local” under winter peak conditions and “regional” contingencies were simulated under summer off-peak conditions with maximum simultaneous NDEX (≈1950MW), MHEX (≈2175MW), and MWSI (≈1480MW) transfer levels. The studies were conducted utilizing the April 2004 MS Windows Version of the NMORWG Stability Package. These transfer limits were based on the system data as established by MAPP in November, 2004.

Viable cases with minimum system violations in steady state were used as the starting point for the stability studies and then reduced generation capacities to satisfy network stability constraints or minimum system enhancements. Individual site stability results were compared with base case results for the same faults. Requirement of system enhancements were assessed for different wind generation scenarios.

2.4 Short-Circuit Analysis

The purpose of short circuit analysis is to identify breakers in the transmission system that will not be able to handle the increased fault current due to the addition of the proposed wind generation. The proposed project was added to this short-circuit base case model to create other short-circuit models with proposed generations in service.

Three-phase faults were simulated on these short-circuit models and the impact of the new generation on the increase in fault currents was determined. The calculated fault currents are provided to the transmission owners to assess the need for breaker replacements.

Three-phase fault currents for the base case without wind and the 500 MW and 150 MW alternatives at each site were calculated for the new wind stations and the adjacent stations.

3. STEADY STATE ANALYSIS

The steady state analysis was performed on the winter peak case for the year 2013. The base case power flow model for System Intact Studies are taken from the case "a11-wp13aa.0NWVY1W.sav". The case title and a summary of the interface flows in the case can be summarized as below:

```
A11-WP13AA.0NWVY1W.SAV;WINTER;PK LD;SYSTEM INTACT
ND=21,MH=-697,MW=-379,OHMH=-197,OHMP=-98,EWTW=39,BD=-150
```

3.1 Base Case Development

Following assumptions made in base case model are:

- Generations in the North Dakota Coalfields are dispatched at its higher URGE levels defined in the MAPP Members Reliability Criteria and Study Procedures Manual.
- 200 MW are imported from the WECC System at the Rapid City Back-to-Back
- 150 MW are imported from that same system at the Miles City Station
- The load flow case model all the generations at the MAPP URGE levels.

After establishing the base power flow case, the proposed wind generation project was added each of the seven locations. The proposed wind farm is modeled in the load flow as a single equivalent DFIG wind turbine generator (see Figure 3-1). The generator step-up transformer (GSU) is also modeled as a single lumped equivalent. The single substation transformer of required capacity is modeled. The DFIG wind turbine generator is assumed to control the voltage on 34.5kV while taps on GSU and substation transformer maintain good power factor and collector bus voltage more than its voltage in base case respectively. In order to have a good voltage profile across the wind farm and maintaining power factors at collector bus, the LTCs on the GSU and substation are taken in the range of 0.95pu to 1.05pu in steps of 2.5%. Additional substation capacitor (fixed shunt) of required MVAR capacity is placed on the 34.5 kV bus in the cases where DFIG touches its reactive power limits. The GSU and substation transformer taps are locked for contingency analysis purposes.

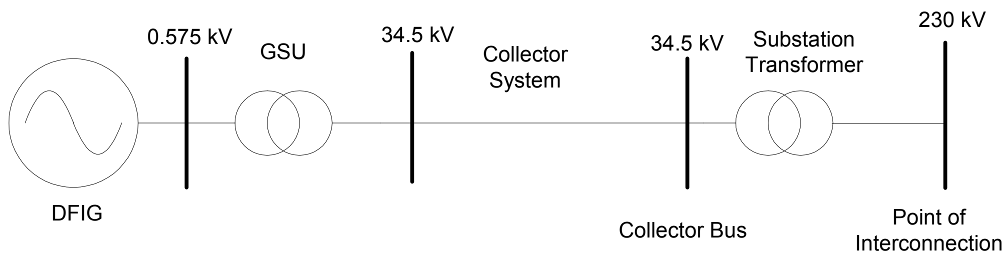

Figure 3-1 Wind Farm Modeling for Steady State Analysis

Equivalent numbers of GE 1.5MW DFIG units are used in the models and parameters of these of unit listed below Table 3-1.

Table 3-1 GE DFIG and GSU Ratings and Parameters

DFIG & GSU Parameters	Value	Units
Voltage	0.575	KV
WTG Rating	1.667	MVA
GSU Rating	1.75	MVA
GSU Resistance	0.0077	Pu
GSU Reactance	0.0579	Pu
GTAP	1	
Pmax	1.5	MW
Pmin	0	MW
Ra	0.00706	Ohms
La	0.1714	H
Lm	2.904	H
R1	0.005	Ohms
L1	0.1563	H
Inertia	0.62	Sec
Damping	0	

The details of Wind farm models used at each of the proposed interconnection sites indicating the values of substation transformer and generator step-up transformer are described in ***Appendix-A***.

Case names and nomenclature are described in Section 1. Case 8 has 100 MW of wind generation interconnected at Garrison, Ft. Thompson and White with the remaining four sites connected with 50MW of wind generation.

3.2 System Intact Analysis

The power flows and voltages were checked in XEL-NSP, MP, SMMPA, GRE, OTP, MPW, MEC, NPPD, OPPD, LES, WAPA, MH, SPC and DPC areas to assess the impact of adding the new wind generation interconnections. The criteria used for flagging thermal overloads are the 100% of Rate B information (from the PSS/E data). Bus voltages that fall outside the band of 0.95pu – 1.05 pu were flagged as violations.

3.2.1 Base Case Violations

Winter peak load condition for the year 2013 (base case) is studied for existing overloads on facilities and bus voltage violations.

3.2.1.1 Facility Overloading (> 100% of Rate B)

No overloaded lines are observed in the monitored areas. However there are overloaded transformers in the base case used for the study. A total of 33 transformers are found overloaded and loading ranges from 101.1% to 158.7% (158.7% at 63192, HENSEL Y 115/69kV, 40MVA). The list of all the overloaded transformers is tabulated in ***Appendix-B.*** Most of the overloaded transformers are generator step-up transformers.

3.2.1.2 Bus Voltage Violations (<0.95pu and >1.05pu)

Bus voltages from 115-kV to 345-kV buses are monitored for voltage violations. A total of 60 buses violate the criteria and range from 0.942pu (at 63297, ROLETTE7) to 1.1pu (at 67648, POINTD27) in the base case used. List of all facilities with voltage violations are tabulated in ***Appendix-B***. All but one of the voltage violations is for over-voltage conditions.

3.2.1.3 Area and Network Losses

Summary of area generation, loads and losses and also total network losses are tabulated for reference as shown in Table 3-2. Total network losses are 10859MW.

Table 3-2 Area and Network Losses in Base Case

Area / Name		Generation	Load	Bus Shunt	Line Shunt	Charging	To Net Int	Losses	Desired Net Int
600	MW	8550	8333	0	0	0	-81	292	-28
XEL-NSP	MVAR	453	1830	-3030	727	2168	357	2736	
608	MW	1818	1788	0	0	0	-89	120	-105
MP	MVAR	388	599	-1247	0	551	46	1540	
613	MW	91	288	0	0	0	-198	1	-198
SMMPA	MVAR	47	72	-26	0	8	5	4	
618	MW	1717	1365	0	0	0	222	130	159
GRE	MVAR	683	75	-1285	0	312	195	2010	
626	MW	1454	2312	0	0	0	-1011	154	-914
OTP	MVAR	309	272	-675	26	599	25	1262	
633	MW	159	159	0	0	0	-1	1	-1
MPW	MVAR	52	40	0	0	9	11	11	
635	MW	4382	4240	0	0	0	26	117	43
MEC	MVAR	612	891	-404	51	1285	-39	1399	
640	MW	2815	2436	0	0	0	260	143	-58
NPPD	MVAR	376	483	-468	263	1161	-33	1299	
645	MW	1982	2028	0	0	0	-69	23	-68
OPPD	MVAR	485	607	-73	14	345	-112	394	
650	MW	21	591	0	0	0	-576	6	-575
LES	MVAR	2	97	-93	0	87	-14	98	
652	MW	4779	3009	0	0	0	1412	333	766
WAPA	MVAR	347	561	-646	721	3107	-150	2961	
667	MW	3559	3910	0	0	0	-496	146	833
MH	MVAR	359	650	-2310	348	1342	-56	3068	
672	MW	3511	3548	0	0	0	-151	114	0
SPC	MVAR	406	597	-387	63	1092	97	1127	
680	MW	1209	978	0	0	0	146	75	140
DPC	MVAR	136	168	-144	0	189	-107	403	
Network MW	MW	**513220**						**10859**	
MVAR		**84633**						**151195**	

3.2.2 Proposed Wind Site Cases

The cases described in Section 1 are developed such that collector bus voltage has a better value than base case and maintaining good power factor at the point of interconnection. Summary of collector bus voltages, reactive power exchange at collector bus, GSU taps, substation transformer taps and DFIG performance is tabulated in Table 3-1.

3.2.2.1 Garrison Interconnection (500 MW at 230 kV)

The case with 500 MW of wind interconnected at Garrison 230-kV is labeled Case10. One 115-kV line from PRASWCP to PRAIRIE is observed to have a loading of 104.9%.

A total of 34 transformers are found to have overloads ranging from 100% to 158.7% which is one more than in the base case so most of these transformers are already overloaded in the base case. The list of all the violations is tabulated in ***Appendix-B***. Apart from these thermal overloads, a total of 81 buses are found violating the criteria and range from 0.906pu (at 63297, ROLETTE7, 115 kV) to 1.116pu (at 60116, PRASWCP7, 115 kV). There are about 20 more buses in voltage violation than in the base case. Twenty-five of these violations are low voltages. Most of these violations are observed in the Jamestown – Buffalo – Rugby – Hilltop areas. Shunt capacitor compensation in this area will eliminate these low voltages.

3.2.2.2 Pickert Interconnection (500M W at 230 kV)

The case with 500 MW of wind interconnected at Pickert 230 kV is labeled Case 20. No overloaded lines are found in the monitored areas. However a total of 28 transformers are found to be overloaded and loadings on these facilities range from 100% to 158.7% (at 63192, HENSEL Y 115/69kV, 40MVA). Also a total of 57 buses are found to violate the voltage criteria and the values range from 0.941pu (at 63297, ROLETTE7, 115kV) to 1.1pu (at 67648, POINTD27, 121kV).

3.2.2.3 Ellendale Interconnection (500 MW interconnection on the Leland Olds – Groton 345 kV)

The case for the analysis of interconnecting 500 MW of generation at Ellendale is named Case 30. No overloaded lines are observed in the monitored areas. However a total of 37 transformers are found overloaded and loading ranges from 100% to 158.7% (at 63192, HENSEL Y 115/69kV, 40MVA). Also, a total of 70 buses are found violating the voltage criteria and range from 0.918pu (at 63297, ROLETTE7, 115kV) to 1.1pu (at 67648, POINTD27, 121kV). Of these buses, 15 buses are found to be at low voltage condition mostly in central North Dakota. Shunt capacitor compensation in this area will eliminate these low voltages.

3.2.2.4 New Underwood Interconnection (500 MW at 230 kV)

The case is labeled as Case 40. No overloaded lines are found in the monitored areas. However a total of 37 transformers are found overloaded and loading ranges from 100% to 158.8% (at 63192, HENSEL Y 115/69kV, 40MVA). Also, a total of 61 buses are found violating the voltage criteria and range from 0.925pu (at 63297, ROLETTE7, 115kV) to 1.1pu (at 67648, POINTD27, 121kV). Of these buses, 12 buses are observed to be at low voltages.

3.2.2.5 Mission Interconnection (250 MW at 115 kV)

The case with 250 MW of wind interconnected at Mission 115 kV is labeled Case 52. The Interconnection of 500 MW and 375 MW at Mission resulted in severe overloads on the underlying 115-kV transmission system along with many violations due to low voltages. Choosing a 250 MW interconnection did not result in overload of any transmission line, however a total of 34 transformers are found overloaded and loading ranges from 100.2% to 158.8% (at 63192, HENSEL Y 115/69kV, 40MVA). Also a total of 59 buses are found violating the voltage criteria and range from 0.942pu (at 63297, ROLETTE7, 115kV) to 1.1pu (at 67648, POINTD27, 121kV).

Another case was also developed for the interconnection into the Mission site, with additional transmission reinforcements. Two 230 kV lines with one from Mission to Ft Randall and one from Mission to Oahe are added in the system along with a 115/230 kV

ABB

transformer at Mission. Results indicate that 500 MW of generation interconnection is feasible without overloading the interconnecting system. The following line data was used to develop the case.

	R(pu)	X(pu)	B (pu)
Mission – Ft Randall:	0.01718	0.18245	0.32087
Mission – Oahe:	0.01632	0.1733	0.30482

3.2.2.6 Ft. Thompson Interconnection (500 MW at 345 kV)

The case is labeled Case 60. The analysis on this case resulted in no overloaded lines but 36 transformers are found overloaded and loading on these facilities range from 100% to 158.7% (at 63192, HENSEL Y 115/69kV, 40MVA). Also, a total of 60 buses are found violating the voltage criteria and range from 0.924pu (at 63297, ROLETTE7, 115kV) to 1.108pu (at 67556, WHTSL1 4, 220kV). Of these buses, 12 buses are found to be at low voltage condition mostly in central North Dakota. Shunt capacitor compensation in this area will eliminate these low voltages.

3.2.2.7 White Interconnection (500 MW at 345 kV)

One overloaded 115-kV line from GRANTE CITY to MORRIS is observed in the monitored areas with loading of 102.1%. The case used for this analysis is labeled Case 60. Also, a total of 35 transformers are found overloaded and loading ranges from 100.8% to 158.7% (at 63192, HENSEL Y 115/69kV, 40MVA) along with 62 buses that violate the voltage criteria and range from 0.93pu (at 63297, ROLETTE7, 115kV) to 1.1pu (at 67648, POINTD27, 121kV).

3.2.2.8 Distributed Interconnection at all Seven Sites

This is 100 MW of wind generation interconnected at Ft Thompson, White and Garrison along with 50 MW interconnected at the remaining sites. This case is named as Case 80. The setup of this case resulted in no Thermal violation on the transmission lines but 36 transformers are found overloaded and loading range from 100.1% to 158.7% (at 63192, HENSEL Y 115/69kV, 40MVA). The voltage criteria used for the analysis resulted in 66 buses violating the criteria and range from 0.932pu (at 63297, ROLETTE7, 115kV) to 1.107pu (at 67589, WHTSL2 4, 220kV). Of these buses, 9 buses are found to be at low voltage condition mostly in central North Dakota. Shunt capacitor compensation in this area will eliminate these low voltages.

3.2.3 Case Comparison – Steady State Performance

Steady state performance of power system for each case is compared with respect to facility loadings, bus voltages, and network losses. Table 3-3 summarizes the different options and their impact on facility loadings, bus voltages and area losses.

The voltage at the point of interconnection is generally improved after connecting the DFIG due to the injection of reactive power into the network and tap adjustments of the substation transformer. In Case 80, a small voltage drop is observed at Ft Thompson after the interconnection of DFIG. This can be further improved by injecting reactive power from DFIG into network through fine adjustment of GSU and substation transformer HV taps. Similarly reactive power flows from the network to the wind generation is observed in the cases 10, 52, and 80.

In all the cases HV taps of substation transformer and GSU are raised to allow reactive power flow into the network and also to maintain approximately unity collector bus voltages. All the taps are maintained within the limits of available range to achieve a maximum of 1.05 pu voltage at the collector bus.

Voltages at 34.5-kV buses are maintained more than 1pu in all the cases except Case 80 at Pickert, which has a low collector bus voltage in the base case. This can be improved by injecting more reactive power supply from plant into the network.

In all the cases, reactive power supply from DFIG is maintained lower than its maximum limit in order to retain considerable margin for dynamic requirements of machine.

Marginal line overloads are observed in Case 10 and Case 70. Despite these violations, these two sites are considered with 500 MW of wind generation for the steady state performance. Considering the Mission interconnection, a substation capacitor bank of 100 MVAR is required in Case 50 to achieve a 500 MW power injection into the 115-kV collector bus. This ensures the power flow case to solve with a tolerance of 1 MVA. Due to the heavy thermal loadings in the underlying 115-kV transmission system, further analysis was done with only 250 MW of wind generation at the site.

There are 19 – 115-kV transformers, 11 – 230-kV transformers, and 3 – 345-kV transformers overloaded in base case. Most of these transformers are generator step-up transformers that are loaded more than the Rate B rating because of the reactive power flow. The overloaded transformers vary only slightly from the base case except in Case 30. An increase in the number of overloaded 230-kV transformers are found in Case 10, Case 40, and Case 80, but the maximum overload observed is insignificant as it can be corrected by adjusting the generator reactive power output or the tap settings of the step-up transformers. Similar changes in the number of overloaded 345-kV transformers are observed from Case 40 to Case 80.

Except in Case 20, all other cases result in the increase of the number of low voltage buses. In Case 50 the minimum voltage on some 115-kV buses is significantly lower than the base case. In other cases the low voltages recorded are not as significant and have a value more than 0.90 pu. The impact on over-voltages on the system is very minimal in all the cases.

The area and network losses for all the cases are described in Figure 3-2. A large reduction in losses is observed in Case 20. Also in Case 30, Case 70 and Case 80 have a minor reduction in losses. The other cases have an increase in losses.

A maximum of 250 MW is only recommended to be connected to Mission 115-kV bus as per as steady state performance is concerned unless two new 230-kV lines are built to accommodate 500 MW.

Comparison of individual line loadings, transformer loadings, bus voltages and losses are tabulated in ***Appendix-B***.

Table 3-3 Summary of Impacts of Different Cases on Network for Normal System Conditions

Parameters	Units	Base	Case10	Case20	Case30	Case40	Case50	Case51	Case52	Case60	Case70	Case80
Overloaded Lines			Garr	Pickert	Ellendl	N.U.	Mission	Mission	Mission	Ft. T	White	All
Site Generation			500	500	500	500	500	375	250	500	500	500
Overloaded 115kV Lines	Nos.	--	1	--	--	--	9	1	--	--	1	--
Max loading on 115kV Lines	%	--	104.9	--	--	--	152.2	107.6	--	--	102.1	--
Overloaded 230kV Lines	Nos.	--	--	--	--	--	--	--	--	--	--	--
Max loading on 230kV Lines	%	--	--	--	--	--	--	--	--	--	--	--
Overloaded 345kV Lines	Nos.	--	--	--	--	--	--	--	--	--	--	--
Max loading on 345kV Lines	%	--	--	--	--	--	--	--	--	--	--	--
Overloaded Transformers Banks												
Overloaded 115kV Trans.	Nos.	19	19	19	21	19	19	19	19	19	19	19
Max loading on 115kV Trans.	%	158.7	158.7	158.7	158.7	158.8	158.8	158.8	158.8	158.7	158.7	158.7
Overloaded 230kV Trans.	Nos.	11	13	7	10	14	11	11	11	11	11	13
Max loading on 230kV Trans.	%	107.7	110.7	107.3	109.1	158.6	108.1	108.1	108	108.7	108.3	108.3
Overloaded 345kV Trans.	Nos.	3	2	2	6	4	4	4	4	6	5	4
Max loading on 345kV Trans.	%	103.7	102.5	101	120.6	105.3	105.1	105.1	104.7	109.2	106.4	101.7
Undervoltage Buses												
115kV Buses	Nos.	1	15	1	6	4	30	12	2	4	4	3
Min Voltage on 115kV	pu	0.942	0.906	0.941	0.918	0.925	0.721	0.917	0.936	0.924	0.93	0.932
230kV Buses	Nos.	--	4	--	3	2	2	1	1	2	2	--
Min Voltage on 230kV	pu	--	0.941	--	0.941	0.936	0.946	0.947	0.949	0.935	0.943	--
345kV Buses	Nos.	--	6	--	6	6	3	3	3	6	3	3
Min Voltage on 345kV	pu	--	0.936	--	0.941	0.94	0.945	0.946	0.947	0.939	0.944	0.947
Overvoltage Buses												
115kV Buses	Nos.	15	14	13	13	10	10	10	11	10	10	16
Max Voltage on 115kV	pu	1.092	1.116	1.097	1.089	1.082	1.087	1.088	1.089	1.081	1.085	1.106
121kV Buses	Nos.	3	3	3	3	3	3	3	3	3	3	3
Max Voltage on 121kV	pu	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
138kV Buses	Nos.	7	7	7	7	7	7	8	7	8	8	8
Max Voltage on 138kV	pu	1.091	1.091	1.091	1.091	1.091	1.091	1.091	1.091	1.091	1.091	1.091
161kV Buses	Nos.	3	3	4	3	3	3	3	3	3	3	3
Max Voltage on 161kV	pu	1.057	1.058	1.058	1.058	1.057	1.056	1.057	1.057	1.057	1.058	1.058
220kV Buses	Nos.	2	2	2	2	2	2	2	2	2	2	2
Max Voltage on 220kV	pu	1.095	1.096	1.094	1.095	1.095	1.095	1.096	1.095	1.108	1.095	1.107
230kV Buses	Nos.	26	24	24	24	22	23	24	24	24	24	25
Max Voltage on 230kV	pu	1.093	1.093	1.093	1.093	1.093	1.093	1.093	1.093	1.093	1.093	1.093
345kV Buses	Nos.	3	3	3	3	2	2	3	3	3	3	3
Max Voltage on 345kV	pu	1.074	1.075	1.075	1.075	1.074	1.074	1.074	1.074	1.075	1.075	1.075
Total Network Losses	MW	10859	10863	10739	10855	10930	11041	10932	10883	10869	10839	10835
DFIG Performance												
Coll. Bus Voltage Before	pu	--	1.03	0.983	1.017	1.007	0.994	0.994	0.994	1.044	1.041	
Coll. Bus Voltage After	pu	--	1.03	1.017	1.024	1.018	1.019	1.016	1.029	1.046	1.046	
Coll. Bus Qinj	MVAR	--	-8	32.2	9.8	26.9	130.1	25.8	-2.5	18.8	17.6	
SS Trans. HV Tap		--	1.025	1.025	1.025	1.025	1.05	1.025	1.025	1.05	1.05	
34.5kV Bus Voltage	pu	--	1.013	1.008	1.011	1.009	1.008	1.007	1.012	1.009	1.009	
Substation Capacitor	MVAR	--	--	--	--	--	100	--	--	--	--	
GSU HV Tap		--	1.025	1.025	1.025	1.025	1.025	1.025	1.025	1.025	1.025	
DFIG Qgen	MVAR	--	68	110.5	86.7	104.8	112.6	84.4	35.6	96.2	94.9	
Coll. Bus Voltage After	pu		1.003	0.991	1.029	1.027	1.034			1.041	1.043	
Coll. Bus Qinj	MVAR		-1.2	3.1	-0.7	0	-2.1			7.5	6	
SS Trans. HV Tap			1.025	1.025	1.025	1.025	1.025			1.05	1.05	
34.5kV Bus Voltage	pu		1.012	0.984	1.012	1.011	1.014			1.008	1.009	
Substation Capacitor	MVAR		--	--	--	--	--			--	--	
GSU HV Tap			1.025	1	1.025	1.025	1.025			1.025	1.025	
DFIG Qgen	MVAR		13.7	11.4	7.1	7.9	5.7			22.9	21.3	

From the above table several details are summarized that should be noted as follows:

- The Mission site can only support 250 MW without adding new 230-kV lines
- There are two cases with one slightly overloaded line
- Most of the transformer overloads are also in the base case except for the New Underwood site which overloads the existing transformer at New Underwood

The losses are summarized in Figure 3-2 below. Locating the wind sites on the 230-kV and 115-kV systems away from the 345-kV bulk system tends to increase the system losses. The exception is the Pickert site. Since the Pickert site is close to Manitoba and Manitoba is importing power, when the Pickert site is added power flows increase from North Dakota to Manitoba and decrease from Minnesota. This results in lower loading and losses on the WAPA system in the Dakotas and on the Xcel-NSP system in Minnesota.

