System Impact Study - Project # GI-0515
130 MW in Ziebach & Dewey County, SD

DRAFT REPORT

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CEII Removed - Critical Energy Infrastructure Information

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System Impact Study - Project # GI-0515	Date: August 26, 2010	# Pages 35

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Executive Summary

Basin Electric Power Co-operative (BEPC) commissioned ABB Inc., to perform a System Impact Study for the interconnection of Project GI-0515, a 130 MW (net) wind farm comprising 88 x 1.5 MW GE wind turbines to Eagle Butte 115 kV Substation, about 10 miles from the Cheyenne River Project substation, in Ziebach & Dewey County, SD. This Generation Interconnection Study included system performance evaluation based on steady state, stability and short circuit analyses. An evaluation of the constrained interfaces of MAPP and MISO (flow gates) was also performed. These evaluations were performed for year 2010 conditions.

As part of this study, an analysis (power flow only) of the future system conditions depicting summer peak load conditions for the year 2016 was also performed. The most notable changes in the study area for this future year include the proposed addition of approximately 268 MW of new load (Keystone Pumping load) distributed along transmission corridor extending from Montana (Miles City area) to South Dakota (Maurine – Philip – Midland – Whitten – Gregory) and additional transmission (Big Bend – Whitten 115 kV), transformer upgrades (Belfield, Leland Olds, New Underwood, Oahe, Philip) and static capacitors for power factor correction at the respective Pumping load substations. Two scenarios were studied to evaluate the impact of the proposed GI-0515 wind farm – i) Without the Keystone additions, and ii) With the Keystone additions.

This report is structured in the following manner – Section 1 gives a brief introduction of the Project Interconnection. The Study Methodology is given in Section 2. Sections 3, 4, 5 and 6 discuss respectively, the Steady State Analysis, Constrained Interface Analysis, Stability Analysis and Short Circuit Analysis. Section 7 summarizes the results of the out-year power flow analysis. Section 8 summarizes the interconnection related issues identified during the study. Mitigation of the interconnection related issues is discussed in Section 9.

A summary of the study results is given below:

Steady State Analysis

Eagle Butte – Faith – Maurine 115 kV (Rate A/Rate B/ Rate C – 77/143/77 MVA): This transmission line, which is one of the two outlets for GI-0515 indicated a maximum loading of 119 MVA during N-1 conditions (2010 summer off-peak load conditions; outage of the second outlet, Eagle Butte – Oahe 115 kV) which translates into 153% on 77 MVA rating (Rate-A in PSS/E). The loading under summer peak conditions was slightly lower (150%). The maximum pre-project loading was 21 MVA.

Eagle Butte – Oahe 115 kV (Rate A/Rate B/ Rate C – 80/143/88 MVA): This is the second outlet for GI-0515 wind farm. The outage of Eagle Butte – Faith – Maurine 115 kV caused a loading of 119 MVA (i.e. 148% on 80 MVA normal rating, 134.5% on emergency rating) for summer off-peak load conditions. The loading under summer peak conditions was slightly lower (145% on normal rating; 132% on emergency rating). The maximum pre-project loading was 15 MVA.

Oahe 230/115 kV transformer (Rate A/Rate B/ Rate C – 107/107/134 MVA): This transformer indicated a loading of 110 MVA under system intact, summer off-peak load conditions for year 2010 in the post-project case. The continuous rating of this transformer is 107 MVA and therefore the loading is 103%. The pre-project loading was 55 MVA (49%). During N-1 contingencies (outage of Eagle Butte – Faith – Maurine 115 kV during summer off-peak load conditions, year 2010), a maximum loading of 147 MVA (137.6% on normal rating; 110% on emergency rating) was noted. The corresponding loading for summer peak load conditions was 120 MVA. The maximum pre-project loading was 43 MVA. The prior outage of Eagle Butte – Faith – Maurine 115 kV line followed by the outage of Irv Simmons – Midland 115 kV line indicated a loading of 152 MVA (142% on continuous rating; 113.4% on emergency rating).