The area numbers in Figure 3-2 represent the following utilities:

- 600 XEL-NSP
- 608 MP
- 613 SMMPA
- 618 GRE
- 626 OTP
- 633 MPW
- 635 MEC
- 640 NPPD
- 645 OPPD
- 650 LES
- 652 WAPA
- 667 MH
- 672 SPC
- 680 DPC

The two areas with the highest losses are 600 (XCEL-NSP), and 652, (Western Area and Basin Electric), with the larges impact of losses due to the wind on the Western Area and Basin Electric system. Both these areas have losses above 200 MW.

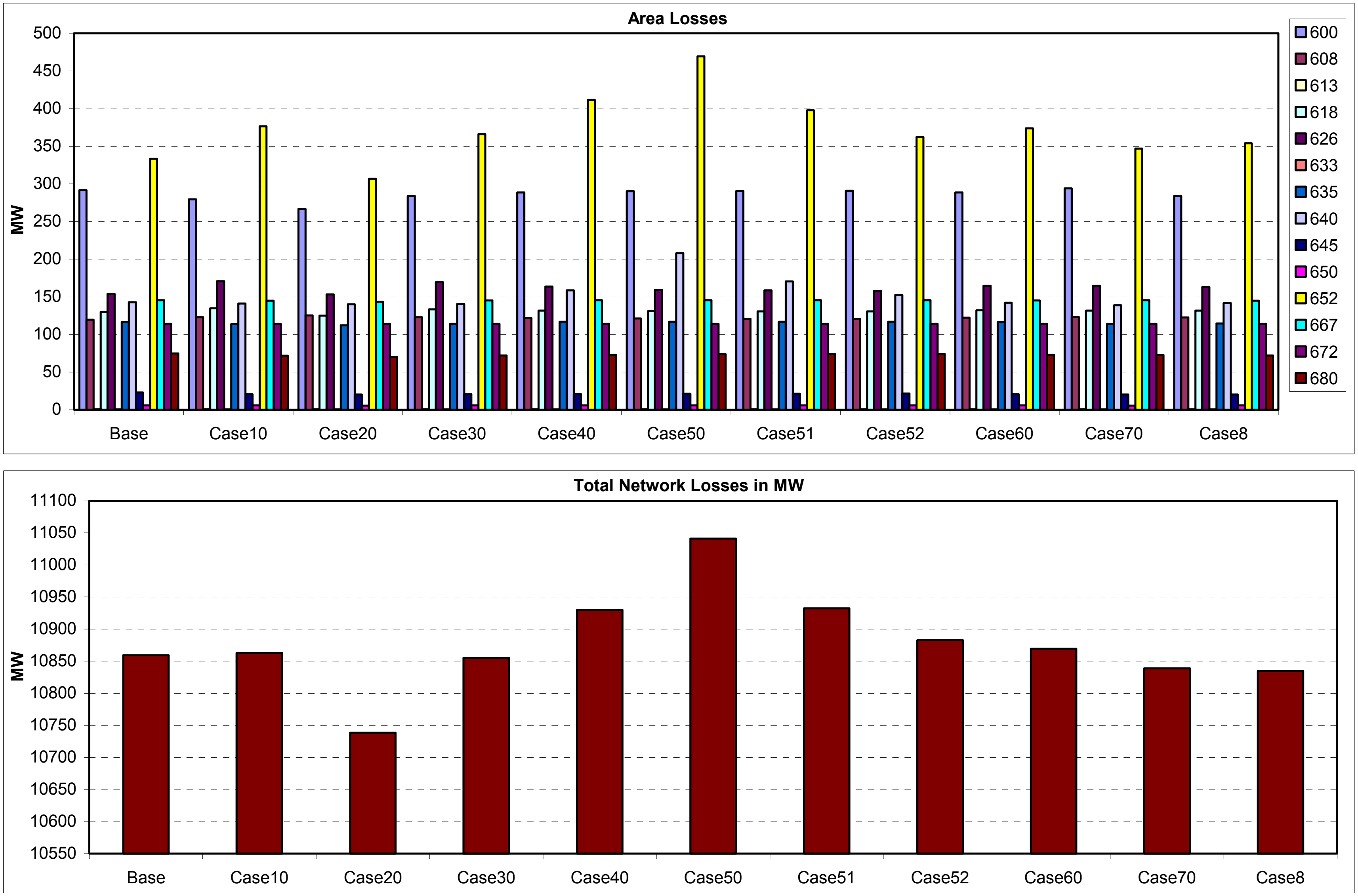

Figure 3-2 Area and Network Losses

3.3 N-1 Contingency Analysis

After establishing the system intact performance, the steady-state performance is assessed during N-1 contingency conditions on the winter peak cases. The analyses are conducted using the activity ACCC of PSS/E.

Thermal violations are flagged based on the facility ratings (Rate B in the power flow case). For transmission lines, this rating should be the continuous rating under normal conditions and does not include limits due to any terminal equipment constraints. Facilities with loadings of more than 100% plus a minimum change in power from normal condition of more than 1 MW is flagged. Bus voltages outside the range of 0.92-1.08pu and minimum of 2% change from normal condition are flagged as criteria violations. In the Base Case, Case 50, Case 51, Case 52 and Case 80 outages of 115-kV facilities are considered in N-1 contingencies and monitoring elements. Other cases only have 230-kV and 345-kV facility outages considered for contingency and monitoring.

The analysis starts with 500 MW at each site, identified the system enhancements and then goes to the next lower level of generation in sizes of 500MW, 375MW, 250MW, 150MW and 50MW. Developed cases for different sites are solved with phase shifting, tap changing, switched shunts and DC line control options fixed and not allowed to regulate.

Table 3-4 summarizes the number of overloaded transmission lines and transformers. The values of the worst loadings and worst voltage violation are recorded. Note that the Base Case and Cases 50, 51, 52, and 60 include the 115-kV system that has some higher overloaded lines.

Table 3-4 Summary of Facility Over loadings and Bus Voltage Violations during N-1 Contingency

Parameters	Units	Base	Case10	Case20	Case30	Case40	Case50	Case51	Case52	Case60	Case70	Case80
Overloaded Lines												
No. of Overloading Lines	Nos	14	1	2	1	21	29	20	19	1	1	13
Max Loading	%	268.3	131.1	116.8	127.7	125.2	270.6	270.3	269.7	125.0	122.5	267.1
Overloaded Transformers												
No. of Overloading Trans	Nos	47	27	23	26	25	44	46	45	30	29	49
Max Loading	%	263.5	193.7	225.7	307.6	270.7	267.6	267.3	266.4	278.3	270.4	257.8
Under voltages												
Under voltage Buses	Nos	--	--	--	--	--	17	2	--	--	--	--
Lowest Voltage	pu	--	--	--	--	--	0.721	0.918	--	--	--	--
Over voltages												
Over voltage Buses	Nos	7	4	4	4	4	7	7	7	2	4	8
Highest Voltage	pu	1.095	1.093	1.093	1.093	1.093	1.095	1.096	1.095	1.093	1.093	1.107

Appendix-C shows bus voltage violations and facility loadings for different case comparison. In all the cases, no new bus over-voltages are observed that are not in the base case. The voltages violating the criteria of less than 0.92 pu are observed in Case 50 and Case 51. These results are also validated with MUST transfer capability analysis (see Sec 3.5).

3.4 Constrained Interface Analysis

The purpose of this task is to determine if the proposed wind farms would have an impact upon the regional constrained interfaces (PTDF and OTDF interfaces) of the MAPP system. The analysis is done using the NMORWG DFCALC IPLAN program on the 2013 Winter Peak power flow models with and without proposed wind generation in different cases.

The interface definitions for this analysis are provided by the study ad hoc group, based on the postings on the MAPP OASIS. The interface data definition file provided by the study ad hoc group is compatible with the 2003/2004 Series MAPP cases. The same definitions are used here for Winter Peak 2013 case. The Table 3.5 describes the impact on total exports on each of the interfaces. The table only indicates the PTDF's i.e., the percentage of the interconnected MW on the constrained paths as per MAPP criteria[1].

The cases used to monitor the interfaces are setup with the sink as the Twin cities (Zone 601 in the power flow case) generation. All the interfaces on which the TDF of 5% or more is recorded are highlighted. The amount of additional power flowing on each of the interface is recorded in the column "Diff (MW)" which indicates the additional MW flowing on the interface compared to the base case.

The maximum increase in power flow was found on the NDEX interface following the connections in the North Dakota Region at Garrison, Ellendale and Pickert. Almost all of the interconnected power flows through this interface. Only 250 MW of generator interconnection is possible at the Mission Site with just the existing system due to network constrains and voltage problems.

Mitigation may be required if it is determined that there is insufficient or no available transfer capability (ATC) on the affected MAPP constrained interfaces. This is an issue that should be addressed with the system impact study for transmission service should the proposed interconnection go forward.

[1] As per MAPP Design Review Subcommittee criteria (see MAPP DRS document entitled "*Steady-State Facility & Constrained Path Impact Determination Requirements & Screening Guidelines for Study Submissions"* approved July 18, 2003), the minimum PTDF threshold for MAPP PTDF Interfaces is 5% and the minimum MW impact threshold is 1 MW or 1% of the impacted Path TTC (whichever is smaller). 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 or 1% of the impacted Path TTC (whichever is smaller). OTDF Interfaces that have OTDFs >= 3% -and- a MW impact >= minimum MW impact threshold are considered significantly impacted.

Interface name	Base case Flow (MW)	Site / MW Interconnected Garrison / 500 MW			Site / MW Interconnected Pickert / 500 MW			Site / MW Interconnected Ellendale / 500 MW			Site / MW Interconnected New Underwood / 500 MW			Site / MW Interconnected Mission / 250 MW			Site / MW Interconnected Ft Thompson / 500 MW			Site / MW Interconnected White / 500 MW			Site / MW Interconnected All Sites / 500 MW		
		Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)	Ch.Case Flow (MW)	Diff (MW)	TDF (%)
COOPER_S	133.6	132.6	-1	-0.2	155	21.4	4.28	137.4	3.8	0.76	122.5	-11.1	-2.22	73.1	-60.5	**-24.2**	143.7	10.1	2.02	145	11.4	2.28	144.8	11.2	2.24
ECL-ARP	-192.9	-229.1	-36.2	**-7.2**	-204.7	-11.8	-2.36	-230.1	-37.2	**-7.4**	-245.4	-52.5	**-10.5**	-265.5	-72.6	**-29.04**	-238.1	-45.2	**-9.04**	-230.1	-37.2	**-7.44**	-229	-36.1	**-7.22**
FTCAL_S	-28.7	-35.5	-6.8	-1.36	-19.3	9.4	1.88	-28.3	0.4	0.08	-60.7	-32	**-6.4**	-77.5	-48.8	**-19.52**	-43.4	-14.7	-2.94	-7.9	20.8	4.16	-28.1	0.6	0.12
GGS	1769.8	1780.3	10.5	2.1	1779	9.2	1.84	1777.7	7.9	1.58	1874.8	105	21	1791.1	21.3	**8.52**	1778	8.2	1.64	1772	2.2	0.44	1791.7	21.9	4.38
GRIS_LNC	614.4	649.9	35.5	7.1	642.6	28.2	**5.64**	645.2	30.8	**6.16**	692	77.6	**15.5**	639.1	24.7	**9.88**	692.5	78.1	**15.62**	624.7	10.3	2.06	656.2	41.8	**8.36**
LKM-WFB	-29.6	-36.2	-6.6	-1.32	-33.4	-3.8	-0.76	-36.8	-7.2	-1.44	-37.8	-8.2	-1.64	-38.5	-8.9	-3.56	-37.9	-8.3	-1.66	-38	-8.4	-1.68	-36.9	-7.3	-1.46
MHEX_N+	-337	-219.2	117.8	**23.6**	-90.7	246	**49.3**	-247.2	89.8	**18**	-270.5	66.5	**13.3**	-302.7	34.3	13.72	-266.6	70.4	**14.08**	-277.5	59.5	**11.9**	-234.7	102.3	**20.46**
MHEX_S+	352.8	240.9	-112	**-22**	110.8	-242	**-48**	267.4	-85.4	**-17**	288.9	-63.9	**-12.8**	320.1	-32.7	**-13.08**	285.2	-67.6	**-13.5**	295.4	-57.4	**-11.48**	253.9	-98.9	**-19.8**
MH_SPC_E+	-47.8	-43	4.8	0.96	-45.7	2.1	0.42	-46.9	0.9	0.18	-47.8	0	0	-46.9	0.9	0.36	-47.5	0.3	0.06	-47.7	0.1	0.02	-47.9	-0.1	-0.02
MH_SPC_W+	49.5	44.7	-4.8	-0.96	47.4	-2.1	-0.42	48.5	-1	-0.2	49.5	0	0	48.6	-0.9	-0.36	49.2	-0.3	-0.06	49.4	-0.1	-0.02	49.6	0.1	0.02
MNTZUMA_W	229.4	211.6	-17.8	-3.56	209.2	-20.2	-4.04	207.2	-22.2	-4.44	209.9	-19.5	-3.9	235	5.6	2.24	200	-29.4	**-5.88**	199.8	-29.6	**-5.92**	202.5	-26.9	-5.38
MWSI	-384.3	-489.2	-105	**-21**	-429.4	-45.1	**-9**	-494	-110	**-22**	-528.5	-144	**-28.8**	-565.9	-181.6	**-72.64**	-515.8	-131.5	**-26.3**	-499.4	-115.1	**-23.02**	-493.2	-108.9	**-21.8**
NDDC	-4.2	-4	0.2	0.04	-4.1	0.1	0.02	-4.2	0	0	-4.2	0	0	-4.2	0	0	-4.2	0	0	-4.2	0	0	-4.2	0	0
NDEX	-32	383.2	415.2	**83**	477.9	510	**102**	474.5	506.5	**101**	-78.9	-46.9	**-9.38**	-55.1	-23.1	-9.24	-69.5	-37.5	-7.5	-59.6	-27.6	**-5.52**	-93.6	-61.6	**-12.3**
PRI-BYN	-191.4	-260.1	-68.7	**-14**	-224.8	-33.4	**-6.7**	-263.9	-72.5	**-15**	-283	-91.6	**-18.3**	-300.5	-109.1	**-43.64**	-277.7	-86.3	**-17.3**	-269.3	-77.9	**-15.58**	-264.2	-72.8	**-14.6**
QUADCITY_W	807.2	808.1	0.9	0.18	798.3	-8.9	-1.78	805.1	-2.1	-0.42	812.2	5	1	837.1	29.9	**11.96**	803	-4.2	-0.84	799.5	-7.7	-1.54	801.4	-5.8	-1.16
WNE_WKS	362.4	367	4.6	0.92	370.4	8	1.6	367.2	4.8	0.96	383.3	20.9	4.18	357.7	-4.7	-1.88	372.5	10.1	2.02	365.9	3.5	0.7	371.9	9.5	1.9
Y2DC	-1.8	-1.8	0	0	-1.8	0	0	-1.8	0	0	-1.8	0	0	-1.8	0	0	-1.8	0	0	-1.8	0	0	-1.8	0	0

Table 3.5 Impact of interconnection on the Interface flows along with the Transfer distribution factor.

3.5 Transfer Capability Analysis (MUST- DCCC Analysis)

The purpose of this part of analyses is to assess the power transfer capability of the network to potential markets such as Twin Cities, Central and Eastern Iowa, and Omaha & Kansas City plus a combination of all three. Individual wind sites are analyzed for the transfer capacity to deliver the wind power to these load centers. Using bus participation factors, the transfer of the power is distributed among the loads in the four dispatch scenarios considered.

The MUST program is used to identify the transfer capacity across the interfaces for all wind sites and compare this to the system without any new wind generation. Also identified the system limitations by assessing First Contingency Incremental Transfer Capability (FCITC) to transfer capacity from each of wind sites with each of the marketing scenarios. The list of contingencies considered for these analysis are 230-kV facilities of WAPA, NSP, and OTP and 115-kV facilities in Cases 5 & 8 and 345-kV lines in all cases. FCITC is calculated for both winter peak 2013 and summer off-peak 2003 (refer Section 4 - Stability Analysis for case information) cases using MUST DCCC analysis.

All the results monitored for TDF more 2% and a minimum change of 1 MW for both Winter Peak and Summer Off-peak cases on PSSE Rate B and listed in ***Appendix-D***. From the MUST results, it is observed that the base cases (both winter peak and summer off-peak) have transformers overloaded after performing N-1 contingency analysis (DCCC). The overloads observed are consistent with the results obtained from the ACCC analysis of PSSE.

Winter Peak Case

In the Winter Peak base case, overloads are recorded on the Fargo-Sheyenne 230-kV line during an outage of the James Town-Center 345-kV line and also on the Granite City-Morris 115-kV line during the outage of the Wahpeton - Fargo 230-kV line.

In the base cases used for this analyses, transformer overloads are observed at Grand Forks 230/230kV, Winger 230/230kV, Sioux falls 230/230kV, Leland Olds 345/230kV, New Underwood 230/230kV, Ft. Thompson 345/345kV, Bigstone 230/230kV and Watertown 345/345kV. For the winter peak case, only the Mission site had significant transmission line overloads.

For the Mission site, a number of overloads are recorded at Oahe 230/115-kV transformer plus many lines are overloaded. All of the overloads are attributed to the interconnection of 500 MW. To minimize the overloads for the Mission site, the installed wind generation needs to be limited to 250 MW. Below are some of the overloaded lines with 500 MW at Mission. When two new 230-kV lines were added to Mission, the overloads for 500 MW of wind were eliminated.

OGALALA4-SIDNEY 4	230	line
AINSWRT7-STUART 7	115	line
EMMET 7-ONEILL 7	115	line
HARMONY7-ST.FRANC	115	line
HARMONY7-VALENTN7	115	line
ST.FRANC-MISSION7	115	line
BONESTL7-GREGORY7	115	line
BONESTL7-FTRANDL7	115	line

GREGORY7-WINNER 7	115	line
MARTIN 7-VETALTP7	115	line
MISSION7-WITTEN 7	115	line
MISSION7-VETALTP7	115	line
WINNER 7-WITTEN 7	115	line

Summer Off-Peak

In summer off-peak base case, a total of ten overloaded lines are observed. These overloads include the AsKing – Chisago 345-kV line, the Huron – BirdLand 345-kV line, the Sq. Butte – Center 345-kV line, the AsKing – Eauclaire 345-kV line, the N. Platt – Stock VI 115-kV line, the Ogala – Sidney 115-kV line, the Riverfront – Lenmont 115-kV line, the Maple LF – Cascade 161-kV line, and the Maple – Byron 161-kV line. In addition of these line overloads the transformers at Terminal, Watertown, Sidney, Ft Thompson, BirdLand, GrandForks, Sioux Falls and New Underwood are overloaded considerably. Overloaded transformer facilities in base case as listed below.

TERMID2Y	345/345kV
TERMID1Y	345/345kV
WATERT1T	345/345kV
FTTHMP1T	345/345kV
FTTHMP2T	345/345kV
SIDNEY 3	345/345kV
GROTON 3	345/345kV
WATERT1T	345/230kV
BRDLNDTY	345/230kV
SIDNEYTY	345/230kV
GRNDFKST	230/230kV
SIOUXF1T	230/230kV
SIOUXF2T	230/230kV
WATERT3T	230/230kV
NUNDRWDT	230/230kV
SIOUXC3T	230/230kV
SIOUXC4T	230/230kV
SIDNEY 4	230/230kV

Below is the list of transmission lines that are overloaded for one or more of the wind sites. Facilities that were overloaded in the base case are not included. Others are overloaded in the summer case but not in the winter due to higher transmission line ratings in the winter. Several are short ties between to nearby substations. All of these are noted below along with the overload for each line.

SHEYNNE4-FARGO 4	230 kV	100.1% 1)
MNVLTAP4-GRANITF4	230 kV	120% 1)
ROCKCR 4-ARROWHD4	230 kV	101%
BISMARK4-GARRISN4	230 kV	102%
GRNDFKS4-PICKERT4	230 kV	111% for summer rating
GARRISN4-LELANDO4	230 kV	103%
JAMESTN4-PICKERT4	230 kV	111% for summer rating

1) Short tie between substations

In case of Mission (Case 52 and Case 80), interconnecting into the 115-kV system led to the overload on the following transformers.

TERMID2Y	345/345kV
TERMID1Y	345/345kV
TERMID2Y	345/115kV
TERMID1Y	345/115kV
SIOUXF1T	230/230kV

SIOUXF2T	230/230kV
SIOUXC3T	230/230kV
SIOUXC4T	230/230kV
OAHE 4	230/115kV
DENISON5	230/161kV
MINVALY7	230/115kV

Apart from the transformer overloads, the following transmission facilities are observed in the case of Mission site with 500 MW.

MNVLTAP4-GRANITF4	230 kV
NEAL 4 5-MONONA 5	161 kV
PLYMOTH5-LEMARST5	161 kV
LIT SX 5-LEMARST5	161 kV
NW FTDG5-POMEROY5	161 kV
PINE LK7-WILOWRV7	115 kV
AINSWRT7-STUART 7	115 kV
AINSWRT7-VALENTN7	115 kV
ATKINSN7-EMMET 7	115 kV
AURORA 7-GR ISLD7	115 kV
B.SPRGS7-BRULE 7	115 kV
BEVERLY7-ENDERS 7	115 kV
BRULE 7-OGALALA7	115 kV
CLRWATR7-NELIGH 7	115 kV
CLRWATR7-ONEILL 7	115 kV
EMMET 7-ONEILL 7	115 kV
HARMONY7-ST.FRANC	115 kV
HARMONY7-VALENTN7	115 kV
REDWILO7-STOCKVL7	115 kV
ST.FRANC-MISSION7	115 kV
BONESTL7-GREGORY7	115 kV
BONESTL7-FTRANDL7	115 kV
GREGORY7-WINNER 7	115 kV
MARTIN 7-VETALTP7	115 kV
MISSION7-WITTEN 7	115 kV
MISSION7-VETALTP7	115 kV
WINNER 7-WITTEN 7	115 kV

The FCITC values for each individual limiting criteria is tabulated in ***Appendix-D***.

3.6 Short Circuit Studies

Short-circuit studies are performed to calculate the impact of the proposed project on substation fault current levels for all seven sites on the winter peak cases. Three-phase symmetrical fault current levels are calculated at all study area buses both with and without the proposed project. In order to calculate fault current levels, classical fault assumptions were used with a pre-fault voltage of 1.0 pu. ***Appendix-E*** lists fault current levels at those buses where the increase in fault current levels are 100 A or more with the addition of the proposed project. The cases considered have 500 MW and 150 MW interconnected at each individual sites and Case 8 with the distributed 500 MW capacity over all seven sites.

Fault current levels are to be provided. The transmission owners can review the fault currents during the facilities study phase of this project and determine the need for any switchgear replacement. The fault current levels presented do not include the effects of fault current decay. It is to be noted that wind turbine generators comprising doubly-fed induction generator (DFIG) technology incorporate fast controls that rapidly restore the generator's terminal current to near its pre-fault level following a fault. As a result, the fault current contributions of DFIGs decay rapidly (the rate of decay is a function of the controller design) thereby affecting fault current levels at nearby substations. If the effects of DFIG current control are considered, the fault currents are expected to be smaller than those shown in ***Appendix-E***.

Fault current values more than 40 kA are marked “red”. All these buses are more than 40 kA in base case itself. Therefore not much impact is seen on the system as far as short circuit currents are concerned.

4. STABILITY ANALYSIS

The purpose of these analyses is to determine whether the MAPP system would meet stability criteria after commissioning of the proposed project. With that purpose, stability analysis of the MAPP system is performed with and without the new wind generation at seven individual sites considered and one case with interconnection at all sites.

Each site is modeled at the interconnection point to the existing system without any major system enhancements. Therefore, no enhancements to eliminate the violations obtained from the steady state analyses were included. The same conventions for case names used in the steady state analysis are also used in the stability analysis. The stability is conducted using the April 2004 MS Windows Version of the NMORWG Stability Package (UIP package). MAPP stability guidelines and constraints defined in UIP package are followed for the regional stability analysis. In case of local stability simulations, the critical line and transformer 3-phase faults near to the wind sites are studied. The stability is assessed based on the results obtained with and without new generation.

4.1 Case Development

Studies are carried out on the summer off-peak 2003 case (***ug4-so03aa.withbrdg.sav)*** with maximum simultaneous transfers on the interfaces of NDEX (≈1950MW), MHEX (≈2175MW), and MWSI (≈1480MW). The base case has a title:

```
UG4-SO03AA.SAV;SUMMER;OP LD;SYSTEM INTACT
ND=1950,MH=2173,MW=1476,OHMH=-196,OHMP=150,EWTW=-201,BD=165
```

The following steps were taken:

1. First, a pre-project stability model was developed to represent system conditions before the addition of the proposed wind farm. Power flow models and snapshots developed for the 2003 summer off-peak cases were used as a basis for developing the models for this study. Details of model development are provided in ***Appendix-F***.
2. Next, the proposed wind farm was added to the pre-project stability model at the respective locations in order to create the corresponding post-project models. The "setexports" iplan program from the UIP package redispatched the wind farm. Details pertaining to modeling of proposed wind farm are discussed in Section 3.1.
3. Finally, stability analysis was performed on the post-project stability models to determine the stability of new and existing units for various faults in the local area, as well as for regionally critical faults.

The developed cases are saved to retain the similar title as the basecase as explained in the section 1.1 of the report.

Example: C**10**-so03aa.uyvV4V4.sav represents 500MW (option "**0**") and site interconnection at Garrison (Location **1**).

The manufacturers recommended fault ride through capability of DFIG units with under voltage and frequency protection are considered in the modeling of the machines for dynamics. DFIGPQ6 model for 1.5MW GE DFIG, VTGTRP model for voltage relay and FRQTRP model for frequency relay are used for new wind generation dynamic simulations.

Stability studies at each of the wind sites are studied starting with 500 MW installed at each site and decreasing the wind generation until a level is reached where the system remains stable. The case nomenclature is listed in Table 4-1 below.

Table 4-1 Description of Stability Cases

Location	Interconnected Generation MW	Stability Case Name
Garrison	500	C10-so03aa.uyvV4V4
	375	C11-so03aa.uyvV4V4
	250	C12-so03aa.uyvV4V4
	150	C13-so03aa.uyvV4V4
	50	C14-so03aa.uyvV4V4
Pickert	500	C20-so03aa.uyvV4V4
	375	C21-so03aa.uyvV4V4
	250	C22-so03aa.uyvV4V4
	150	C23-so03aa.uyvV4V4
	50	C24-so03aa.uyvV4V4
Ellendale	500	C30-so03aa.uyvV4V4
	375	C31-so03aa.uyvV4V4
	250	C32-so03aa.uyvV4V4
	150	C33-so03aa.uyvV4V4
	50	C34-so03aa.uyvV4V4
New Underwood	500	C40-so03aa.uyvV4V4
	375	C41-so03aa.uyvV4V4
	250	C42-so03aa.uyvV4V4
	150	C43-so03aa.uyvV4V4
	50	C44-so03aa.uyvV4V4
Mission	250	C52-so03aa.uyvV4V4
	150	C53-so03aa.uyvV4V4
	50	C54-so03aa.uyvV4V4
Ft. Thompson	500	C60-so03aa.uyvV4V4
	375	C61-so03aa.uyvV4V4
	250	C62-so03aa.uyvV4V4
	150	C63-so03aa.uyvV4V4
	50	C64-so03aa.uyvV4V4
White	500	C70-so03aa.uyvV4V4
	375	C71-so03aa.uyvV4V4
	250	C72-so03aa.uyvV4V4
	150	C73-so03aa.uyvV4V4
	50	C74-so03aa.uyvV4V4
All Sites	100&49	C08-so03aa.uyvV4V4
Basecase	--	ug4-so03aa.uyvV4V5

Note: Interconnection possibility of 500 MW and 375 MW cases failed at Mission in steady state analysis.

4.2 Local Stability Analysis

The analysis of the impact of the proposed generator interconnection on local stability focused on the following two issues.

- To determine the stability of the proposed plant for disturbances near the point of interconnection.
- To determine if the proposed plant would adversely impact the stability of nearby generation facilities or system.

Three-Phase faults of 6 cycles are simulated on existing lines or transformers connected to interconnecting buses in order to evaluate local stability. These faults are cleared by tripping the faulted transmission branch. Tables compiled for the faults simulated, describe the dynamic bus voltage violations, system stability and tripped units in the system for respective faults. Individual cases are compared with the base case results for the same faults. Plots showing results of the system's important bus angles and machine rotor angles and proposed wind generation are attached in ***Appendix-G***. All faults are simulated at 0.1sec and cleared at 0.2sec (6 cycles). All simulations are run for 5 seconds.

4.2.1 Interconnection at Garrison 230 kV

The local faults considered for this site are shown in Figure 4-1. Initially, stability runs are performed for 500 MW at the Garrison site and the results indicate that there are no significant impacts in the stability of the system (see below Table 4-2). The system response remains the same as in base case.

Based on the manufacturer's recommended under voltage trip settings, the proposed wind generation tripped for all the close 230-kV faults simulated. The wind generation did not trip for the local 115-kV fault. The same results are recorded with different generation levels at the Garrison site. The interconnection of 500 MW of wind generation at Garrison does not adversely impact local stability.

The stability runs for other generation level interconnections are tabulated in ***Appendix-H*** for all the cases.

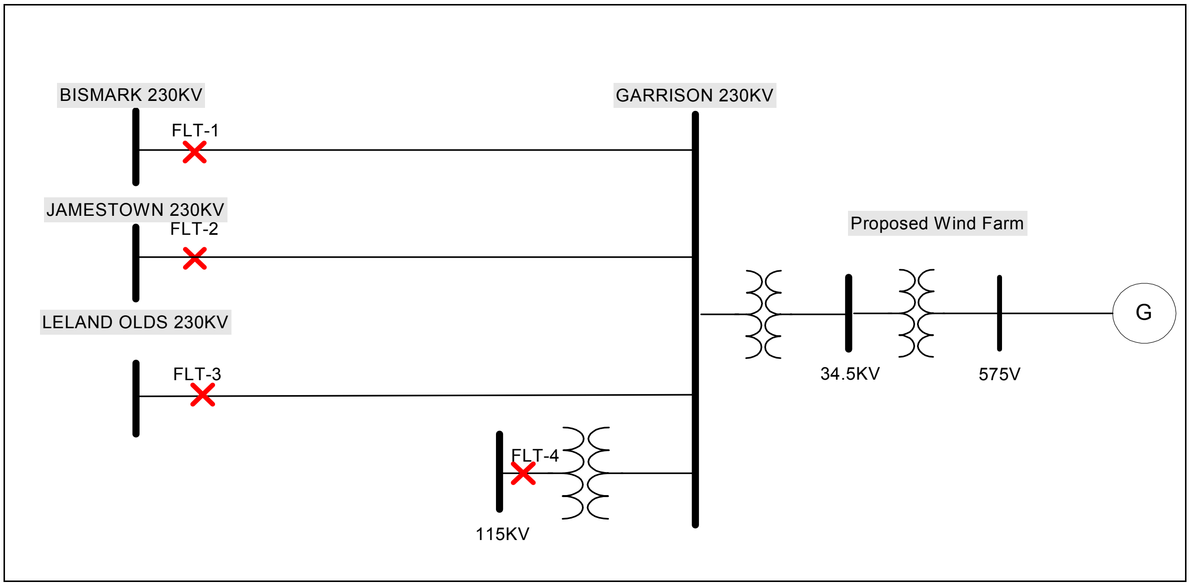

Figure 4-1 Local Faults for Garrison 230-kV Interconnection

Table 4-2 Local Fault Summary at Garrison 500 MW Interconnection

Fault Location	Fault Name	Fault Description	Without DFIG	With DFIG
FLT-1	da3	6 cycle 3 phase fault at Bismark 230kV bus, clear the Garrison to Bismark 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Unit 1 at 90100 [GARR-500 0.5750] t =0.2833
FLT-2	db3	6 cycle 3 phase fault at Jamestown 230kV bus, clear the Garrison to Jamestown 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Unit 1 at 90100 [GARR-500 0.5750] t =0.2833
FLT-3	dc3	6 cycle 3 phase fault at Leland Olds 230kV bus, clear the Garrison to Leland Olds 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Unit 1 at 90100 [GARR-500 0.5750] t =0.2833
FLT-4	Dps	6 cycle 3 phase fault at Garrison 115kV bus, clear by tripping 230/115kV transformer	66442 [GARRISN7] 0.52 66449 [MAX 7] 0.66 System Stable Trippings: None	66442 [GARRISN7] 0.66 System Stable Trippings: None

4.2.2 Interconnection at Pickert 230 kV

The local faults considered for this site are shown in Figure 4-2. Interconnecting of 500 MW of wind generation at Pickert indicates that there is no significant impact to the local stability of the system. System results are similar to the base case. The proposed wind generation tripped for all the faults simulated based on the manufacturers recommended under voltage trip settings. The same results are recorded with different generation capacity at this site. It can be concluded that interconnection of 500 MW of wind generation at Pickert does not adversely impact local stability.

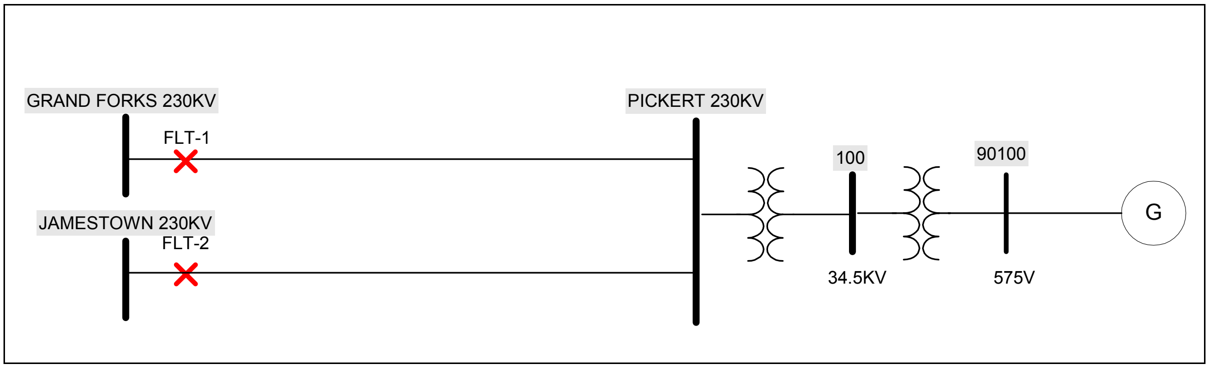

Figure 4-2 Local Faults for Pickert 230-kV Interconnection

4.2.3 Interconnection at Leland Olds-Groton Tap (Ellendale) 345 kV

The Leland Olds – Groton 345-kV line is one of the major transmission lines in the interface defined as NDEX. The NDEX limit set by running the "setexports" iplan program from the UIP package and is assigned a value such that the total flow on the interface remains 1950 MW after the addition of the new plant at Ellendale (Tap on Leland Olds- Groton 345-kV line).

The set of local faults proposed to study the local stability of this interconnection and are shown in Figure 4-3. The system is unstable for 6-cycle faults as follows: dg3 for the base case, dh3 for all cases, and di3 for all wind levels. These faults are repeated with a 4-cycle fault, which is more typical for a 345-kv fault, and labeled dx3, dy3, and dz3 respectively. For fault dg3, a 6-cycle fault at the Groton 345kV bus and clearing the Leland-Groton 345-kV line, the base case is unstable. However, with the wind generation added, NDEX is readjusted to maintain 1950 MW. For close faults such as at Groton the wind generation is tripped which results in a more stable case.

With these three faults at 4 cycles and the rest at 6 cycles, the results indicate no instability and no dynamic voltage violations. System results for all wind generation levels at this site are stable. There are some voltage violations in the base case and the violations become worse as the wind generation at Ellendale increases. Dynamic reactive power compensation such as an SVC will prevent these voltage violations. Therefore the interconnection of up to 500 MW of wind generation at Ellendale does not adversely impact local stability, but dynamic reactive power support may be needed depending on the level of generation at Ellendale.

Table 4-3 lists the definitions of local faults at Ellendale. The Table 4-4 describes the local stability results for various generation levels interconnecting at Ellendale.

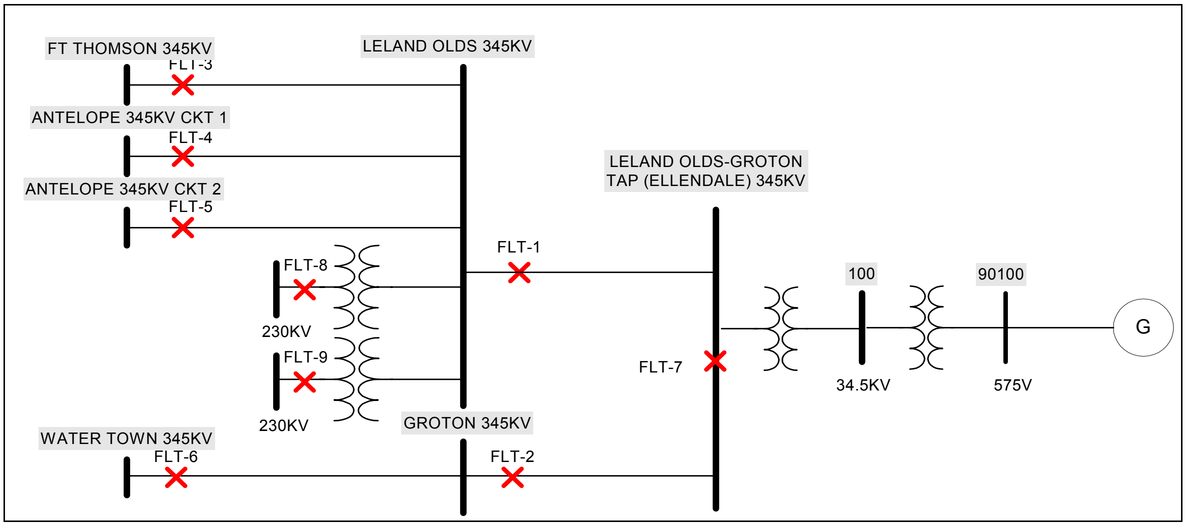

Figure 4-3 Local Faults for Leland Olds-Groton Tap (Ellendale) 345-kV Interconnection

Table 4-3 List of Local fault definitions for Ellendale Interconnection

Fault Location	Fault Name	Fault Description
FLT-1	df3	6 cycle 3 phase fault at Leland Olds 345kV bus, clear the Leland-Groton Tap to Leland Olds 345kV line
FLT-2	dg3	6 cycle 3 phase fault at Groton 345kV bus, clear the Leland-Groton tap to Groton 345kV line
FLT-3	dh3	6 cycle 3 phase fault at Ft. Thomson 345kV bus, clear the Leland Olds to Ft. Thomson 345kV line
FLT-4	di3	6 cycle 3 phase fault at Antelope 345kV bus, clear the Leland Olds to Antelope 345kV line 1
FLT-5	dj3	6 cycle 3 phase fault at Antelope 345kV bus, clear the Leland Olds to Antelope 345kV line 2
FLT-6	dk3	6 cycle 3 phase fault at Watertown 345kV bus, clear the Groton to Watertown 345kV line
FLT-7	dq3	6 cycle 3 phase fault at Groton 345kV bus, clear by tripping Leland Olds-Groton 345kV line (both side of tap)
FLT-8	drs	6 cycle 3 phase fault at Leland Olds 230kV bus, clear by tripping 345/230kV transformer 1
FLT-9	dss	6 cycle 3 phase fault at Leland Olds 230kV bus, clear by tripping 345/230kV transformer 2
FLT-2	dx3	4 cycle 3 phase fault at Groton 345kV bus, clear the Leland-Groton tap to Groton 345kV line
FLT-3	dy3	4 cycle 3 phase fault at Ft. Thomson 345kV bus, clear the Leland Olds to Ft. Thomson 345kV line
FLT-4	dz3	4 cycle 3 phase fault at Antelope 345kV bus, clear the Leland Olds to Antelope 345kV line 1

Table 4-4 Local Stability Simulation Results

Fault Name	Basecase	500 MW interconnection	375 MW interconnection	250 MW interconnection	150 MW interconnection	50 MW interconnection
df3	Not Tested	No Voltage Violations System Stable 90100 [LELN-5000.5750] t =0.2833	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750
dg3	67233 [DGCX4 T] 0.60 67395 [WISHEK 7] 0.64 67120 [HURON 3] 0.64 67394 [WISHEK 4] 0.65 67326 [ELLENDL4] 0.67 63199 [JAMSTN1Y] 0.67 63200 [JAMSTN2Y] 0.67 +more System Unstable Trippings None	No Voltage Violations System Stable 90100 [LELN-5000.5750] t =0.2833	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750
dh3	67233 [DGCX4 T] 0.59 67160 [GROTON 3] 0.65 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.66 66534 [ORDWAY 7] 0.66 67120 [HURON 3] 0.66 67395 [WISHEK 7] 0.66 +more System Unstable Trippings None	67160 [LELAND03] 0.51 67233 [DGCX4 T] 0.54 67222 [AVSD11TY] 0.65 67395 [WISHEK 7] 0.66 1111 [GROTON 3] 0.66 67120 [HURON 3] 0.66 67394 [WISHEK 4] 0.66 +more System Unstable 90100 [LELN-5000.5750] t =0.3000	67160 [LELAND03] 0.52 67233 [DGCX4 T] 0.55 1111 [GROTON 3] 0.65 67222 [AVSD11TY] 0.66 67395 [WISHEK 7] 0.66 67394 [WISHEK 4] 0.66 67203 [GROTONTY] 0.67 +more System Unstable 90100 [HDR_GEN 0.5750] t =0.2917	67160 [LELAND03] 0.53 67233 [DGCX4 T] 0.56 1111 [GROTON 3] 0.66 67203 [GROTONTY] 0.66 67395 [WISHEK 7] 0.66 67120 [HURON 3] 0.67 66512 [GROTON 7] 0.67 +more System Unstable 90100 [HDR_GEN 0.5750] t =0.2917	67160 [LELAND03] 0.53 67233 [DGCX4 T] 0.57 1111 [GROTON 3] 0.66 67203 [GROTONTY] 0.67 67395 [WISHEK 7] 0.67 66512 [GROTON 7] 0.67 66534 [ORDWAY 7] 0.67 +more System Unstable 90100 [HDR_GEN 0.5750] t =0.3000	67160 [LELAND03] 0.55 67233 [DGCX4 T] 0.59 1111 [GROTON 3] 0.65 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.67 66534 [ORDWAY 7] 0.67 67120 [HURON 3] 0.67 +more System Unstable 90100 [HDR_GEN 0.5750] t =0.5916
di3	67233 [DGCX4 T] 0.62 System Stable Trippings None	No Voltage Violations System Unstable Trippings None	No Voltage Violations System Unstable Trippings None	No Voltage Violations System Unstable Trippings None	No Voltage Violations System Unstable Trippings None	No Voltage Violations System Unstable Trippings None
dj3	67233 [DGCX4 T] 0.62 System Stable Trippings None	67233 [DGCX4 T] 0.55 67160 [LELAND03] 0.57 67222 [AVSD11TY] 0.66 67105 [LELANDO3] 0.66 67230 [DGCX3 T] 0.68 67201 [LELND1TY] 0.68 67120 [HURON 3] 0.68 +more System Unstable 90100 [LELN-5000.5750] t =0.3000	67233 [DGCX4 T] 0.57 67160 [LELAND03] 0.59 67105 [LELANDO3] 0.68 67222 [AVSD11TY] 0.69 67120 [HURON 3] 0.69 System Unstable 90100 [HDR_GEN 0.5750] t =0.2917	67233 [DGCX4 T] 0.59 67160 [LELAND03] 0.61 System Unstable 90100 [HDR_GEN 0.5750] t =0.2917	67233 [DGCX4 T] 0.61 67160 [LELAND03] 0.62 System Unstable 90100 [HDR_GEN 0.5750] t =0.3000	67233 [DGCX4 T] 0.63 67160 [LELAND03] 0.64 System Unstable 90100 [HDR_GEN 0.5750] t =0.6250
dk3	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable 90100 [LELN-5000.5750] t =0.3167	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.3583	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
dq3	Not Tested	No Voltage Violations System Stable 90100 [LELN-5000.5750] t =0.2833	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750	No Voltage Violations System Stable 90100 [HDR_GEN 0.5750] t =0.2750
drs	67233 [DGCX4 T] 0.65	67233 [DGCX4 T] 0.57	67233 [DGCX4 T] 0.60	67233 [DGCX4 T] 0.62	67160 [LELAND03] 0.62	67233 [DGCX4 T] 0.65

Fault Name	Basecase	500 MW interconnection	375 MW interconnection	250 MW interconnection	150 MW interconnection	50 MW interconnection
	System Stable Trippings None	67160 [LELAND03] 0.58 67222 [AVSD11TY] 0.67 67105 [LELANDO3] 0.68 67230 [DGCX3 T] 0.69 System Stable 90100 [LELN-5000.5750] t =0.2917	67160 [LELAND03] 0.61 67222 [AVSD11TY] 0.69 System Stable 90100 [HDR_GEN 0.5750] t =0.2917	67160 [LELAND03] 0.63 System Stable 90100 [HDR_GEN 0.5750] t =0.2917	67233 [DGCX4 T] 0.64 1111 [GROTON 3] 0.69 System Stable 90100 [HDR_GEN 0.5750] t =0.6000	67160 [LELAND03] 0.66 System Stable
dss	67233 [DGCX4 T] 0.66 System Stable Trippings None	67233 [DGCX4 T] 0.57 67160 [LELAND03] 0.59 67222 [AVSD11TY] 0.67 67105 [LELANDO3] 0.68 67230 [DGCX3 T] 0.69 System Stable 90100 [LELN-5000.5750] t =0.3083	67233 [DGCX4 T] 0.61 67160 [LELAND03] 0.62 System Stable 90100 [HDR_GEN 0.5750] t =0.3000	67233 [DGCX4 T] 0.63 67160 [LELAND03] 0.64 System Stable 90100 [HDR_GEN 0.5750] t =0.3000	67160 [LELAND03] 0.64 67233 [DGCX4 T] 0.65 System Stable 90100 [HDR_GEN 0.5750] t =0.6000	90100 [HDR_GEN 0.5750] t =0.6333 67233 [DGCX4 T] 0.66 67160 [LELAND03] 0.67 System Stable 90100 [HDR_GEN 0.5750] t =0.6333
dx3	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable 90100 [LELN-5000.5750] t = 0.2833	Not Tested	Not Tested	Not Tested	Not Tested
dy3	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable 90100 [LELN-5000.5750] t= 0.3000	Not Tested	Not Tested	Not Tested	Not Tested
dz3	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable 90100 [LELN-5000.5750] t = 0.3000	Not Tested	Not Tested	Not Tested	Not Tested

4.2.4 Interconnection at New Underwood 230 kV

Local faults considered for this site are shown in Figure 4-4. The description of the faults and stability results are summarized in Table 4-5 for the New Underwood site. These tables describe dynamic bus voltage violations, system stability and unit tripping for respective faults. The proposed wind generation tripped for all the faults simulated based on the manufacturers recommended under voltage trip settings.

With high levels of wind generation at the New Underwood site (see subsections below), the system doesn't converge due to lower voltages at the Rapid City DC during faults. Due to this, the simulations have the DC line tripped during the fault. With this remedial action, the system is stable for all line faults with no dynamic voltage violations. The interconnection of up to 500 MW of wind generation at the New Underwood site does not adversely impact local stability when the DC is tripped.

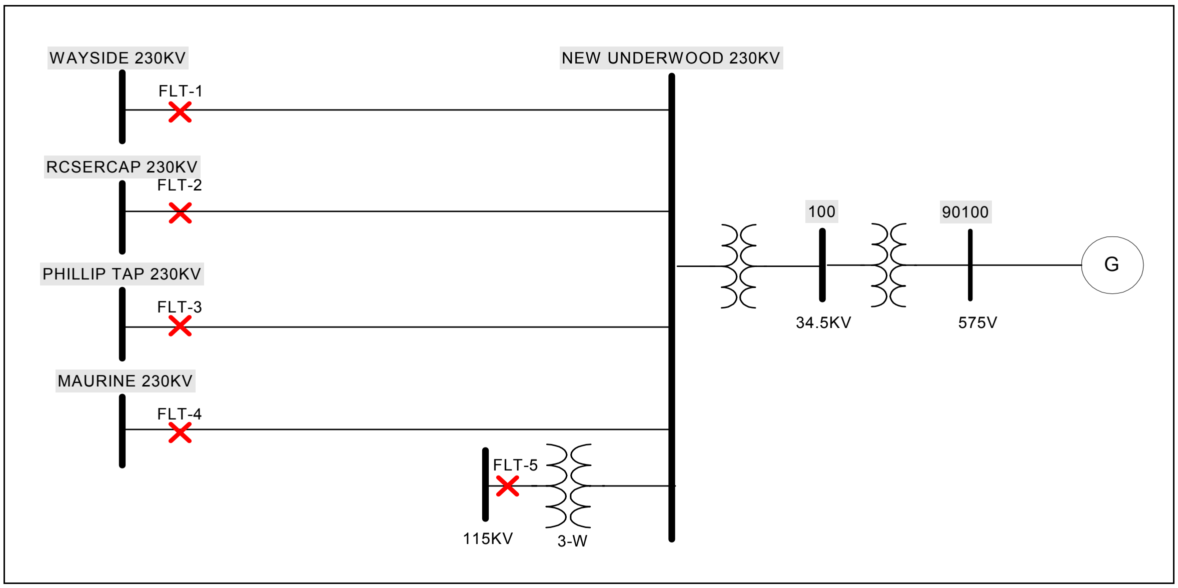

Figure 4-4 Local Faults for New Underwood 230-kV Interconnection

Table 4-5 Local Fault Summary at New Underwood 500 MW Interconnection

Fault Location	Fault Name	Fault Description	Without DFIG	With DFIG
FLT-1	Dls	6 cycle 3 phase fault at Wayside 230kV bus and disconnection of RCDC line, clear the New Underwood to Wayside 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable [3999] Unit1 at 90100 [NUND-5000.5750] t = 0.3167
FLT-2	Dms	6 cycle 3 phase fault at Rcsercap 230kV bus and disconnection of RCDC line, clear the New Underwood to Wayside 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable [3960] Unit 1 at 90100 [NUND-5000.5750] t = 0.2917
FLT-3	Dns	6 cycle 3 phase fault at Pillips tap 230kV bus and disconnection of RCDC line, clear the New Underwood to Pillips tap 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable [4014] Unit 1 at 90100 [NUND-5000.5750] t = 0.3000
FLT-4	Dos	6 cycle 3 phase fault at Maurine 230kV bus and disconnection of RCDC line, clear the New Underwood to Maurine 230kV line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable [3986] Unit 1 at 90100 [NUND-5000.5750] t = 0.3083
FLT-5	Dts	6 cycle 3 phase fault at New Underwood 115kV bus, clear by tripping 230/115/13.8kV 3-Winding transformer	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable [4172] Unit 1 at 90100 [NUND-5000.5750] t = 0.3000

4.2.5 Interconnection at Mission 115 kV

Interconnecting new wind generation at Mission at the 500 MW and 375 MW has been shown to not be feasible from the steady state analysis unless significant transmission is added. Therefore, this analysis for Mission site starts with 250 MW of wind generation. Local faults considered for this site are shown in Figure 4-5. The description of the faults and stability results are summarized in Table 4-6.

The system remains stable for all generation levels at Mission starting from 250 MW. With 50 MW, the proposed wind generation is not tripped where at higher levels it is tripped. The interconnection of up to 250 MW of wind generation at the Mission site does not adversely impact local stability.

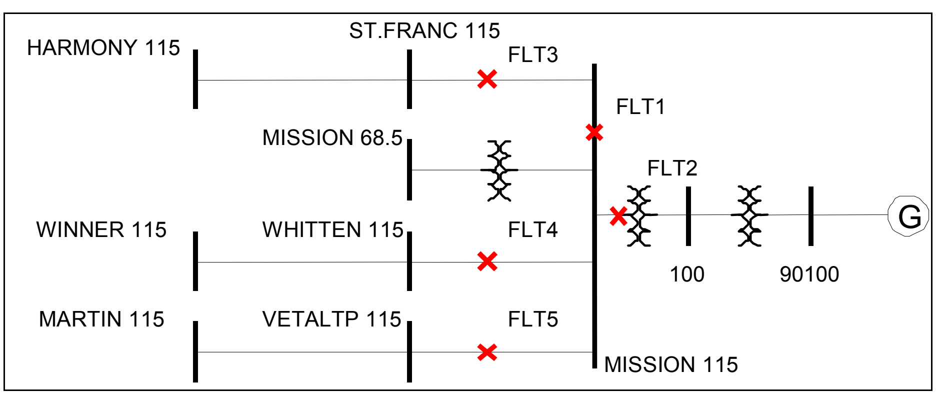

Figure 4-5 Local Faults for Mission 115-kV Interconnection

Table 4-6 Local Fault Summary at Mission 250MW Interconnection

Fault Location	Fault Name	Fault Description	Without DFIG	With DFIG
FLT-1	hms	6 Cycle 3 phase fault @ Mission 115kV, Clear the fault	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [3650] Unit 1 at 90100 [HDR_GEN 0.5750] t = 0.2750
FLT-2	his	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Wind generating stn. Transformer 34.5/115 kV	---NA---	No Voltage Violations System Stable [3796] Unit 1 at 90100 [HDR_GEN 0.5750] t = 0.2750
FLT-3	Hj3	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Mission – St.Franc line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [3637] Unit 1 at 90100 [HDR_GEN 0.5750] t= 0.3000
FLT-4	Hk3	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Mission – Whitten line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [3653] Unit 1 at 90100 [HDR_GEN 0.5750] t = 0.3000
FLT-5	Hl3	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Mission – Vetaltp line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [3646] Unit 1 at 90100 [HDR_GEN 0.5750] t = 0.3000

4.2.6 Interconnection at Fort Thompson 345 kV

Local faults considered for generator Interconnection at Ft Thompson are shown in Figure 4-6. The description of the faults and stability results are summarized below.

Based on the results of local stability analysis, the interconnection of 500 MW at Ft Thompson is feasible. The fault "hd3" in Table 4-7 indicates the system is unstable for a 6-cycle fault on the 345-kV system so the case was rerun with a 4-cycle fault and was stable. The wind generation was not tripped for any of the local faults.

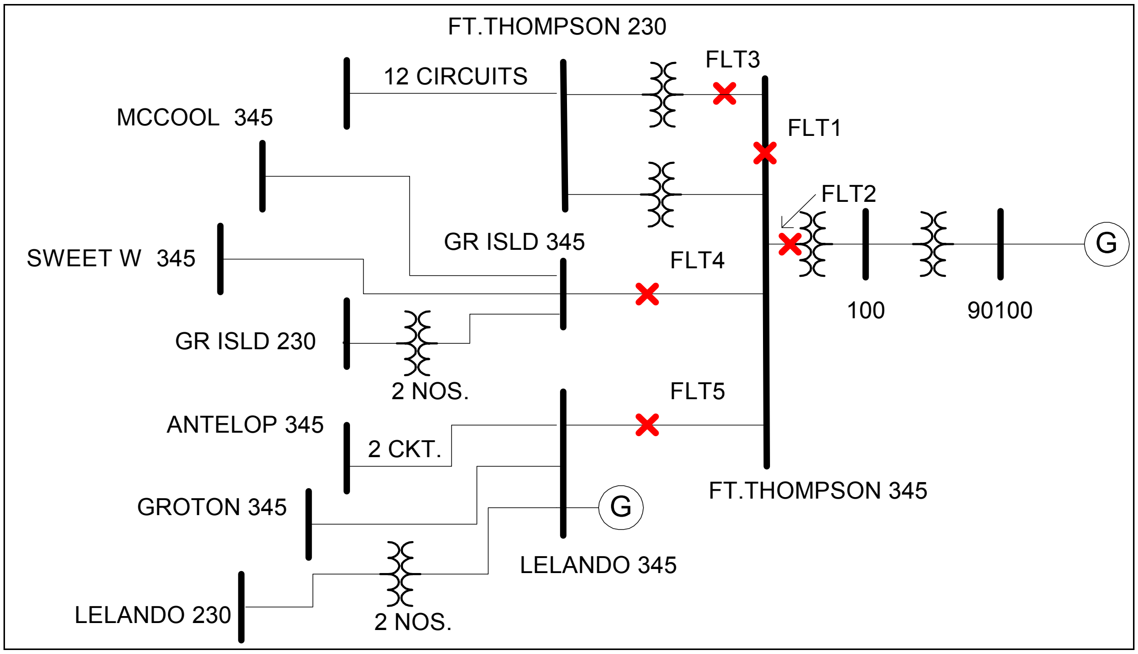

Figure 4-6 Local Faults for Ft. Thomson 345-kV Interconnection

Table 4-7 Local Fault Summary at Ft. Thompson 500 MW Interconnection

Fault Location	Fault Name	Fault Description	Without DFIG	With DFIG
FLT-1	hes	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear the fault	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Trippings: None
FLT-2	Has	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Wind Generating Stn. Transformer 345/115 kV	---NA---	No Voltage Violations System Stable Trippings None
FLT-3	hbs	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson 345/230 kV transformer	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Trippings: None
FLT-4	hc3	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson – Gr Isld line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Trippings: None
FLT-5	hd3	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson – Lelando line	67233 [DGCX4 T] 0.59 67160 [GROTON 3] 0.65 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.66 66534 [ORDWAY 7] 0.66 67120 [HURON 3] 0.66 67395 [WISHEK 7] 0.66 +more System Unstable Trippings: None	67233 [DGCX4 T] 0.60 67160 [GROTON 3] 0.63 66512 [GROTON 7] 0.64 67203 [GROTONTY] 0.64 66534 [ORDWAY 7] 0.64 67401 [ABDNJCT7] 0.65 67402 [ABDNSBT7] 0.65 +more System Unstable Trippings: None
FLT-6	hf3	4 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson – Lelando line	No Voltage Violations System Stable Trippings: None	No Voltage Violations System Stable Trippings: None

4.2.7 Interconnection at White 345 kV

The White Station is one of the major outlets for the Buffalo Ridge wind generation. The cases used to run stability have significant amount of wind generation near this area. The local faults considered for this site are shown in

Figure 4-7. The description of the faults and stability results are summarized in Table 4-8.

The system is stable for all faults and no dynamic voltage violations are recorded. It is important to note that the wind generation at the Yankee station is directly connected to the White Substation and it is tripped in the base cases as well as tripped in most cases with the new wind generation. The new wind generation has little impact on the unit tripping of the Yankee Wind generators. The interconnection of up to 500 MW of wind generation at the White site does not adversely impact local stability.

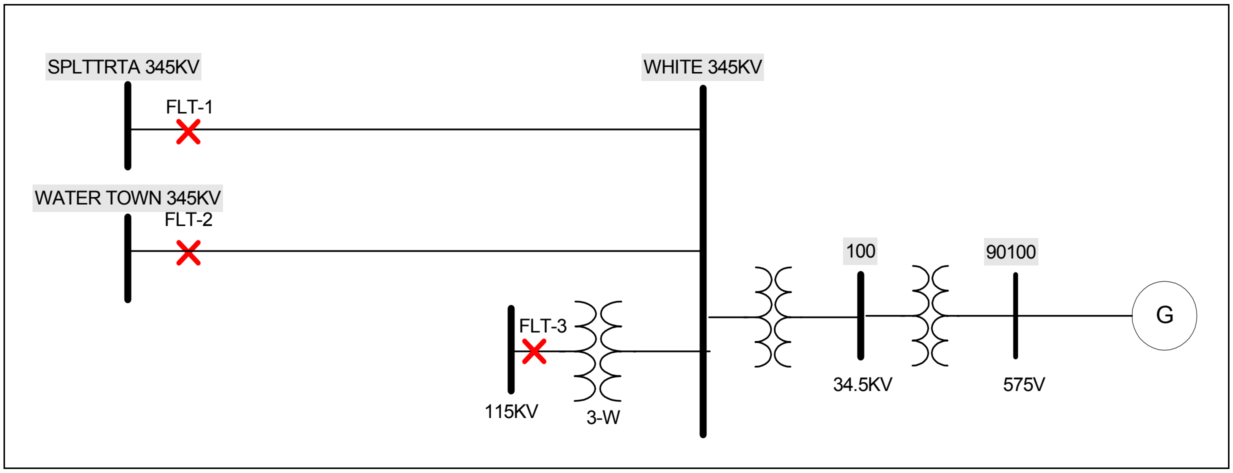

Figure 4-7 Local Faults for White 345-kV Interconnection

Table 4-8 Local Fault Summary at White 500 MW Interconnection

Fault Location	Fault Name	Fault Description	Without DFIG	With DFIG
FLT-1	du3	6 cycle 3 phase fault at SPLTRTA 345kV bus, clear by tripping White-SPLTRTA 345kV line	No Voltage Violations System Stable [3762] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250	No Voltage Violations System Stable [3803] Unit 1 at 90100 [WHIat-5000.5750] t =0.2833 [3873] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250
FLT-2	dv3	6 cycle 3 phase fault at Water Town 345kV bus, clear by tripping White-Water Town 345kV line	No Voltage Violations System Stable [3758] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250	No Voltage Violations System Stable [3796] Unit 1 at 90100 [WHIat-5000.5750] t =0.2833 [3863] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250
FLT-3	dws	6 Cycle fault at White 115kV bus, Clear by tripping 345/115/13.8kV 3-Winding Transformer	No Voltage Violations System Stable [4062] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.2833	No Voltage Violations System Stable [4055] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.2833

4.2.8 Interconnection a Total of 500 MW at Seven Sites

In this option, 100 MW of new wind generation is connected at each of three sites: Garrison, Ft. Thompson and White respectively; and 50 MW each at other four sites. Since 50 MW is connected at Ellendale on the Leland Olds to Groton 345 kV which is one of the NDEX interfacing lines, The NDEX is set to 1900 MW by the “setexports” program such that total NDEX including proposed wind generation is 1950 MW. Local faults considered for all seven individual sites are studied for this option. The description of the faults and stability results are summarized in Table 4-9 below.

All the simulations where the system is unstable for 6-cycles 345-kV faults (*dg3, dh3, di3 and hd3)* are rerun with 4 cycle faults and no violations are recorded.

Results indicate that the system results following the local faults will not cause system instability and no bus voltage violations. Generator unit tripping is found for the Yankee wind generation, but it also recorded in the base case. It can be concluded that impact of this option of interconnection will not adversely impact system dynamic performance for local faults.

Table 4-9 Local Fault Summary at Distributed Interconnection of 500 MW Over all Seven Sites

Fault Location	Fault Name	Fault Description	Without DFIG	With DFIG
Garrison 230Kv				
FLT-1	da3	6 cycle 3 phase fault at Bismark 230kV bus, clear the Garrison to Bismark 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [4192] Unit 1 at 90100 [GARR-1000.5750] t =0.2833
FLT-2	db3	6 cycle 3 phase fault at Jamestown 230kV bus, clear the Garrison to Jamestown 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [4137] Unit 1 at 90100 [GARR-1000.5750] t =0.2833
FLT-3	dc3	6 cycle 3 phase fault at Leland Olds 230kV bus, clear the Garrison to Leland Olds 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable [4208] Unit 1 at 90100 [GARR-1000.5750] t =0.2833
FLT-4	dps	6 cycle 3 phase fault at Garrison 115kV bus, clear by tripping 230/115kV transformer	66442 [GARRISN7] 0.52 66449 [MAX 7] 0.66 System Stable Trippings None	No Voltage Violations System Stable Trippings None
Pickert 230kV				
FLT-1	dd3	6 cycle 3 phase fault at Grand Fks 230kV bus, clear the Pickert to Grand Fks 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-2	de3	6 cycle 3 phase fault at Jamestown 230kV bus, clear the Pickert to Jamestown 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
Leland Olds- Groton Tap (Ellendale) 345kV				
FLT-1	df3	6 cycle 3 phase fault at Leland Olds 345kV bus, clear the Leland-Groton tap to Leland Olds 345kV line	Not Tested	No Voltage Violations System Stable Trippings None
FLT-2	dg3	6 cycle 3 phase fault at Groton 345kV bus, clear the Leland-Groton tap to Groton 345kV line	67233 [DGCX4 T] 0.60 67395 [WISHEK 7] 0.64 67120 [HURON 3] 0.64 67394 [WISHEK 4] 0.65 67326 [ELLENDL4] 0.67 63199 [JAMSTN1Y] 0.67 63200 [JAMSTN2Y] 0.67 +more System Unstable Trippings None	No Voltage Violations System Stable Trippings None
FLT-3	dh3	6 cycle 3 phase fault at Ft. Thomson 345kV bus, clear the Leland Olds to Ft. Thomson 345kV line	67233 [DGCX4 T] 0.59 67160 [GROTON 3] 0.65 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.66 66534 [ORDWAY 7] 0.66	67233 [DGCX4 T] 0.58 1111 [GROTON 3] 0.64 66512 [GROTON 7] 0.65 67203 [GROTONTY] 0.65 66534 [ORDWAY 7] 0.66

			67120 [HURON 3] 0.66 67395 [WISHEK 7] 0.66 +more System Unstable Trippings None	67120 [HURON 3] 0.66 67395 [WISHEK 7] 0.67 +more System Unstable Trippings None
FLT-4	di3	6 cycle 3 phase fault at Antelope 345kV bus, clear the Leland Olds to Antelope 345kV line 1	67233 [DGCX4 T] 0.62 System Stable Trippings None	No Voltage Violations System Unstable Trippings None
FLT-5	dj3	6 cycle 3 phase fault at Antelope 345kV bus, clear the Leland Olds to Antelope 345kV line 2	67233 [DGCX4 T] 0.62 System Stable Trippings None	67233 [DGCX4 T] 0.61 1111 [GROTON 3] 0.68 67120 [HURON 3] 0.69 67203 [GROTONTY] 0.69 66512 [GROTON 7] 0.69 67402 [ABDNSBT7] 0.69 67401 [ABDNJCT7] 0.69 System Unstable Trippings None
FLT-6	dk3	6 cycle 3 phase fault at Watertown 345kV bus, clear the Groton to Watertown 345kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-7	dq3	6 cycle 3 phase fault at Groton 115kV bus, clear by tripping Leland Olds-Groton 345kV line (both side of tap)	Not Tested	No Voltage Violations System Stable Trippings None
FLT-8	drs	6 cycle 3 phase fault at Leland Olds 345kV bus, clear by tripping 345/230kV tansformer	67233 [DGCX4 T] 0.65 System Stable Trippings None	67233 [DGCX4 T] 0.64 System Unstable Trippings None
FLT-9	dss	6 cycle 3 phase fault at Leland Olds 345kV bus, clear by tripping 345/230kV tansformer	67233 [DGCX4 T] 0.66 System Stable Trippings None	67233 [DGCX4 T] 0.65 System Unstable Trippings None
FLT-2	dx3	4cycle 3 phase fault at Groton 345kV bus, clear the Leland-Groton tap to Groton 345kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-3	dy3	4 cycle 3 phase fault at Ft. Thomson 345kV bus, clear the Leland Olds to Ft. Thomson 345kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-4	dz3	4 cycle 3 phase fault at Antelope 345kV bus, clear the Leland Olds to Antelope 345kV line 1	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
New Underwood 230kV				
FLT-1	dls	6 cycle 3 phase fault at Wayside 230kV bus and disconnection of RCDC line, clear the New Underwood to Wayside 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-2	dms	6 cycle 3 phase fault at Rcsercap 230kV bus and disconnection of RCDC line, clear the New Underwood to Wayside 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-3	dns	6 cycle 3 phase fault at Pillips tap 230kV bus and disconnection of RCDC line, clear the New Underwood to Pillips tap 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-4	dos	6 cycle 3 phase fault at Maurine 230kV bus and disconnection of RCDC line, clear the New Underwood to Maurine 230kV line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-5	dts	6 cycle 3 phase fault at New Underwood 115kV bus, clear by tripping 230/115/13.8kV 3-Winding tansformer	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
Mission 115kV				
FLT-1	hms	6 Cycle 3 phase fault @ Mission 115kV, Clear the fault	No Voltage Violations System Stable Trippings None	Not tested
FLT-2	his	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Wind generating stn. Transformer 34.5/115 kV	---NA---	No Voltage Violations System Stable Trippings None
FLT-3	hj3	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Mission – St.Franc line	No Voltage Violations System Stable	No Voltage Violations System Stable

			Trippings None	Trippings None
FLT-4	hk3	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Mission – Whitten line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-5	hl3	6 Cycle 3 phase fault @ Mission 115kV, Clear fault by tripping Mission – Vetaltp line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
Ft. Thomson 345kV				
FLT-1	hes	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear the fault	No Voltage Violations System Stable Trippings None	Not tested
FLT-2	has	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Wind generating stn. Transformer 34.5/115 kV	---NA---	No Voltage Violations System Stable Trippings None
FLT-3	hbs	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson 345/230 kV transformer	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-4	hc3	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson – Gr Isld line	No Voltage Violations System Stable Trippings None	No Voltage Violations System Stable Trippings None
FLT-5	hd3	6 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson – Lelando line	67233 [DGCX4 T] 0.59 67160 [GROTON 3] 0.65 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.66 66534 [ORDWAY 7] 0.66 67120 [HURON 3] 0.66 67395 [WISHEK 7] 0.66 +more System Unstable Trippings None	67233 [DGCX4 T] 0.58 1111 [GROTON 3] 0.64 66512 [GROTON 7] 0.65 67203 [GROTONTY] 0.65 66534 [ORDWAY 7] 0.66 67120 [HURON 3] 0.66 67395 [WISHEK 7] 0.67 +more System Unstable Trippings None
FLT-6	hf3	4 Cycle 3 phase fault @ Ft.Thompson 345kV, Clear fault by tripping Ft.Thompson – Lelando line	No Voltage Violations System Stable Trippings None	Same as dx3
White 345kV				
FLT-1	du3	6 cycle 3 phase fault at SPLTRTA 345kV bus, clear by tripping White-SPLTRTA 345kV line	No Voltage Violations System Stable [3762] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250	No Voltage Violations System Stable [3797] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250
FLT-2	dv3	6 cycle 3 phase fault at Water Town 345kV bus, clear by tripping White-Water Town 345kV line	No Voltage Violations System Stable [3758] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250	No Voltage Violations System Stable [3774] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.3250
FLT-3	dws	6 Cycle fault at White 115kV bus, Clear by tripping 345/115/13.8kV 3-Winding Transformer	No Voltage Violations System Stable [4062] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.2833	No Voltage Violations System Stable [4059] Unit 1 at 90714 [YNKEDFIG0.5750] t =0.2833

4.3 Regional Stability Analysis

The objective of the regional stability assessment is to determine the impact of the proposed new wind generation on the regional stability performance of the bulk power system. Maximum simultaneous NDEX (≈1950MW), MHEX (≈2175MW), and MWSI (≈1480MW) transfer levels are adjusted in all the case scenarios with non firm transfers and no limits on the interfaces in the firm transfer cases. In case of interconnection at a tap on the Leland Olds-Groton 345-kV line, (NDEX interfacing line) NDEX export is reduced by proposed wind generation capacity by "setexports" program such that total interface flow remains at 1950MW. Report files from the UIP stability package for all the cases are given in ***Appendix-I***.

Following are the standard faults from the UIP package that are critical to regional stability and are considered for regional stability assessment.

1. **ag1** 4 cy slgf @ l.old 345 on ft.thomp line, lo brkr 2692 stkclr @ 11 cy by tripping fltd line.
2. **ei2** Permanent bipole fault on the CU dc line, both coal creek units tripped at 0.28 sec.
3. **nbz** 4 cycle, three phase fault at chisago county trip f601ccross trip d602f, use new 100% reduction init from chisago.
4. **nmz** 4 cycle, three phase fault at chisago county trip f601ccross trip 602f, use new 100% reduction init from chisago, leave SVC on MP system.
5. **pcs** slg fault at king-eau claire line with a breaker failure at king trips king ecl,ecl-arp, and ask-chi line.

The faults are simulated for the base case and the cases with new wind generation at each site in order to assess individual interconnections. ***Appendix-J*** shows all the plots for the regional stability analysis on all cases. The tables listed in the subsequent sections include dynamic bus voltage violations, unit tripping during simulations, and system stability/instability for the given fault and case.

It is important to note that the results of this study depend significantly on delivery assumptions of prior-queued generator interconnections that were included in the study models. The MISO Group 2 generation plus the transmission studied in Group 2 are included in the system model. Including these proposed projects in the study seems to severely stress the transmission system due to limited reinforcements being applied for delivery components of prior-queued generators. The prior-queued projects identified as Group 2 are mostly wind generation in southwest Minnesota and northwestern Iowa. The MISO report on these facilities is titled "*Coordinated Interconnection Studies #2*: *Sensitivity Studies to Resolve Local and Regional Stability Limitations – Draft Final Report,* Prepared by ABB Inc., February 2, 2005".

The Group 2 generation level is 825 MW and the following transmission additions, enhancements, and upgrades are made to accommodate the Grouop 2 wind generation.

- Split Rock-Nobles Co.-Lakefield Junction 345 kV – 94 miles new line
- Nobles Co 345/115 kV Sub – New sub with 448 MVA tx+Nobles Co-Fenton-
- Chanarambie 115 kV
- Buffalo Ridge-Yankee-White 115 kV – 26 miles new line
- Brandon-Elbow Lake 115 kV – Reconductor 17 miles
- Paynesville 230/115 kV tx – Install 336 MVA Unit
- Minn Valley-Redwood Falls Tap-Franklin 115 kV – Reconductor 41 miles
- Black Dog 230/115 kV tx – Replace 187 with 336 MVA unit
- Paynesville-RoscoeTap-Munson 69 kV – Rebuild 11.6 miles
- Douglas Co.-Long Prairie 115 kV – Reconductor 19.3 miles
- A 2nd Douglas Co. Transformer 115/69 kV was added and LTC capability was given to both transformers.
- Wind Ratings for Existing 115 kV Circuits
- Split Rock-Pathfinder; a minimum 240 MVA rating (2ft/s).
- PathFinder-Pipestone, a maximum 225 MVA rating (8.8 ft/s)
- Pipestone-BuffaloRidge, a maximum 292 MVA rating (22 ft/s)
- BuffaloRidge-Lake Yankton, a maximum 292 MVA rating (22 ft/s)
- Lake Yankton-Lyon County #1, a maximum 274 MVA rating (17.6 ft/s)
- Lyon County-Minnesotta Valley has a minimum 157 MVA rating and a maximum
- 225 rating wind ratings. It was not set as such in the Pre-Group 1 Studies, where it
- was left at 120 MVA. Leave for now but may revisit if line overloads.
- Chanarambie-Pipestone, a maximum 384 MVA rating (22ft/s)

4.3.1 Base Case Stability

The regional faults listed above were simulated for the analysis of regional stability. Results indicate that the system remains stable for all the faults. No dynamic voltage violations are observed in any of the fault simulations except for the fault *"nbz".* The MAPP case used for this study is a stressed case with maximum simultaneous exports on the interfaces. Loosing the 500-kV line from the Forbes to Chisago, severely overloads the 230-kV and the 115-kV lines due to a power surge from Arrowhead to the Twin cities. The plots of power flows from Arrowhead and Riverton to Twin Cities are plotted in Figure 4-8 following the fault " nbz". The dynamic voltage violations at Arrowhead and Riverton indicate that the system is overstressed and additional dynamic reactive power is needed at these locations to eliminate the violations.

In this study, the impact of the proposed wind sites in the Dakotas on the transmission system in northeastern Minnesota is questionable due to severe stress conditions in the pre-project cases.

Also Figure 4-9 indicates that the system is having low voltages in the areas of Granite falls – Willmar – McLeod.

Fault *nbz* resulted in transient under voltage violations both before and after the addition of the new wind farm. This disturbance involves a fault on the Chisago-Forbes 500 kV line (which feeds the Twin Cities) followed by cross-tripping of the Forbes-Dorsey 500 kV line and Manitoba Hydro DC reduction. The *nbz* fault represents today's configuration in which the Forbes SVS is tripped following the fault. The *nmz* fault represents a planned future configuration in which the Forbes

SVS is kept on-line following the fault. The impact of the proposed wind farm on the transient voltages following fault *nbz* is largely insignificant; however, a deterioration of 0.01 pu in the minimum transient voltage at the Wahpeton 115-kV bus was observed. No criteria violations were observed following fault *nmz*.

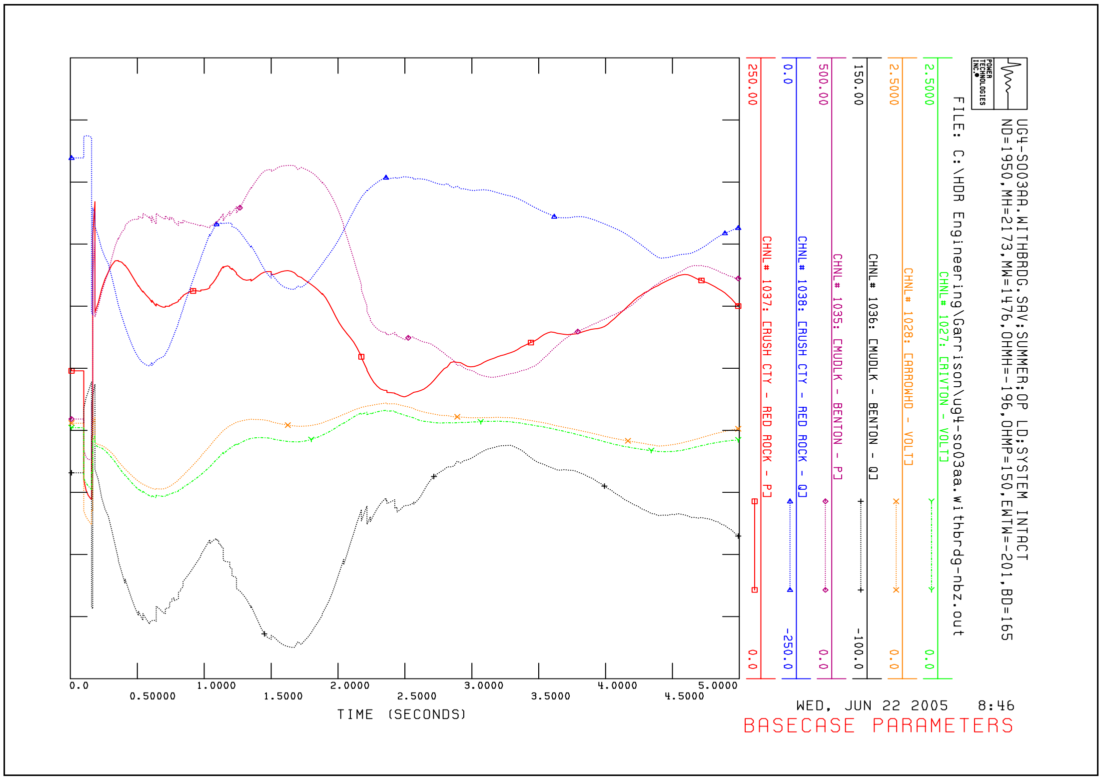

Figure 4-8 Base Case Violations For Fault "nbz" At Arrow Head, Riverton To Twin Cities

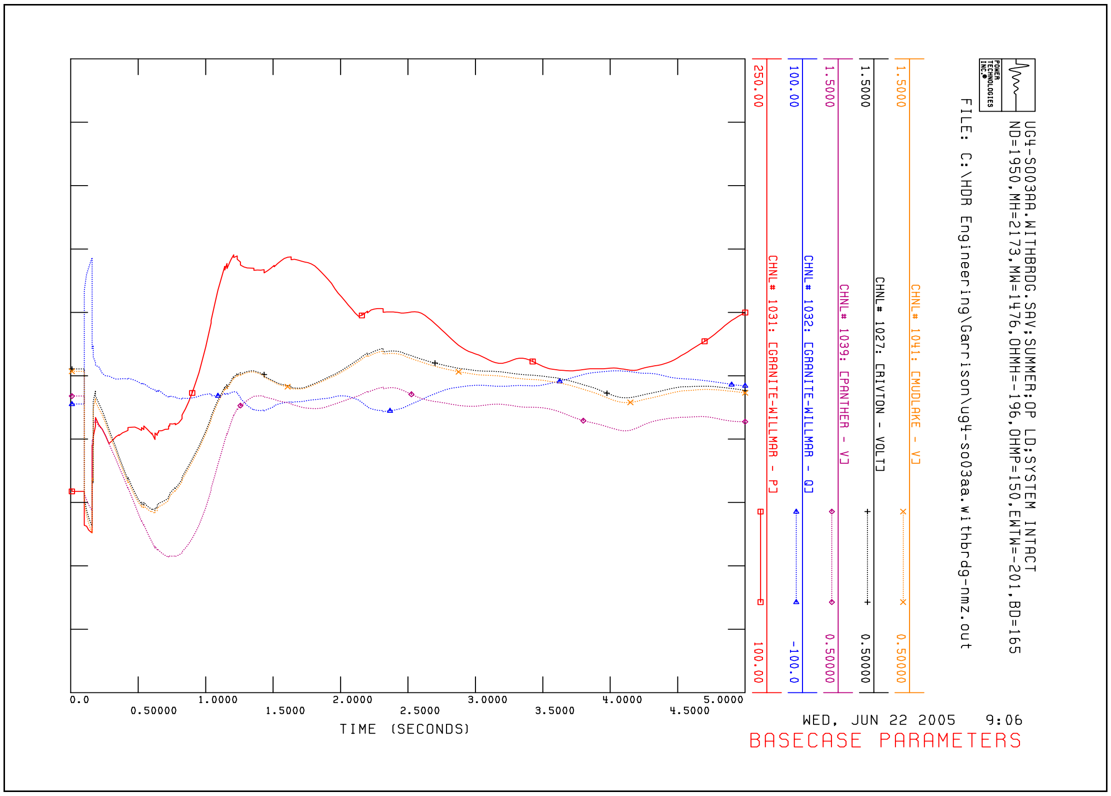

Figure 4-9 Base Case Violations For The Fault “nmz” At Granite Falls, Will Mart To Mcleod

4.3.2 Firm and Non-Firm transfers for generator interconnection.

The Regional stability has been studied to evaluate the non-firm transfers and firm transfers for the MAPP system following the generator interconnections at each of the sites identified earlier in the report.

For all the local stability simulations, the system was tested only for a non-firm transfer condition so that the flows on the constrained interfaces were within the desired limits based on the MAPP criteria.

The following interfaces were used to establish non-firm transfers for all the generator interconnections:

- NDEX = 1450 MW (prior to connecting the wind generation)
- MWSI = 1480 MW
- MHEX = 2175 MW

The following interfaces were used to establish firm transfers for all the generator interconnections:

- NDEX = 1950 MW (prior to connecting the wind generation)
- MWSI = 1480 MW
- MHEX = 2175 MW

ABB

The above interface flow limits were used in the cases to perform regional fault analysis. The cases for which the interconnection of 500 MW was found to be unstable along with dynamic voltage violations, were retested for stability using transmission reinforcements, dynamic shunt compensation etc. The results indicated an improvement in the interconnection generation level at which the system regained stability for the regional faults simulated. A further reinforcement of the transmission lines with series compensation was also evaluated for the specific interconnections. Table 4-10 indicates briefly the results for the generation interconnection at various sites based on these non-firm transfers in the MAPP system.

The sections 4.3.3.1 – 4.3.3.7 describe the results in detail for each of the interconnection site for this non-firm transfer set on all the cases.

Table 4-10 Summary of Regional Stability for **Non firm transfers**

Site	MW Interconnected	Comments
Garrison	250	stable
Pickert	500	stable
Ellendale	250	stable
New Underwood	500	stable
Mission	375	stable
Ft Thompson	500	stable
White	500	stable

The cases for regional stability were also tested by setting up firm transfers on the MAPP constrained interfaces. The cases used for generator interconnection initially had the interface flows set up to their allowable limits and the new generator was then added to the cases without making any adjustments to the flows on the constrained interfaces. The cases were tested for the regional stability and results are tabulated in Table 4-11. The cases that were unstable for a level of generator interconnection, transmission reinforcements were added to the cases and the system was re-assessed for regional stability. The section 4.3.4 describes in detail the case development for each of the site interconnection along with the results.

Table 4-11 Summary of Regional Stability for **Firm transfers**

Site	MW Interconnected	Comments
Garrison	50	stable
Ellendale	50	stable
Pickert	50	stable
New Underwood	50	stable
Mission	150	stable
Ft Thompson	50	stable
White	250	stable

4.3.3 Non-firm transfers on the MAPP system for generator interconnection.

4.3.3.1 Interconnection at Garrison 230kV

Table 4-12 summarizes the regional stability faults for the different wind generation levels at the Garrison site.

- With 500 MW of wind generation at Garrison, the system is unstable following faults "*ei2", "nbz" and "nmz"*. Reducing the wind generation to 250 MW results in a stable system operation for all the faults. Similar dynamic voltage violations are observed for the base case and 250 MW wind case at the Arrowhead 230-kV bus and along 115-kV line from Arrowhead to Riverton for fault *"nbz"*.

- The fault "*ei2*" also resulted in an unstable operation when 500 MW is interconnected at Garrison. This system instability is relieved when the generation is reduced to 375 MW, but there are dynamic voltage violations recorded at the Gorton 345-kV bus and the 115-kV lines out of Groton station towards Aberdeen and Ordway. Further reducing the interconnected generation to 250 MW leads to a stable system operation and no dynamic voltage violations.

- Simulating the fault *"nmz"* resulted in an unstable system operation for the interconnection of 500 MW at Garrison. Figure 4-11 shows the voltage collapsing in Northern Minnesota for this fault simulation as compared with lower levels of wind generation where it recovers. Reducing the interconnected generation to 375 MW relieves the system instability following the fault but the dynamic voltage violations occur in southwestern Minnesota until the wind generation is reduced to 150 MW. With 150 MW of wind generation the results are stable with no dynamic voltage violations.

Table 4-12 Summary of Regional Stability Assessment for the **Garrison Site**

Fault	Basecase	500 MW at Garrison	375 MW at Garrison	250 MW at Garrison	150 MW at Garrison	50 MW at Garrison
ag1	Stable none None	Stable 67160 [GROTON 3] 0.66 67203 [GROTONTY] 0.67 66512 [GROTON 7] 0.67 67401 [ABDNJCT7] 0.67 66534 [ORDWAY 7] 0.67 67402 [ABDNSBT7] 0.67 67395 [WISHEK 7] 0.68 +more None	Stable none None	Stable none None	Stable none None	Stable None None
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Unstable 63198 [BUFFALOY] 0.67 63358 [BUFFALO3] 0.67 63199 [JAMSTN1Y] 0.68 63200 [JAMSTN2Y] 0.68 66792 [MAPLE R3] 0.68 63369 [JAMESTN3] 0.68 63258 [BUFFALO7] 0.69 +more 90714 [YNKEDFIG0.5750] t = 1.0666 90287 [NOBLDFIG0.5750] t = 1.0750 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1166 90708 [BRDGDFIG0.5750] t = 1.1333	Stable 67160 [GROTON 3] 0.66 67401 [ABDNJCT7] 0.67 67402 [ABDNSBT7] 0.67 66512 [GROTON 7] 0.67 67203 [GROTONTY] 0.67 66534 [ORDWAY 7] 0.68 66533 [BRISTOL7] 0.68 +more 90714 [YNKEDFIG0.5750] t = 1.2416 [90287 [NOBLDFIG0.5750] t = 1.2500 [90715 [CHANDFIG0.5750] t = 1.2666 90123 [PIPSDFIG0.5750] t = 1.2833 90708 [BRDGDFIG0.5750] t = 1.3083	Stable 66712 [PRAIRIE7] 1.23 60141 [NORDIC 7] 1.23 None	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 0.9750 90714 [YNKEDFIG0.5750] t = 0.9833 90715 [CHANDFIG0.5750] t = 0.9916 90123 [PIPSDFIG0.5750] t = 1.0083 90708 [BRDGDFIG0.5750] t = 1.0250	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0000 90714 [YNKEDFIG0.5750] t = 1.0083 90715 [CHANDFIG0.5750] t = 1.0250 90123 [PIPSDFIG0.5750] t = 1.0416 90708 [BRDGDFIG0.5750] t = 1.0500	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0333 90714 [YNKEDFIG0.5750] t = 1.0416 90715 [CHANDFIG0.5750] t = 1.0500 90123 [PIPSDFIG0.5750] t = 1.0750 [90708 [BRDGDFIG0.5750] t = 1.0833	Stable 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61614 [98L TAP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0666 90714 [YNKEDFIG0.5750] t = 1.0833 90715 [CHANDFIG0.5750] t = 1.0916 90123 [PIPSDFIG0.5750] t = 1.1083 90708 [BRDGDFIG0.5750] t = 1.1250	Stable 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61614 [98L TAP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.1166 [90714 [YNKEDFIG0.5750] t = 1.1333 90715 [CHANDFIG0.5750] t = 1.1416 90123 [PIPSDFIG0.5750] t = 1.1583 90708 [BRDGDFIG0.5750] t = 1.1833
nmz	Stable none None	Unstable 62001 [BENSON 7] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 63050 [WILLMAR4] 0.67 60147 [MINVALY4] 0.67 62002 [WALDON 7] 0.68 62005 [KERKHOT7] 0.68 +more [90287 [NOBLDFIG0.5750] t = 1.0333 90714 [YNKEDFIG0.5750] t = 1.0416 90715 [CHANDFIG0.5750] t = 1.0583 90123 [PIPSDFIG0.5750] t = 1.0750 90708 [BRDGDFIG0.5750] t = 1.0916	Stable 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 63050 [WILLMAR4] 0.67 62001 [BENSON 7] 0.68 60147 [MINVALY4] 0.68 66550 [GRANITF4] 0.68 62005 [KERKHOT7] 0.68 +more 90287 [NOBLDFIG0.5750] t = 1.1000 90714 [YNKEDFIG0.5750] t = 1.1083 90715 [CHANDFIG0.5750] t = 1.1166 90123 [PIPSDFIG0.5750] t = 1.1333 90708 [BRDGDFIG0.5750] t = 1.1583	Stable 63050 [WILLMAR4] 0.69 60149 [MINVALT4] 0.69 60150 [MNVLTAP4] 0.69 60147 [MINVALY4] 0.69 66550 [GRANITF4] 0.69 None	Stable None None	Stable None None
pcs	Stable none	Stable None	Stable None	Stable None	Stable None	Stable None

The plots for the voltages at Arrowhead 230 kV and Riverton 230 kV are plotted in Figure 4-10 for the base case along with the cases with 500 MW and 250 MW interconnection. Also Figure 4-11 shows Riverton and Mudlake voltages for "nmz" fault. As explained earlier about the base case violations, interconnecting more than 250 MW at Garrison leads to a voltage collapse in this area.

In order to further analyze these violations, the case with 500 MW interconnection at Garrison is simulated with the fault "nbz" by adding 200 MVAr SVC's at Riverton, Arrowhead and Granite Falls 230 kV. The results shown in Table 4-13 below indicate that the system recovers after the fault and no dynamic voltage violations are observed.

Note: The over voltages recorded at Prairie, Nordic and other buses in the Northern MAPP area are due to fast capacitor switching and are allowed to operate up to 1.3 pu for a duration uptown 200 msec.

Table 4-13 Summary of "nbz" Fault with 3 New SVC's of 200 MVAR Each

Regional Faults	nbz
500MW (C10) Voltage Violations	Stable 60141 [NORDIC 7] 1.25 66712 [PRAIRIE7] 1.25 66755 [PRAIRIE4] 1.22
375MW (C11) Voltage Violations	Stable None

Adding 200 MVAr SVC at Groton 345 kV simulates the case with 500 MW interconnection at Garrison for the faults "ei2" and "ag1". Results shown in Table 4-14 indicate that the system remains Stable with minimal voltage violations. The results are tabulated below.

Table 4-14 Summary of "nbz" Fault with SVC of 200MVAR

Regional Faults	ag1	ei2
500MW (C10) Voltage Violations	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	Stable 63358 [BUFFALO3] 0.69 66755 [PRAIRIE4] 1.21 66712 [PRAIRIE7] 1.24 60141 [NORDIC 7] 1.24
375MW (C11) Voltage Violations	--	Stable None

ABB

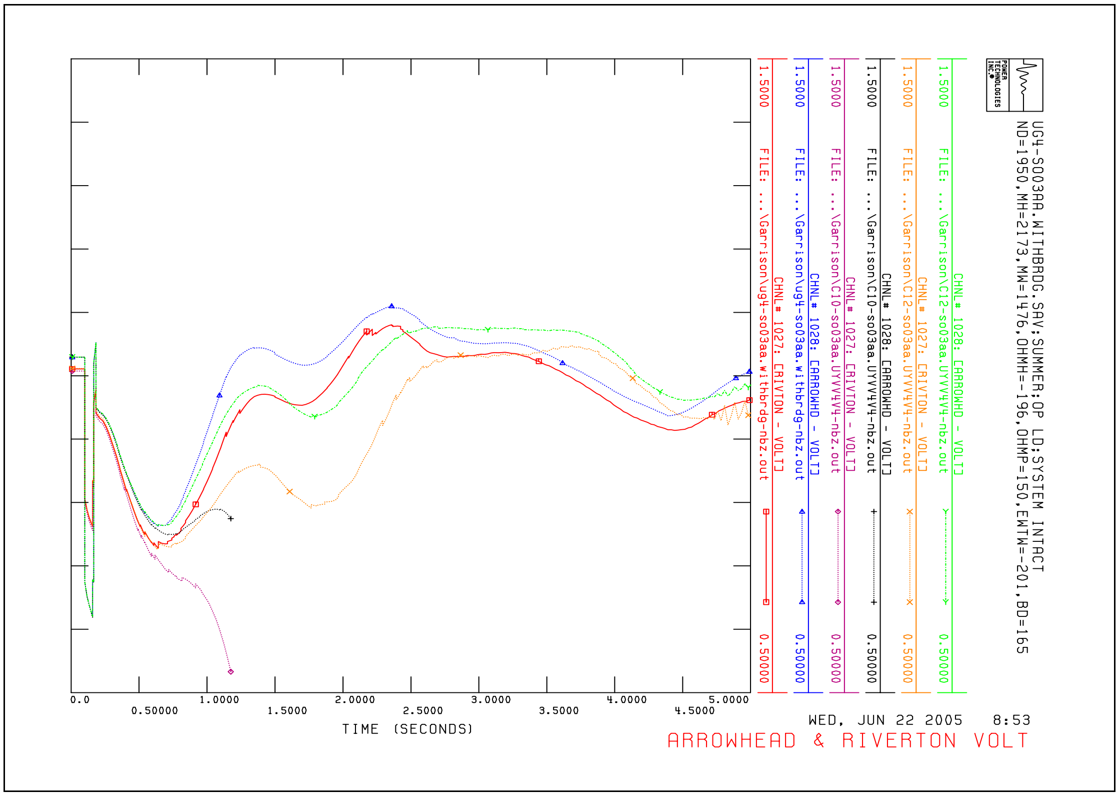

Figure 4-10 Arrow Head And Riverton Voltages For The “nbz” Cases

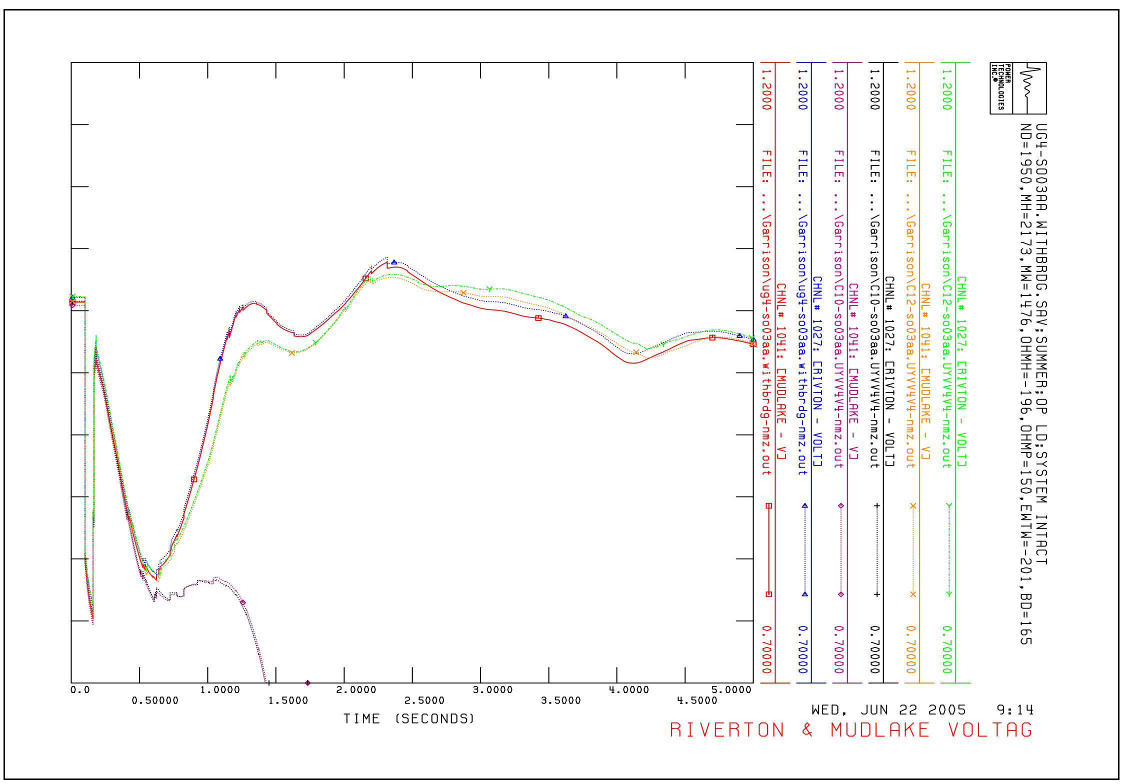

Figure 4-11 Riverton And Mud Lake Voltages For The “nmz” Cases

4.3.3.2 Interconnection at Pickert 230 kV

Table 4-15 summarizes the regional stability faults at different wind generation levels for the Pickert site.

The system is stable for all the regional faults tested on the system for the Pickert site. The fault “nbz” indicates dynamic voltage violations at all levels of the generator interconnection but these violations are also observed in the Base Case so it can be concluded that the dynamic voltage violations are not due to the addition of more generation at Pickert.

Fault	Basecase	500 MW Interconnection	375 MW Interconnection	250 MW Interconnection	150 MW Interconnection	50 MW Interconnection
ag1	Stable none None	Stable none None	Stable none None	Stable none None	Stable none None	Stable none None
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable none None	Stable none None	Stable none None	Stable none None
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0583 90714 [YNKEDFIG0.5750] t = 1.0750 90715 [CHANDFIG0.5750] t = 1.0833 90123 [PIPSDFIG0.5750] t = 1.1000 90708 [BRDGDFIG0.5750] t = 1.1250	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61656 [MAHTOWA7] 0.80 61686 [15TH AV7] 0.80 61576 [HILTPJCT] 0.80 61672 [HILLTOP7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0833 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.1500 90715 [CHANDFIG0.5750] t = 1.1750 90714 [YNKEDFIG0.5750] t = 1.1750 90123 [PIPSDFIG0.5750] t = 1.1916 90708 [BRDGDFIG0.5750] t = 1.2250	Stable 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61614 [98L TAP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90715 [CHANDFIG0.5750] t = 1.2250 90714 [YNKEDFIG0.5750] t = 1.2250 90123 [PIPSDFIG0.5750] t = 1.2416 90708 [BRDGDFIG0.5750] t = 1.2833	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.80 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 +more None
nmz	Stable none None	Stable 62001 [BENSON 7] 0.69 None	Stable none None	Stable none None	Stable none None	Stable none None
pcs	Stable none	Stable none	Stable none	Stable none	Stable none	Stable none

Table 4-15 Summary of Regional Stability Assessment at the **Pickert Site**

4.3.3.3 Interconnection at Ellendale 345 kV

Table 4-17 summarizes the regional stability faults for different wind generation level at the Ellendale site, which is a tap on Leland Olds – Groton 345-kV line.

- The system is stable for all the faults tested except for the fault “nbz” when the wind generation is at the 500 MW and 375 MW level.
- The Base Case has dynamic voltage violations or the fault “nbz”. With the wind generation added, several of the faults have dynamic voltage violations.
- The system is stable for all the faults for 250 MW or less interconnection at Ellendale. The dynamic voltage violations following “nmz” fault are only due to the addition of the new generation at Ellendale, that overloads the lines from Leland Olds - Groton 345-kV and the 115-kV lines from Groton towards Aberdeen and Ordway. Reducing the size of interconnection at Ellendale relieves the system at Groton but many violations are still observed on the 230-kV lines towards Minnesota Valley and Granite Falls.

The case with 500 MW interconnection at Ellendale is simulated for the fault *“ei2”* by adding 200 MVAr SVC at Groton 345-kV bus. This case had the most sever dynamic voltage violations. Results shown in Table 4-16 indicate that the system remains Stable with minimal voltage violations. These results indicate that a 200 MVAR SVC at Groton may eliminate the dynamic voltage violations shown in Table 4-16.

Table 4-16 Summary of the “ei2” fault with an SVC of 200 MVAR

Ellendale Site	ei2
500MW (C30)	Stable
Voltage Violations	67160 [LELAND03] 0.65
	66712 [PRAIRIE7] 1.23
	60141 [NORDIC 7] 1.23
Trippings	[4308] Unit 1at 90100 [LELN-5000.5750] t = 0.8666

Table 4-17 Summary of Regional Stability Assessment at the **Ellendale Site**

Fault	Basecase	500 MW Interconnection	375 MW Interconnection	250 MW Interconnection	150 MW Interconnection	50 MW Interconnection
ag1	Stable none	Stable 67160 [LELAND03] 0.64 66755 [PRAIRIE4] 1.20 66712 [PRAIRIE7] 1.21 60140 [NORDIC 7] 1.22 90100 [LELN-5000.5750] t = 0.3832	Stable 67160 [LELAND03] 0.68 90100 [HDR_GEN 0.5750] t = 0.3917	Stable None 90100 [HDR_GEN 0.5750] t = 0.3917	Stable None 90100 [HDR_GEN 0.5750] t = 0.3917	Stable None 90100 [HDR_GEN 0.5750] t = 0.3917
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable 67160 [LELAND03] 0.60 1111 [GROTON 3] 0.62 66512 [GROTON 7] 0.64 67203 [GROTONTY] 0.64 66534 [ORDWAY 7] 0.65 66533 [BRISTOL7] 0.66 67402 [ABDNSBT7] 0.66 +more 90100 [LELN-5000.5750] t = 0.7750 90714 [YNKEDFIG0.5750] t = 1.1250 90287 [NOBLDFIG0.5750] t = 1.1666 90715 [CHANDFIG0.5750] t = 1.1750 90123 [PIPSDFIG0.5750] t = 1.1916 90708 [BRDGDFIG0.5750] t = 1.2000	Stable 1111 [GROTON 3] 0.65 67160 [LELAND03] 0.65 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.67 66534 [ORDWAY 7] 0.68 66533 [BRISTOL7] 0.68 67402 [ABDNSBT7] 0.68 +more [90100 [HDR_GEN 0.5750] t = 0.8666	Stable None None	Stable None None	Stable None None
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 1111 [GROTON 3] 0.68 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61614 [98L TAP4] 0.79 61686 [15TH AV7] 0.80 61576 [HILTPJCT] 0.80 61672 [HILLTOP7] 0.80 +more 90100 [LELN-5000.5750] t = 0.7750 90714 [YNKEDFIG0.5750] t = 0.9416 90287 [NOBLDFIG0.5750] t = 0.9583 90715 [CHANDFIG0.5750] t = 0.9750 90123 [PIPSDFIG0.5750] t = 0.9916 90708 [BRDGDFIG0.5750] t = 1.0000	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61656 [MAHTOWA7] 0.80 61686 [15TH AV7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90100 [HDR_GEN 0.5750] t = 0.8666 90287 [NOBLDFIG0.5750] t = 0.9750 90714 [YNKEDFIG0.5750] t = 0.9750 90715 [CHANDFIG0.5750] t = 1.0000 90123 [PIPSDFIG0.5750] t = 1.0083 90708 [BRDGDFIG0.5750] t = 1.0250	Stable 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61614 [98L TAP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90100 [HDR_GEN 0.5750] t = 0.9333 90287 [NOBLDFIG0.5750] t = 1.0166 90714 [YNKEDFIG0.5750] t = 1.0250 90715 [CHANDFIG0.5750] t = 1.0416 90123 [PIPSDFIG0.5750] t = 1.0500 90708 [BRDGDFIG0.5750] t = 1.0666	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0750 90714 [YNKEDFIG0.5750] t = 1.0916 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1416	Stable 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61614 [98L TAP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.1833 90715 [CHANDFIG0.5750] t = 1.2000 90714 [YNKEDFIG0.5750] t = 1.2000 90123 [PIPSDFIG0.5750] t = 1.2166 90708 [BRDGDFIG0.5750] t = 1.2500
nmz	Stable none	Stable 1111 [GROTON 3] 0.61 67160 [LELAND03] 0.61 67203 [GROTONTY] 0.63 66512 [GROTON 7] 0.63 66534 [ORDWAY 7] 0.65 66533 [BRISTOL7] 0.65 67402 [ABDNSBT7] 0.66 +more 90100 [LELN-5000.5750] t = 0.7833 90714 [YNKEDFIG0.5750] t = 0.9916 90287 [NOBLDFIG0.5750] t = 1.0083 90715 [CHANDFIG0.5750] t = 1.0250 90708 [BRDGDFIG0.5750] t = 1.0416 90123 [PIPSDFIG0.5750] t = 1.0416	Stable 1111 [GROTON 3] 0.64 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.66 67160 [LELAND03] 0.66 66534 [ORDWAY 7] 0.68 66533 [BRISTOL7] 0.68 60149 [MINVALT4] 0.68 +more 90100 [HDR_GEN 0.5750] t = 0.8916 90287 [NOBLDFIG0.5750] t = 1.0500 90714 [YNKEDFIG0.5750] t = 1.0500 90715 [CHANDFIG0.5750] t = 1.0833 90123 [PIPSDFIG0.5750] t = 1.1000 90708 [BRDGDFIG0.5750] t = 1.1166	Stable 1111 [GROTON 3] 0.68 60149 [MINVALT4] 0.69 60150 [MNVLTAP4] 0.69 63050 [WILLMAR4] 0.69 60147 [MINVALY4] 0.69 66550 [GRANITF4] 0.69 62005 [KERKHOT7] 0.69 90714 [YNKEDFIG0.5750] t = 1.2166 90715 [CHANDFIG0.5750] t = 1.2250 90123 [PIPSDFIG0.5750] t = 1.2416 90708 [BRDGDFIG0.5750] t = 1.2666	Stable none	Stable none
pcs	Stable none	Stable none	Stable None	Stable none	Stable none	Stable none

4.3.3.4 Interconnection at New Underwood 230kV

The three previous sites were interconnected at sites in North Dakota and with the addition of wind generation; flow on the NDEX interface was readjusted to maintain the 1950 MW export limit with the wind generation. As the new generation was added, the existing generation and/or loads are adjusted to maintain 1950 MW so there is no increase in the overall transfers to the east, which may over stress the transmission system. However, for the sites in South Dakota NDEX is maintained at 1950 MW and as the wind generation is added in South Dakota it adds to the total North and South Dakota power transfers to the east which stress the system considerably more than the North Dakota sites. For setting up the cases for interconnection into South Dakota sites, NDEX is set to a value of 1450 MW in the base case and then the new generation is added so that the over all transfer is equal to 1950 MW. Results indicate that at New Underwood 500 MW can be connected without any stability problems. Dynamic voltage violations are found after the simulation of the faults, which can be eliminated by using other transmission reinforcements like Dynamic Shunt compensation etc.

Table 4-22 summarizes the results from the regional stability faults simulated for different wind generation levels at the New Underwood site.

Table 4-18 Summary of Regional Stability Assessment **(Non-Firm Transfer cases)** at the **New Underwood Site**

Interconnection Site		**Fault definitions**		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
New Underwood	500	STABLE 66477 [ELSWRTH7] 0.54 66030 [RCSERCAP] 0.54 66266 [NUNDRWDT] 0.54 66496 [RUSHMRE7] 0.56 66485 [NUNDRWD7] 0.56 66490 [RAPIDCY7] 0.56 66484 [NUNDRWD4] 0.56 +more	STABLE 66484 [NUNDRWD4] 0.55 66266 [NUNDRWDT] 0.56 66477 [ELSWRTH7] 0.56 66030 [RCSERCAP] 0.56 66485 [NUNDRWD7] 0.56 66490 [RAPIDCY7] 0.56 66493 [WICKSVL7] 0.56 +more	STABLE 61614 [98L TAP4] 0.80 61615 [ARROWHD4] 0.80 61616 [HILLTOP4] 0.80 61656 [MAHTOWA7] 0.80 61686 [15TH AV7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more

4.3.3.5 Interconnection at Mission 115 kV

As described in the interconnection at New Underwood, the NDEX was initially reduced to 1450 MW and then the new generation was added at Mission so that overall transfers to the east was equal to 1950 MW. Results indicate that 375 MW can be interconnected without violating system regional stability. Dynamic voltage violations were found only for the fault “nbz” which can be eliminated by

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transmission reinforcements like Dynamic Shunt compensation etc. The following Table 4-25 describes the results for interconnection into Mission site.

Table 4-19 Summary of Regional Stability Assessment **(Non-Firm Transfer cases)** at the **Mission Site**

Interconnection Site		Fault definitions		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
Mission	375	STABLE None	STABLE None	STABLE 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more

4.3.3.6 Interconnection at Ft Thompson 345 kV

The cases for the interconnection at Ft Thompson have a value of NDEX at 1450 MW set by the “setexports” iplan program before the interconnection of the new generation. The new generation at Ft Thompson is then added which indicates an overall power transfer to the east as 1950 MW. Regional stability analysis on this case indicates that an interconnection of 500 MW is feasible without disturbing regional stability. The following Table 4-26 describes the results of the disturbances simulated.

Dynamic voltage violations are recorded for the fault “nbz” and using proper dynamic shunt compensation can eliminate these violations.

Table 4-20 Summary of Regional Stability Assessment **(Non-Firm Transfer cases)** at the **Ft Thompson Site**

Interconnection Site		Fault definitions		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
Ft Thompson	500	STABLE 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	STABLE None	STABLE 61615 [ARROWHD4] 0.80 61616 [HILLTOP4] 0.80 61614 [98L TAP4] 0.80 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more

4.3.3.7 Interconnection at White 345 kV

The Table 4-21 summarizes the results from the regional stability faults for the new wind generation at the White 345-kV bus. As with the other South Dakota sites, NDEX is initially set to 1450 MW for this analysis. The new generation is then added at White 345 kV so that the overall power transfer to the east was at 1950 MW. Results indicate no dynamic voltage violations for any of the faults simulated.

Table 4-21 Summary of Regional Stability Assessment **(Non-Firm Transfer cases)** at the **White Site**

Interconnection Site		**Fault definitions**		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
White	500	STABLE None	STABLE None	STABLE None

4.3.4 Firm transfers on the MAPP system for generator interconnection.

Sensitivity analysis is performed on the cases developed in section 4.2 for studying regional stability. In this section of stability analysis, the flow on the NDEX interface is retained at 1950 MW before the addition of the new generation. The new plant is added without any specific dispatch and readjustment of the interface flows in the system.

The following sections explain in detail the interconnections into each of the site.

4.3.4.1 Interconnection at Garrison 230kV

Table 4-22 summarizes the regional stability faults for the different wind generation level at the Garrison site. Results indicate that only 50 MW can be interconnected without violation regional stability. For interconnection of 150 MW the fault "nbz" is found to be unstable. Also, dynamic voltage violations were recorded for the fault "nbz" for the interconnection of 50 MW, which can be eliminated by dynamic shunt compensation.

Table 4-22 Summary of Regional Stability Assessment **(Firm Transfer cases)** at the **Garrison Site**

Interconnection Site		Fault definitions		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
Garrison	150	STABLE 67160 [GROTON 3] 0.69 60141 [NORDIC 7] 1.21 66712 [PRAIRIE7] 1.21	STABLE 62001 [BENSON 7] 0.67 63050 [WILLMAR4] 0.67 60150 [MNVLTAP4] 0.68 62005 [KERKHOT7] 0.68 60149 [MINVALT4] 0.68 60147 [MINVALY4] 0.68 60356 [PAYNES 4] 0.68 +more	UNSTABLE 61614 [98L TAP4] 0.78 61615 [ARROWHD4] 0.78 61616 [HILLTOP4] 0.78 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.79 61672 [HILLTOP7] 0.79 61673 [ARROWHD7] 0.79 +more
	50	STABLE 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	STABLE None	STABLE 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61672 [HILLTOP7] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.79 61576 [HILTPJCT] 0.80 +more

4.3.4.2 Interconnection at Pickert 230kV

The results for the interconnection into Pickert are similar to that of Garrison interconnection. As the value of NDEX before the addition of the new generation was set to 1950 MW, any amount of generation addition at the North Dakota sites increases the transfers to the east more than the stability constrained value of NDEX. Only 50 MW can be interconnected at Pickert without violating regional stability criteria. The following Table 4-23 summarizes the results for this interconnection. Dynamic voltage violations are recoded for the fault “nbz” which can be eliminated by using Dynamic Shunt compensation techniques.

Table 4-23 Summary of Regional Stability Assessment **(Firm Transfer cases)** at the **Pickert Site**

Interconnection Site		Fault definitions		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
Pickert	150	STABLE None	STABLE 62001 [BENSON 7] 0.68 63050 [WILLMAR4] 0.68 60149 [MINVALT4] 0.68 60150 [MNVLTAP4] 0.68 60147 [MINVALY4] 0.68 60356 [PAYNES 4] 0.68 62005 [KERKHOT7] 0.68 +more	UNSTABLE 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61672 [HILLTOP7] 0.79 61679 [GARY 7] 0.79 61686 [15TH AV7] 0.79 61673 [ARROWHD7] 0.79 +more
	50	STABLE 60141 [NORDIC 7] 1.21 66712 [PRAIRIE7] 1.21	STABLE None	STABLE 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more

4.3.4.3 Interconnection at Ellendale 345kV

The results for the generation interconnection at Ellendale are very similar to the interconnection at other North Dakota sites of Garrison and Pickert. Only 50 MW can be interconnected at this site without violating regional stability criteria. Dynamic voltage violations are also recorded for the fault “nbz” which can be eliminated using dynamic shunt compensation. The following Table 4-24 summarizes the results for this interconnection.

Table 4-24 Summary of Regional Stability Assessment **(Firm Transfer cases)**at the **Ellendale Site**

Interconnection Site		Fault definitions		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
Ellendale	50	STABLE 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	STABLE None	STABLE 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more

4.3.4.4 Interconnection at New Underwood 230kV

New Underwood is one of the sites identified for generator interconnection in South Dakota and the generator is interconnected into the case with NDEX at 1950 MW. As the wind generation is added in South Dakota it adds to the total North and South Dakota power transfers to the east, which stress the system considerably than the basecase. Due to these increased system transfers, system instability will occur at much lower wind generation levels. This same consideration will impact all of the South Dakota sites.

Table 4-25 summarizes the results from the regional stability faults simulated for different wind generation levels at the New Underwood site. A maximum of 50 MW of wind generation can be accommodated at New Underwood before the system becomes unstable for fault “nbz”. A maximum of 150 MW can be accommodated at New Underwood before the system becomes unstable for fault “nmz” and a maximum of 250 MW can be accommodated at New Underwood before the system becomes unstable for fault “ei2”.

The Figure 4-12 shows the plots for the voltages at the terminals of the DC connection at Rapid City. It is clear that the additional generation at New Underwood causes the system to be unstable and the voltage collapse even back in western South Dakota.

Further analysis shows that series compensation of 35% on the Leland –Groton 345-kV line, the Leland – Ft Thompson 345-kV line, and the Antelope – Bradley 345-kV line results in a stable system up to 150 MW of new wind generation at New Underwood. With a higher series compensation of 50% on the above-mentioned lines, the new wind generation can be increased to 250 MW and the system will remain stable. Even though system is stable during simulations, dynamic voltage violations are observed as in the Base Case and wind cases.

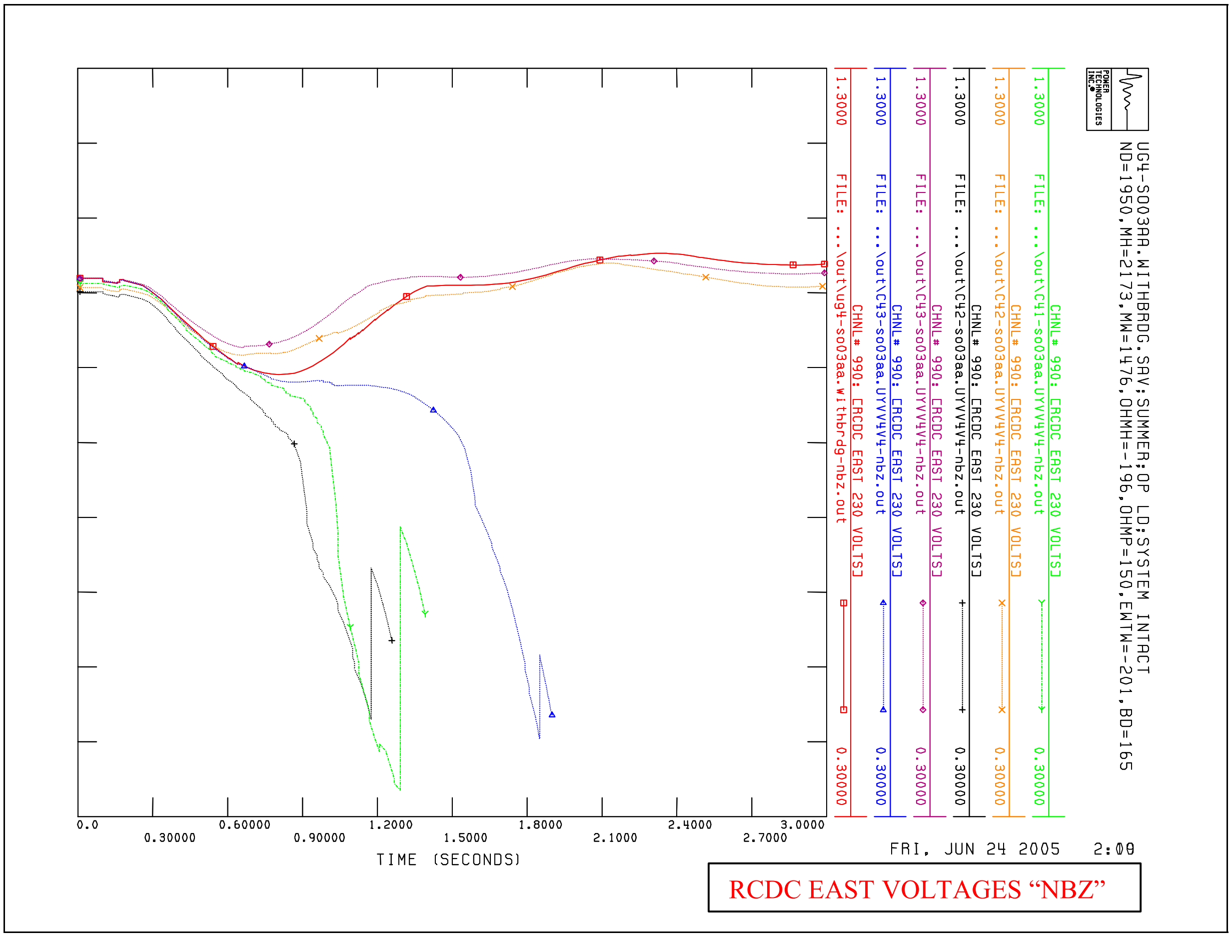

Figure 4-12 Rapid City Terminal Voltages for fault "nbz"

Table 4-25 Summary of Regional Stability Assessment **(Firm Transfer cases)** at the **New Underwood Site**

Fault	Basecase	500 MW Interconnection	375 MW Interconnection	250 MW Interconnection	150 MW Interconnection	50 MW Interconnection
ag1	Stable none	Stable 66477 [ELSWRTH7] 0.50 66484 [NUNDRWD4] 0.50 66485 [NUNDRWD7] 0.51 66030 [RCSERCAP] 0.51 66266 [NUNDRWDT] 0.51 66496 [RUSHMRE7] 0.53 66493 [WICKSVL7] 0.54 +more 90100 [NUND-5000.5750] t = 0.7000	Stable none	Stable none	Stable none	Stable none
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Unstable 66479 [MARTIN 7] 0.64 66482 [MISSION7] 0.66 67153 [VETALTP7] 0.66 66792 [MAPLE R3] 0.67 63358 [BUFFALO3] 0.67 63198 [BUFFALOY] 0.68 67401 [ABDNJCT7] 0.68 +more 90100 [NUND-5000.5750] t = 0.7666 90287 [NOBLDFIG0.5750] t = 0.9083 90714 [YNKEDFIG0.5750] t = 0.9083 90715 [CHANDFIG0.5750] t = 0.9416 90123 [PIPSDFIG0.5750] t = 0.9583 90708 [BRDGDFIG0.5750] t = 0.9666	Unstable 67401 [ABDNJCT7] 0.67 67402 [ABDNSBT7] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 67160 [GROTON 3] 0.67 60147 [MINVALY4] 0.67 62001 [BENSON 7] 0.68 +more 90287 [NOBLDFIG0.5750] t = 0.9583 90714 [YNKEDFIG0.5750] t = 0.9750 90100 [NUND-3750.5750] t = 0.9750 90715 [CHANDFIG0.5750] t = 0.9916 90123 [PIPSDFIG0.5750] t = 1.0083 90708 [BRDGDFIG0.5750] t = 1.0333	Stable 60149 [MINVALT4] 0.68 60150 [MNVLTAP4] 0.68 67160 [GROTON 3] 0.68 60147 [MINVALY4] 0.68 67203 [GROTONTY] 0.68 67402 [ABDNSBT7] 0.68 63050 [WILLMAR4] 0.68 +more 90287 [NOBLDFIG0.5750] t = 1.1083 90714 [YNKEDFIG0.5750] t = 1.1166 90715 [CHANDFIG0.5750] t = 1.1333 90123 [PIPSDFIG0.5750] t = 1.1500 90708 [BRDGDFIG0.5750] t = 1.1833	Stable none	Stable none
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 61611 [WINGRIV4] 0.73 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.79 61614 [98L TAP4] 0.79 61672 [HILLTOP7] 0.80 +more 90100 [NUND-5000.5750] t = 0.7750 90287 [NOBLDFIG0.5750] t = 0.8416 90714 [YNKEDFIG0.5750] t = 0.8416 90715 [CHANDFIG0.5750] t = 0.8666 90123 [PIPSDFIG0.5750] t = 0.8750 90708 [BRDGDFIG0.5750] t = 0.8916	Unstable 61617 [MUDLAKE4] 0.74 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.79 61614 [98L TAP4] 0.79 61680 [WNTR ST7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 0.8583 90714 [YNKEDFIG0.5750] t = 0.8833 90715 [CHANDFIG0.5750] t = 0.9000 90123 [PIPSDFIG0.5750] t = 0.9083 90708 [BRDGDFIG0.5750] t = 0.9250 90100 [NUND-3750.5750] t = 0.9416	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 0.9166 90714 [YNKEDFIG0.5750] t = 0.9416 90715 [CHANDFIG0.5750] t = 0.9583 90123 [PIPSDFIG0.5750] t = 0.9666 90708 [BRDGDFIG0.5750] t = 0.9833 90100 [NUND-2500.5750] t = 1.1750	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more 0287 [NOBLDFIG0.5750] t = 0.9833 0714 [YNKEDFIG0.5750] t = 1.0083 0715 [CHANDFIG0.5750] t = 1.0166 0123 [PIPSDFIG0.5750] t = 1.0250 0708 [BRDGDFIG0.5750] t = 1.0416 0100 [NUND-1500.5750] t = 1.8499	Stable none
nmz	Stable None	Unstable 62001 [BENSON 7] 0.67 60147 [MINVALY4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60356 [PAYNES 4] 0.67 63050 [WILLMAR4] 0.67 62005 [KERKHOT7] 0.68 +more 90100 [NUND-5000.5750] t = 0.7833 90287 [NOBLDFIG0.5750] t = 0.8583 90714 [YNKEDFIG0.5750] t = 0.8583 90715 [CHANDFIG0.5750] t = 0.8833 90123 [PIPSDFIG0.5750] t = 0.8916 90708 [BRDGDFIG0.5750] t = 0.9083	Unstable 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60356 [PAYNES 4] 0.67 62001 [BENSON 7] 0.67 63050 [WILLMAR4] 0.67 60147 [MINVALY4] 0.67 62005 [KERKHOT7] 0.68 +more 90287 [NOBLDFIG0.5750] t = 0.8833 90714 [YNKEDFIG0.5750] t = 0.9083 90715 [CHANDFIG0.5750] t = 0.9166 90123 [PIPSDFIG0.5750] t = 0.9333 90708 [BRDGDFIG0.5750] t = 0.9583 90100 [NUND-3750.5750] t = 0.9833	Unstable 62001 [BENSON 7] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 62005 [KERKHOT7] 0.67 63050 [WILLMAR4] 0.67 60147 [MINVALY4] 0.67 60356 [PAYNES 4] 0.68 +more 90287 [NOBLDFIG0.5750] t = 0.9666 90714 [YNKEDFIG0.5750] t = 0.9750 90715 [CHANDFIG0.5750] t = 1.0000 90123 [PIPSDFIG0.5750] t = 1.0083 90708 [BRDGDFIG0.5750] t = 1.0250 90100 [NUND-2500.5750] t = 1.5999	Stable 63050 [WILLMAR4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 62001 [BENSON 7] 0.68 60147 [MINVALY4] 0.68 63054 [PANTHER4] 0.68 60356 [PAYNES 4] 0.68 +more 90287 [NOBLDFIG0.5750] t = 1.0666 90715 [CHANDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.0916 90123 [PIPSDFIG0.5750] t = 1.1083 90708 [BRDGDFIG0.5750] t = 1.1333	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0500 90714 [YNKEDFIG0.5750] t = 1.0750 90715 [CHANDFIG0.5750] t = 1.0833 90123 [PIPSDFIG0.5750] t = 1.1000 90708 [BRDGDFIG0.5750] t = 1.1250
pcs	Stable none	Stable none	Stable none	Stable none	Stable none	Stable none

4.3.4.5 Interconnection at Mission 115 kV

As described for the interconnection at New Underwood, for the sites in South Dakota NDEX is maintained at 1950 MW and as the wind generation is added in South Dakota it adds to the total North and South Dakota power transfers to the east which stress the system considerably more than the North Dakota sites. Due to these increased system transfers, system instability will occur at much lower wind generation levels if NDEX is set to 1950 MW.

Table 4-26 summarizes the results from the regional stability faults simulated at different generation levels for the interconnection at Mission 115-kV bus.

- Based on the results from the steady state analysis, the stability analysis is limited to a maximum of 250 MW of new wind generation at Mission. At 250 MW, the system was stable for all the faults except for the fault *"nbz".* Reducing the wind generation to 150 MW results in a stable system for fault "nbz".

- As it can be seen from the table below, the faults "nbz" and "nmz" result in dynamic voltage violations at the Arrowhead 230-kV bus and the 115-kV lines from Arrowhead to Riverton. These dynamic voltage violations are also seen in the base case for fault "nbz".

- No violations are found when the interconnected generation is reduced to 50 MW following the fault "nmz". The results follow the basecase, as the 50 MW interconnection doesn't stress the transmission system.

Table 4-26 Summary of Regional Stability Assessment **(Firm Transfer cases)** at the **Mission Site**

Fault	Basecase	250 MW Interconnection	150 MW Interconnection	50 MW Interconnection
ag1	Stable none	Stable none	Stable none	Stable none
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21 None	Stable 66712 [PRAIRIE7] 1.21 None
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more [18343] Unit 1 at 90287 [NOBLDFIG0.5750] t = 0.9583 [19044] Unit 1 at 90714 [YNKEDFIG0.5750] t = 0.9750 [19639] Unit 1 at 90715 [CHANDFIG0.5750] t = 0.9916 [20234] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.0083 [20672] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.0166 [23151] Unit 1 at 90100 [HDR_GEN 0.5750] t = 1.1000	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more [15097] Unit 1 at 90287 [NOBLDFIG0.5750] t = 1.0083 [15335] Unit 1 at 90714 [YNKEDFIG0.5750] t = 1.0250 [15502] Unit 1 at 90715 [CHANDFIG0.5750] t = 1.0333 [15667] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.0416 [15978] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.0666	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more [10793] Unit 1 at 90287 [NOBLDFIG0.5750] t = 1.0833 [10893] Unit 1 at 90714 [YNKEDFIG0.5750] t = 1.1000 [10959] Unit 1 at 90715 [CHANDFIG0.5750] t = 1.1083 [11045] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.1250 [11116] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.1500
nmz	Stable None	Stable 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60147 [MINVALY4] 0.68 62001 [BENSON 7] 0.68 63050 [WILLMAR4] 0.68 60356 [PAYNES 4] 0.68 62005 [KERKHOT7] 0.68 +more [7585] Unit 1 at 90287 [NOBLDFIG0.5750] t = 1.0166 [7855] Unit 1 at 90715 [CHANDFIG0.5750] t = 1.0416 [7860] Unit 1 at 90714 [YNKEDFIG0.5750] t = 1.0416 [8050] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.0583 [8259] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.0833	Stable 60149 [MINVALT4] 0.68 60150 [MNVLTAP4] 0.68 63050 [WILLMAR4] 0.68 63054 [PANTHER4] 0.68 60147 [MINVALY4] 0.68 66550 [GRANITF4] 0.68 62001 [BENSON 7] 0.69 +more [5924] Unit 1 at 90287 [NOBLDFIG0.5750] t = 1.1583 [5972] Unit 1 at 90715 [CHANDFIG0.5750] t = 1.1833 [5977] Unit 1 at 90714 [YNKEDFIG0.5750] t = 1.1833 [6014] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.2000 [6077] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.2333	Stable None None
pcs	Stable None	Stable none	Stable none	Stable none

4.3.4.6 Interconnection at Ft Thompson 345 kV

In order to establish firm transfers on the MAPP system, the sites in South Dakota, NDEX is maintained at 1950 MW and as the wind generation is added in South Dakota which adds to the total North and South Dakota power transfers to the east which stress the system considerably. Due to these increased system transfers, system instability will occur at much lower wind generation level of interconnection.

The cases for the interconnection at Ft Thompson have a value of NDEX at 1950 MW set by the "setexports" iplan program. This flow doesn't account for the additional MW connected at Ft Thompson. Table 4-27 summarizes the results from the regional stability faults simulated for different wind generation levels at the Ft. Thompson site. A maximum of 50 MW of wind generation can be accommodated at Ft. Thompson before the system becomes unstable for fault "nbz". A maximum of 150 MW can be accommodated at Ft. Thompson before the system becomes unstable for fault "nmz" and a maximum of 250 MW can be accommodated at Ft. Thompson before the system becomes unstable for fault "ej2".

A case was simulated with 500 MW of new wind generation at Ft. Thompson and NDEX set to 1450 MW. This case would be equivalent to the first three sites in North Dakota where NDEX was readjusted after 500 MW of wind generation was added. Results from this Simulation are in ***Appendix-K***. The case is stable and Figure 4-13 indicates the plots of the voltages at Arrowhead and Riverton recover following the fault "nbz" on the case with the 1450 MW adjusted NDEX.

Table 4-27 Summary of Regional Stability Assessment **(Firm Transfer cases)** at the **Ft Thompson Site**

Fault	Basecase	500 MW Interconnection	375 MW Interconnection	250 MW Interconnection	150 MW Interconnection	50 MW Interconnection
ag1	Stable none	Stable none	Stable none	Stable none	Stable none	Stable none
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	Unstable 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 62001 [BENSON 7] 0.67 60147 [MINVALY4] 0.67 63050 [WILLMAR4] 0.67 66550 [GRANITF4] 0.67 62006 [KERKHO 7] 0.68 +more 90287 [NOBLDFIG0.5750] t = 0.9333 90100 [FTTH-5000.5750] t = 0.9333 90714 [YNKEDFIG0.5750] t = 0.9416 90715 [CHANDFIG0.5750] t = 0.9666 90123 [PIPSDFIG0.5750] t = 0.9833 90708 [BRDGDFIG0.5750] t = 0.9916	Unstable 60149 [MINVALT4] 0.66 60150 [MNVLTAP4] 0.66 62001 [BENSON 7] 0.67 60147 [MINVALY4] 0.67 66550 [GRANITF4] 0.67 63050 [WILLMAR4] 0.68 62002 [WALDON 7] 0.68 +more 90287 [NOBLDFIG0.5750] t = 0.9666 90714 [YNKEDFIG0.5750] t = 0.9833 90715 [CHANDFIG0.5750] t = 1.0083 90123 [PIPSDFIG0.5750] t = 1.0250 90100 [FTTH-3750.5750] t = 1.0333 90708 [BRDGDFIG0.5750] t = 1.0500	Stable none	Stable none	Stable none
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 61617 [MUDLAKE4] 0.73 61616 [HILLTOP4] 0.78 61615 [ARROWHD4] 0.78 61686 [15TH AV7] 0.79 61614 [98L TAP4] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 0.8500 90714 [YNKEDFIG0.5750] t = 0.8666 90715 [CHANDFIG0.5750] t = 0.8833 90100 [FTTH-5000.5750] t = 0.8916 90123 [PIPSDFIG0.5750] t = 0.9000 90708 [BRDGDFIG0.5750] t = 0.9083	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61679 [GARY 7] 0.80 61680 [WNTR ST7] 0.80 61672 [HILLTOP7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 0.8666 90714 [YNKEDFIG0.5750] t = 0.8833 90715 [CHANDFIG0.5750] t = 0.9000 90123 [PIPSDFIG0.5750] t = 0.9083 90708 [BRDGDFIG0.5750] t = 0.9250 90100 [FTTH-3750.5750] t = 0.9416	Unstable 61615 [ARROWHD4] 0.79 61614 [98L TAP4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.79 61674 [HANESRD7] 0.79 61673 [ARROWHD7] 0.79 +more 90287 [NOBLDFIG0.5750] t = 0.9333 90714 [YNKEDFIG0.5750] t = 0.9583 90715 [CHANDFIG0.5750] t = 0.9750 90123 [PIPSDFIG0.5750] t = 0.9833 90708 [BRDGDFIG0.5750] t = 1.0000 90100 [HDR_GEN 0.5750] t = 1.0750	Unstable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.79 61674 [HANESRD7] 0.79 61679 [GARY 7] 0.79 +more 90287 [NOBLDFIG0.5750] t = 0.9833 90714 [YNKEDFIG0.5750] t = 1.0083 90715 [CHANDFIG0.5750] t = 1.0166 90123 [PIPSDFIG0.5750] t = 1.0333 90708 [BRDGDFIG0.5750] t = 1.0416 90100 [HDR_GEN 0.5750] t = 1.3749	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.80 61576 [HILTPJCT] 0.80 61656 [MAHTOWA7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0416 90714 [YNKEDFIG0.5750] t = 1.0583 90715 [CHANDFIG0.5750] t = 1.0750 90123 [PIPSDFIG0.5750] t = 1.0833 90708 [BRDGDFIG0.5750] t = 1.1083
nmz	Stable None	Unstable 63050 [WILLMAR4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60356 [PAYNES 4] 0.67 62001 [BENSON 7] 0.67 62005 [KERKHOT7] 0.67 62006 [KERKHO 7] 0.67 +more 90287 [NOBLDFIG0.5750] t = 0.8583 90714 [YNKEDFIG0.5750] t = 0.8833 90715 [CHANDFIG0.5750] t = 0.9000 90123 [PIPSDFIG0.5750] t = 0.9083 90100 [FTTH-5000.5750] t = 0.9166 90708 [BRDGDFIG0.5750] t = 0.9250	Unstable 60149 [MINVALT4] 0.66 60150 [MNVLTAP4] 0.66 60147 [MINVALY4] 0.66 63050 [WILLMAR4] 0.67 62001 [BENSON 7] 0.67 60356 [PAYNES 4] 0.67 62002 [WALDON 7] 0.67 +more 90287 [NOBLDFIG0.5750] t = 0.8833 90714 [YNKEDFIG0.5750] t = 0.9083 90715 [CHANDFIG0.5750] t = 0.9166 90123 [PIPSDFIG0.5750] t = 0.9333 90708 [BRDGDFIG0.5750] t = 0.9500 90100 [FTTH-3750.5750] t = 0.9833	Unstable 63050 [WILLMAR4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60356 [PAYNES 4] 0.67 62001 [BENSON 7] 0.67 62005 [KERKHOT7] 0.67 60147 [MINVALY4] 0.67 +more 90287 [NOBLDFIG0.5750] t = 0.9833 90714 [YNKEDFIG0.5750] t = 1.0000 90715 [CHANDFIG0.5750] t = 1.0166 90123 [PIPSDFIG0.5750] t = 1.0250 90708 [BRDGDFIG0.5750] t = 1.0416 90100 [HDR_GEN 0.5750] t = 1.3333	Stable 63050 [WILLMAR4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60356 [PAYNES 4] 0.68 62001 [BENSON 7] 0.68 62005 [KERKHOT7] 0.68 63054 [PANTHER4] 0.68 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1083 90715 [CHANDFIG0.5750] t = 1.1166 90123 [PIPSDFIG0.5750] t = 1.1333 90708 [BRDGDFIG0.5750] t = 1.1583	Stable 63050 [WILLMAR4] 0.69 None
pcs	Stable None	Stable none	Stable none	Stable none	Stable none	Stable none

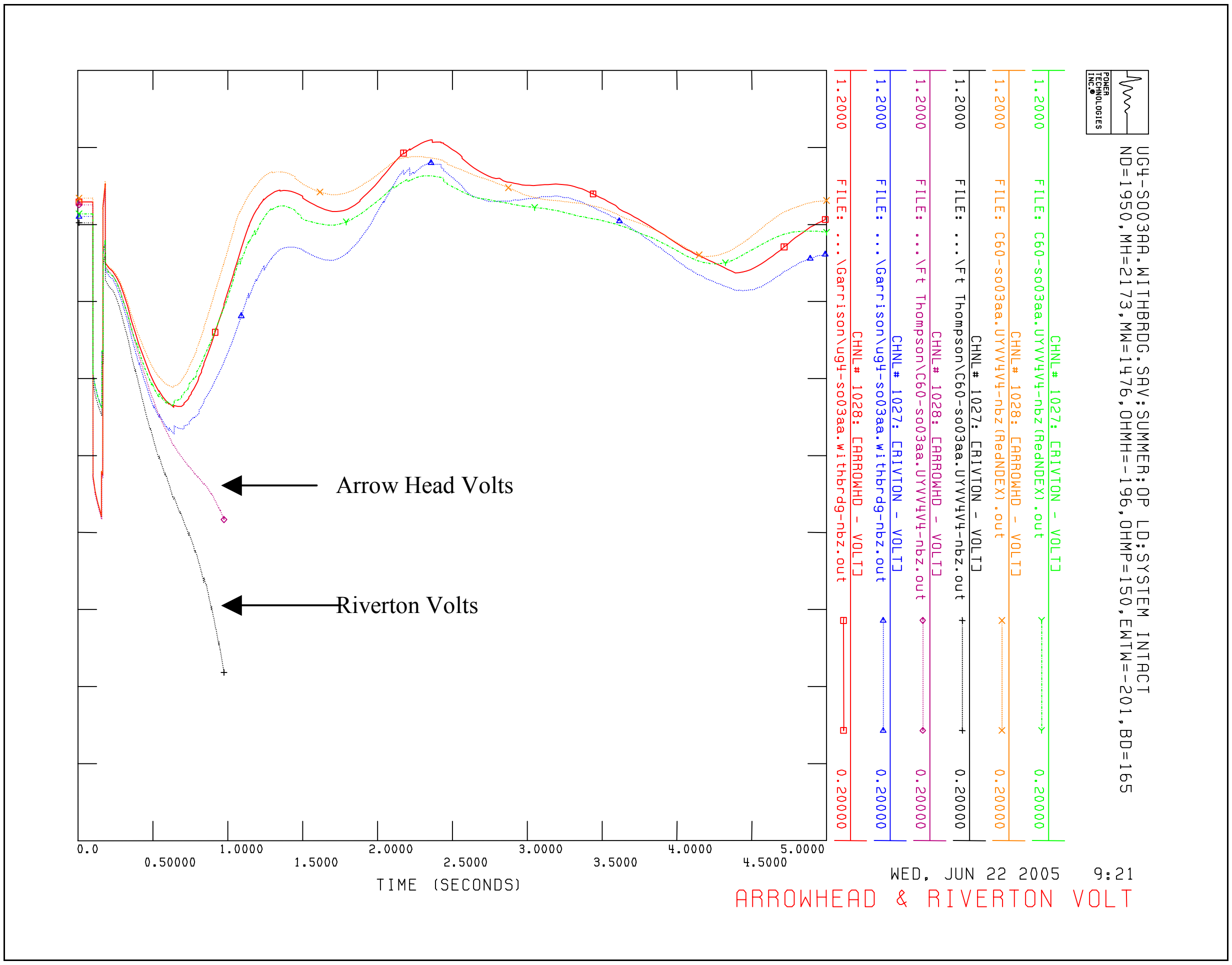

Figure 4-13 Arrowhead and Riverton Voltages following "nbz" Fault with Limited NDEX

4.3.4.7 Interconnection at White 345 kV

Error! Reference source not found. summarizes the results from the regional stability faults simulated at different generation levels for the new wind generation at the White 345-kV bus. As with the other South Dakota sites, NDEX is initially set to 1950 MW for this analysis.

- The results form the regional stability analysis, indicate system instability for the faults *"nmz",* and *"nbz".* A maximum of 250 MW of wind generation can be accommodated at White before the system becomes unstable for fault "nbz". A maximum of 375 MW can be accommodated at White before the system becomes unstable for fault "nmz"

- As it can be seen from the tables below, the fault "nbz" results in dynamic voltage violations at the Arrowhead 230-kV bus and the 115-kV lines from Arrowhead to Riverton. These dynamic voltage violations are also seen in the base case.

- The fault "nmz" also has dynamic voltage violations due to the heavily stressed system on the lines from Willmar – Granite Falls - Minnesota Valley – Panther 230-kV lines and 115 kV-line from Willmar – Paynesville. Installing reactive support such as SVC's in this area will overcome the dynamic violations. The addition of just 50 MW of wind does not result in any new system voltage violations.

- As with the Ft. Thompson site, reducing NDEX (a non firm transfer system) would also make the system more stable and result in fewer voltage violations.

Table 4-28 Summary of Regional Stability Assessment at the **White Site**

Fault	Basecase	500 MW Interconnection	375 MW Interconnection	250 MW Interconnection	150 MW Interconnection	50 MW Interconnection
ag1	Stable none	Stable none	Stable none	Stable none	Stable none	Stable none
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	Stable 60369 [FENTON 7] 0.68 60362 [CHANRMB7] 0.68 60123 [PIPESTN7] 0.69 62712 [ELSBORO7] 0.69 [WHIT-5000.5750] t = 1.0916 [NOBLDFIG0.5750] t = 1.1000 [CHANDFIG0.5750] t = 1.1666 [PIPSDFIG0.5750] t = 1.1833 [YNKEDFIG0.5750] t = 1.1833 [BRDGDFIG0.5750] t = 1.2416	Stable None	Stable 66712 [PRAIRIE7] 1.21	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	Stable 60141 [NORDIC 7] 1.21 66712 [PRAIRIE7] 1.21
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 61614 [98L TAP4] 0.78 61615 [ARROWHD4] 0.78 61616 [HILLTOP4] 0.78 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.79 61673 [ARROWHD7] 0.80 61674 [HANESRD7] 0.80 +more 90100 [WHIT-5000.5750] t = 0.8750 90287 [NOBLDFIG0.5750] t = 0.8833 90715 [CHANDFIG0.5750] t = 0.9166 90714 [YNKEDFIG0.5750] t = 0.9166 90123 [PIPSDFIG0.5750] t = 0.9250 90708 [BRDGDFIG0.5750] t = 0.9500	Unstable 61614 [98L TAP4] 0.78 61615 [ARROWHD4] 0.78 61616 [HILLTOP4] 0.78 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more 90100 [HDR_GEN 0.5750] t = 0.9083 90287 [NOBLDFIG0.5750] t = 0.9166 90715 [CHANDFIG0.5750] t = 0.9666 90714 [YNKEDFIG0.5750] t = 0.9666 90123 [PIPSDFIG0.5750] t = 0.9750 90708 [BRDGDFIG0.5750] t = 1.0000	Stable 61615 [ARROWHD4] 0.78 61614 [98L TAP4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.79 61656 [MAHTOWA7] 0.80 61576 [HILTPJCT] 0.80 +more 90100 [HDR_GEN 0.5750] t = 0.9750 90287 [NOBLDFIG0.5750] t = 0.9833 90715 [CHANDFIG0.5750] t = 1.0083 90714 [YNKEDFIG0.5750] t = 1.0083 90123 [PIPSDFIG0.5750] t = 1.0333 90708 [BRDGDFIG0.5750] t = 1.0416	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0333 90715 [CHANDFIG0.5750] t = 1.0583 90714 [YNKEDFIG0.5750] t = 1.0583 90100 [HDR_GEN 0.5750] t = 1.0666 90123 [PIPSDFIG0.5750] t = 1.0833 90708 [BRDGDFIG0.5750] t = 1.1000	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61674 [HANESRD7] 0.79 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1083 90100 [HDR_GEN 0.5750] t = 1.1083 90715 [CHANDFIG0.5750] t = 1.1166 90123 [PIPSDFIG0.5750] t = 1.1333 90708 [BRDGDFIG0.5750] t = 1.1583
nmz	Stable None	Unstable 63054 [PANTHER4] 0.66 60356 [PAYNES 4] 0.66 62005 [KERKHOT7] 0.66 63050 [WILLMAR4] 0.66 60149 [MINVALT4] 0.66 60150 [MNVLTAP4] 0.66 62006 [KERKHO 7] 0.66 +more 90100 [WHIT-5000.5750] t = 0.9083 90287 [NOBLDFIG0.5750] t = 0.9166 90715 [CHANDFIG0.5750] t = 0.9500 90714 [YNKEDFIG0.5750] t = 0.9500 90123 [PIPSDFIG0.5750] t = 0.9666 90708 [BRDGDFIG0.5750] t = 0.9916	Stable 63054 [PANTHER4] 0.67 60356 [PAYNES 4] 0.67 63050 [WILLMAR4] 0.67 62005 [KERKHOT7] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 62006 [KERKHO 7] 0.67 +more 90287 [NOBLDFIG0.5750] t = 0.9750 90100 [HDR_GEN 0.5750] t = 0.9833 90715 [CHANDFIG0.5750] t = 1.0250 90714 [YNKEDFIG0.5750] t = 1.0250 90123 [PIPSDFIG0.5750] t = 1.0416 90708 [BRDGDFIG0.5750] t = 1.0583	Stable 63050 [WILLMAR4] 0.67 60356 [PAYNES 4] 0.67 63054 [PANTHER4] 0.67 62005 [KERKHOT7] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60147 [MINVALY4] 0.67 +more 90287 [NOBLDFIG0.5750] t = 1.0750 90715 [CHANDFIG0.5750] t = 1.1083 90100 [HDR_GEN 0.5750] t = 1.1083 90714 [YNKEDFIG0.5750] t = 1.1166 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1583	Stable 63050 [WILLMAR4] 0.69 63054 [PANTHER4] 0.69 60149 [MINVALT4] 0.69 None	Stable None
pcs	Stable none	Stable None	Stable none	Stable none	Stable none	Stable none

4.3.4.8 Interconnection at All Seven Sites

The results shown in Table 4-29 indicate system instability for the fault *"nbz".* The instability exists even in the base case. The fault *"nmz"* results in a stable system operation but many dynamic voltage violations are recorded in the Buffalo Ridge area.

Table 4-29 Summary of Regional Stability Assessment at **All Seven Sites**

Fault	Basecase	500 MW Interconnection at All Sites
ag1	Stable none	Stable none
ei2	Stable 66712 [PRAIRIE7] 1.21 60141 [NORDIC 7] 1.21	Stable none
nbz	Stable 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61673 [ARROWHD7] 0.80 +more 90287 [NOBLDFIG0.5750] t = 1.0916 90714 [YNKEDFIG0.5750] t = 1.1000 90715 [CHANDFIG0.5750] t = 1.1083 90123 [PIPSDFIG0.5750] t = 1.1250 90708 [BRDGDFIG0.5750] t = 1.1500	Unstable 61615 [ARROWHD4] 0.78 61616 [HILLTOP4] 0.78 61614 [98L TAP4] 0.78 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.79 61672 [HILLTOP7] 0.79 61673 [ARROWHD7] 0.80 +more [19063] Unit 1 at 90287 [NOBLDFIG0.5750] t = 0.9583 [19939] Unit 1 at 90714 [YNKEDFIG0.5750] t = 0.9750 [20814] Unit 1 at 90715 [CHANDFIG0.5750] t = 0.9916 [21391] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.0000 [21964] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.0083
nmz	Stable None	Stable 63050 [WILLMAR4] 0.67 60356 [PAYNES 4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 62001 [BENSON 7] 0.67 62005 [KERKHOT7] 0.67 62006 [KERKHO 7] 0.67 +more [7966] Unit 1 at 90287 [NOBLDFIG0.5750] t = 1.0250 [8146] Unit 1 at 90714 [YNKEDFIG0.5750] t = 1.0333 [8320] Unit 1 at 90715 [CHANDFIG0.5750] t = 1.0416 [8577] Unit 1 at 90123 [PIPSDFIG0.5750] t = 1.0583 [8992] Unit 1 at 90708 [BRDGDFIG0.5750] t = 1.0833
pcs	Stable none	Stable none

4.3.4.9 Generator Interconnection With Series Compensation

Some of the wind generation sites that were unstable following the faults with just the existing system were rerun with 35% and 50% of series compensation on the Leland Olds-Groton 345-kV line, Leland Olds-Ft. Thompson 345-kV line, and Antelope Valley-Broadland 500-kV line (operating at 345 kV). Table 4-30 indicate the results on these cases against the cases with no compensation. It is important to note that even though the system is stable, dynamic voltage violations were recorded in most of the cases. All the fault summaries and report files are attached in ***Appendix-L***.

Table 4-30 Summary of Results with Series Compensation

Site	MW Interconnected	Fault	No compensation	35% Compensation	50% Compensation
Non-Firm Transfer cases					
Garrison	500	ei2	UNSTABLE	STABLE	--
	500	nbz	UNSTABLE	STABLE	--
	375	nbz	UNSTABLE	STABLE	--
Ellendale	500	nbz	UNSTABLE	STABLE	--
	375	nbz	UNSTABLE	STABLE	--
Firm Transfer Cases					
New Underwood	500	ei2	UNSTABLE	UNSTABLE	STABLE
	375	ei2	UNSTABLE	STABLE	--
	500	nbz	UNSTABLE	UNSTABLE	UNSTABLE
	375	nbz	UNSTABLE	UNSTABLE	UNSTABLE
	250	nbz	UNSTABLE	UNSTABLE	STABLE
	150	nbz	UNSTABLE	STABLE	--
Mission	250	nbz	UNSTABLE	STABLE	--
Ft Thompson	500	ei2	UNSTABLE	UNSTABLE	--
	375	ei2	UNSTABLE	STABLE	--
	500	nbz	UNSTABLE	UNSTABLE	UNSTABLE
	150	nbz	UNSTABLE	UNSTABLE	UNSTABLE
	250	nbz	UNSTABLE	UNSTABLE	STABLE
	150	nbz	UNSTABLE	STABLE	--
White	500	nbz	UNSTABLE	UNSTABLE	UNSTABLE
	375	nbz	UNSTABLE	STABLE	--
All sites	500	nbz	UNSTABLE	STABLE	--

4.3.4.10 Sensitivity analysis with transmission reinforcements

For the interconnections in North Dakota at the sites of Garrison, Pickert and Ellendale the flow on NDEX is 1950 MW prior to the interconnection. Any amount of interconnection at these sites would increase the flows on the NDEX interface violating the stability criteria. Proper transmission reinforcements have to be added to increase the transfer capabilities of these constrained interfaces. The following paragraphs describe some of the transmission upgrades and their impact on the generator interconnections.

- The cases developed as described above were re-run by adding a new transmission line from Maple River-Benton County at 345 kV for all the interconnection sites except for the interconnection at Mission. For interconnection into Mission, two 230 kV lines from Mission – Ft Randall and Mission – Oahe were added as additional reinforcements. The results for the simulations are recorded in Table 4-31.

- Apart form the additional reinforcements, an additional line from Water town-Granite Falls-Blue Lake 345 kV was added in the case of Garrison interconnection and is tested for regional stability and it is found to be unstable for a 500 MW interconnection. For Interconnection into Mission, apart from the two 230 kV lines, another additional line from Maple River to – Benton Co. was added and the 250 MW interconnection is also found to be unstable for the fault “nbz”.

- The following results indicate the system stability and the dynamic voltage violations following the fault. The values in the table show the worst violations out of many reported in the output files. Special mitigation has to be performed to overcome the voltage violations like making use of dynamic shunt compensation.

Table 4-31 Summary Of Results With Firm Transfers And New Maple River-Benton County 345-kV Line for Garrison, Ellendale, and White and 230-kV reinforcements for Mission

Interconnection Site		Fault definitions		
Site Name	**MW Interconnected**	**ei2**	**nmz**	**nbz**
Garrison	**500**	**UNSTABLE** 63199 [JAMSTN1Y] 0.62 63200 [JAMSTN2Y] 0.62 63369 [JAMESTN3] 0.63 63271 [AVIKO 7] 0.63 63272 [JAMESPK7] 0.63 63273 [JAMETAP7] 0.63 63274 [JAMSDTN7] 0.63 +more	**UNSTABLE** 63199 [JAMSTN1Y] 0.65 63200 [JAMSTN2Y] 0.65 63369 [JAMESTN3] 0.65 63358 [BUFFALO3] 0.65 63270 [LADISH 7] 0.66 63271 [AVIKO 7] 0.66 63272 [JAMESPK7] 0.66 +more	**UNSTABLE** 63199 [JAMSTN1Y] 0.64 63200 [JAMSTN2Y] 0.64 63198 [BUFFALOY] 0.65 63369 [JAMESTN3] 0.66 63358 [BUFFALO3] 0.66 63270 [LADISH 7] 0.66 63271 [AVIKO 7] 0.66 +more
	375	**STABLE** 63199 [JAMSTN1Y] 0.69 63200 [JAMSTN2Y] 0.69 60141 [NORDIC 7] 1.22 66712 [PRAIRIE7] 1.22	**STABLE** 63199 [JAMSTN1Y] 0.69 63200 [JAMSTN2Y] 0.69 63369 [JAMESTN3] 0.69 63358 [BUFFALO3] 0.69 60141 [NORDIC 7] 1.21 66712 [PRAIRIE7] 1.22	**STABLE** 63199 [JAMSTN1Y] 0.68 61615 [ARROWHD4] 0.80 61616 [HILLTOP4] 0.80 61686 [15TH AV7] 0.80 61656 [MAHTOWA7] 0.80 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 +more
Ellendale	**500**	**STABLE** 67160 [LELAND03] 0.64 1111 [GROTON 3] 0.66 63199 [JAMSTN1Y] 0.67 63200 [JAMSTN2Y] 0.67 63271 [AVIKO 7] 0.68 63272 [JAMESPK7] 0.68 63273 [JAMETAP7] 0.68 +more	**STABLE** 67160 [LELAND03] 0.62 1111 [GROTON 3] 0.64 67203 [GROTONTY] 0.66 66512 [GROTON 7] 0.66 63200 [JAMSTN2Y] 0.67 63199 [JAMSTN1Y] 0.67 66534 [ORDWAY 7] 0.67 +more	**STABLE** 1111 [GROTON 3] 0.65 67160 [LELAND03] 0.65 63199 [JAMSTN1Y] 0.67 63200 [JAMSTN2Y] 0.67 63270 [LADISH 7] 0.68 63271 [AVIKO 7] 0.68 63272 [JAMESPK7] 0.68 +more
Mission	**500**	**UNSTABLE** 60149 [MINVALT4] 0.66 60150 [MNVLTAP4] 0.66 60147 [MINVALY4] 0.67 62001 [BENSON 7] 0.67 63050 [WILLMAR4] 0.67 66550 [GRANITF4] 0.67 62002 [WALDON 7] 0.68 +more	**UNSTABLE** 62001 [BENSON 7] 0.66 60147 [MINVALY4] 0.66 60149 [MINVALT4] 0.66 60150 [MNVLTAP4] 0.66 63050 [WILLMAR4] 0.67 60356 [PAYNES 4] 0.67 62005 [KERKHOT7] 0.67 +more	**UNSTABLE** 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61576 [HILTPJCT] 0.79 61672 [HILLTOP7] 0.79 61679 [GARY 7] 0.79 +more
	375	**STABLE** 60149 [MINVALT4] 0.68 60150 [MNVLTAP4] 0.68 60147 [MINVALY4] 0.68 66550 [GRANITF4] 0.68 66513 [HANLON 4] 0.68 63050 [WILLMAR4] 0.69 67410 [MITCLNW7] 0.69 +more	**UNSTABLE** 63050 [WILLMAR4] 0.66 60149 [MINVALT4] 0.66 60150 [MNVLTAP4] 0.66 62001 [BENSON 7] 0.67 60147 [MINVALY4] 0.67 60356 [PAYNES 4] 0.67 62005 [KERKHOT7] 0.67 +more	**UNSTABLE** 61614 [98L TAP4] 0.78 61615 [ARROWHD4] 0.78 61616 [HILLTOP4] 0.78 61686 [15TH AV7] 0.79 61656 [MAHTOWA7] 0.79 61672 [HILLTOP7] 0.79 61673 [ARROWHD7] 0.79 +more
	250	**STABLE** None	**STABLE** 63050 [WILLMAR4] 0.67 60149 [MINVALT4] 0.67 60150 [MNVLTAP4] 0.67 60147 [MINVALY4] 0.67 62005 [KERKHOT7] 0.67 60356 [PAYNES 4] 0.68 62001 [BENSON 7] 0.68 +more	**UNSTABLE** 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.79 61674 [HANESRD7] 0.79 61679 [GARY 7] 0.79 +more
	150	**STABLE** None	**STABLE** None	**STABLE** 61614 [98L TAP4] 0.79 61615 [ARROWHD4] 0.79 61616 [HILLTOP4] 0.79 61686 [15TH AV7] 0.79 61672 [HILLTOP7] 0.80 61674 [HANESRD7] 0.80 61679 [GARY 7] 0.80 +more
White	**500**	**STABLE** None	**STABLE** None	**STABLE** 61615 [ARROWHD4] 0.81 61616 [HILLTOP4] 0.81 61614 [98L TAP4] 0.81 61686 [15TH AV7] 0.81

5. CONCLUSIONS

The steady-state results are summarized in the table below for normal system, N-1, constrained interface, and transfer capability.

Summary of Steady State Results for the Task 3 and Task 4 Analysis

Case Name	System Intact Analysis	(N-1) Contingency Analysis	Constrained Interface Analysis	Transfer Capability Analysis
Case10	Ok	Ok	Ok	Ok
Case11	--	--	--	Ok
Case12	--	--	--	Ok
Case13	--	--	--	Ok
Case14	--	--	--	Ok
Case20	Ok	Ok	Ok	Ok
Case21	--	--	--	Ok
Case22	--	--	--	Ok
Case23	--	--	--	Ok
Case24	--	--	--	Ok
Case30	Ok	Ok	Ok	Ok
Case31	--	--	--	Ok
Case32	--	--	--	Ok
Case33	--	--	--	Ok
Case34	--	--	--	Ok
Case40	Ok	Ok	Ok	Ok
Case41	--	--	--	Ok
Case42	--	--	--	Ok
Case43	--	--	--	Ok
Case44	--	--	--	Ok
Case50	Failed*	Failed*	Ok	Failed*
Case51	Failed*	Failed*	Ok	Failed*
Case52	Ok	Ok	Ok	Ok
Case53	--	--	--	Ok
Case54	--	--	--	Ok
Case60	Ok	Ok	Ok	Ok
Case61	--	--	--	Ok
Case62	--	--	--	Ok
Case63	--	--	--	Ok
Case64	--	--	--	Ok
Case70	Ok	Ok	Ok	Ok
Case71	--	--	--	Ok
Case72	--	--	--	Ok
Case73	--	--	--	Ok
Case74	--	--	--	Ok
Case8	Ok	Ok	Ok	Ok

* With two new 230-kV lines, the Mission site will accomodate 500 MW
** Rapid City was tripped for the local faults at New Underwood

The steady-state analysis is summarized as follows:

- The Mission site can only support 250 MW with the existing transmission. Two new 230-kV lines will support 500 MW out of the Mission site.
- There are two sites with the normal system conditions which load one line to between 100-105%
- There are only a few contingencies that overload transmission lines.
- Most of the transformer overloads are also in the base case except for the New Underwood site which overloads the existing transformer at New Underwood

Most of the wind sites results in a few low voltages in central North Dakota that will need some shunt capacitor support to maintain the system voltage.

The results of the local stability analysis indicate that all sites were stable for 500 MW. These cases were run on the winter peak case. The regional stability analysis was done using a summer off-peak case to maximize transfers.

The following are the conclusions for the regional stability analysis on the non-firm transfer cases:

For the eight scenarios using non-firm transmission, NDEX was readjusted to maintain a 1450 MW export leaving 500 MW for non-firm transfers. The maximum wind generation of 500 MW was added to a wind site and the regional stability simulations were run. The results of the regional stability are as listed below:

Garrison 230 kV	250 MW
Pickert 230 kV	500 MW
Ellendale 345 kV	250 MW
New Underwood 230 kV	500 MW
Mission 115 kV	375 MW
Ft. Thompson 345 kV	500 MW
White 345 kV	500 MW
Scenario 8-All Sites	500 MW

The Garrison and Ellendale sites had some incremental degradation of voltages in the Groton and Granite Falls areas for the levels of generation listed above. A 200 MVAr SVC was modeled at Groton for these two sites and the voltage performance met the criteria with the SVC. Low voltages in the New Underwood area during regional disturbances when wind generation is connected at New Underwood would also require some dynamic voltage support. Low dynamic voltage dips in the northern Minnesota area occur in the base case without any additional wind generation added.

The following are the conclusions for the regional stability analysis on the firm transfer cases:

These are the results with NDEX at 1950 MW for the regional stability cases without any enhancements to the network and then the new wind generation is added for each site evaluation. If the wind generation is added to the existing firm commitments, the following generation can be added at each site without system enhancement to improve inter-regional transfers.

Garrison 230 kV	50 MW
Pickert 230 kV	50 MW
Ellendale 345 kV	50 MW
New Underwood 230 kV	50 MW
Mission 115 kV	150 MW
Ft. Thompson 345 kV	50 MW
White 345 kV	250 MW

Scenario 8 with wind at all sites was unstable for the dispersed 500 MW. Series compensation of 35% of the line reactance in the Leland Olds-Groton 345-kV line, the Leland Olds-Ft. Thompson 345-kV line, and the Antelope Valley-Broadland 345-kV line for the firm transfer cases will raise the interconnection capacity of each site as follows:

Results of 35% series compensation on non-firm transfer cases:

Garrison 230 kV	500 MW
Ellendale 345 kV	500 MW

Results of 35% series compensation on firm transfer cases:

New Underwood 230kV	150 MW
Mission 115kV	250 MW
Ft. Thompson 345kV	150 MW
White 345kV	375 MW
Case 8	500 MW

Series compensation of 50% of the line reactance in the Leland Olds-Groton 345-kV line, the Leland Olds-Ft. Thompson 345-kV line, and the Antelope Valley-Broadland 345-kV line was tested for two sites and will raise the interconnection capacity of the following two sites:

Results of 50% series compensation on firm transfer cases:

Ft. Thompson 345kV	250 MW
White 345kV	500 MW

These cases demonstrate the improved performance due to additional technologies that can be implemented to help eliminate system constraints. Further fine-tuning is required for the above values to design actual values, based on site selection. Regarding series compensation, detailed analysis of potential sub-synchronous resonance impacts will be required to ensure the compensation will not cause an adverse impact which could damage nearby generators. The sub-synchronous resonance effect is described in section 4 of the Task 2 report.

Results of New Maple River-Benton County 345-kV Line on firm transfer cases:

Garrison 230 kV	375 MW
Ellendale 345 kV	500 MW
White 345kV	500 MW

Two new 230-kV lines were modeled connecting Mission to the Oahe and Ft. Randal Substation. With these two new lines, the steady-state performance indicated that 500 MW of wind could be accommodated, but the stability limits for inter-regional stability remain the same as reported above.

For 500 MW of wind generation at Garrison, three SVCs of 200 MVArs each installed at Arrowhead, Riverton, and Granite Falls eliminate the under-voltage violations that occur. These voltage violations occur for fault "nbz" even in the Base Case without new wind generation.

For 500 MW of wind generation at Garrison or Ellendale, one SVC of 200 MVAR installed at Groton eliminates the low voltage violations in the Groton area for faults "ei2" and "ag1".

These cases demonstrate the improved performance due to additional technologies that can be implemented to help eliminate system constraints. Further fine-tuning is required for the above values to design actual values, based on site selection.

All of the study results are summarized in the table below. Those cases with one or two lines loaded between 100 and 110% were listed as OK in the table. Alternatives for relieving these overloads will be addressed in the Task 2 report.

Additional sensitivity on the firm transfer cases are performed by adding new transmission lines in the system to increase the power transfers. 375 MW of generation can be interconnected at Garrison, 500 MW can be connected at each of the sites of Ellendale and White. Details of the new transmission lines and detailed stability results are described in section 4.3.4.10 of the report.

APPENDICES A-L

(Appendix A through Appendix L are attached separately due to the large size)