There are two options to mitigate the thermal loading problems:

1. Establish Operating guideline(s) – Reduce the GI-0515 output to ensure the relevant facilities are loaded within their respective operating limit, or
2. Capacity upgrade of the overloaded facilities

The following tables give the most-limiting overloads and the maximum allowable injection from GI-0515 POI necessary for various operating conditions. It should be noted that these reductions are approximate and were calculated based on the respective TDFs.

System Intact and N-1 Contingencies

Facility	Rating (MVA)			Loading (MVA)		Loading (% on Rate A)		Loading (% on Rate C)	TDF (%)	Contingency	Condition	Max. Allowable Injection at the POI (MW)	Mitigation Facility Upgrade
	Rate A	Rate B	Rate C	Pre-project	Post-project	Pre-project	Post-project	Post-project					
Oahe 230/115 kV Transformer	107.0	107.0	134.0	55.4	110.3	49.0	103.0	82.2	41.5	System Intact	2010 su op	124.0	Upgrade transformer to 115 MVA normal / 150 MVA emergency
Oahe 230/115 kV Transformer	107.0	107.0	134.0	45.8	147.3	42.8	137.6	109.9	78.1	L/O Eagle Butte - Faith - Maurine 115 kV line	2010 su op	113.0	Upgrade transformer to 115 MVA normal / 150 MVA emergency
Eagle Butte - Oahe 115 kV line	80.0	143.0	88.0	9.8	118.7	12.1	147.5	134.1	83.8	L/O Eagle Butte - Faith - Maurine 115 kV line	2010 su op	93.0	Upgrade terminal equipment
Eagle Butte - Faith - Maurine 115 kV line	77.0	143.0	77.0	9.8	119.1	12.7	153.1	153.1	84.1	L/O Eagle Butte - Oahe 115 kV line	2010 su op	80.0	Upgrade terminal equipment

Prior Outage and Contingency (2010 Summer Peak)

Facility	Rating (MVA)			Loading (MVA)		Loading (% on Rate A)		Loading (% on Rate C)	TDF (%)	Contingency	Prior-Outage	Max. Allowable injection at POI (MW)	Mitigation Facility Upgrade
	Rate A	Rate B	Rate C	Pre-project	Post-project	Pre-project	Post-project	Post-project					
Oahe 230/115 kV Transformer	107.0	107.0	134.0	27.1	151.8	25.3	141.9	113.3	94.5	L/O Midland-Irv Simmons 115 kV line	EB-FTH-MRN	113.0	Upgrade transformer to 115 MVA normal / 155 MVA emergency
Eagle Butte - Oahe 115 kV line	80.0	143.0	88.0	12.1	116.9	15.4	145.7	132.5	79.4	L/O Eagle Butte - Faith - Maurine 115 kV line	Oahe #1	97.0	Upgrade terminal equipment
Eagle Butte - Faith - Maurine 115 kV line	77.0	143.0	77.0	12.1	116.9	16.0	150.3	150.3	79.4	L/O Eagle Butte - Oahe 115 kV line	Oahe #1	82.0	Upgrade terminal equipment

As an alternative to operating the proposed wind farm project at reduced output, the overloaded facilities could be upgraded to operate with a higher capacity (that would eliminate the thermal loading problems).

In the case of the two outlet lines, namely Eagle Butte – Faith – Maurine 115 kV and Eagle Butte – Oahe 115 kV lines, the maximum loading was 119 MVA under N-1 conditions whereas the emergency rating on these lines are only 77 MVA and 88 MVA respectively. Therefore the capacity upgrade should be such that these facilities can be loaded to at least 120 MVA.

The Oahe transformer is however earmarked for an upgrade in the year 2016 depending on the Keystone project moving forward. The Oahe transformer is expected to have a capacity of 250 MVA (continuous) with an emergency capability of 312 MVA. Until the Keystone project is implemented (which will also include an upgrade of the Oahe transformer), the GI-0515 may be operated with a reduced output (113 MW). However, if the Keystone project does not materialize or if the developer seeks to operate at the proposed full output, then the Oahe 230/115 kV transformer will have to be upgraded prior to the project (GI-0515) in-service date in order to mitigate the potential overload problem.

No significant impacts were noted on bus voltages in the interconnection vicinity.

Constrained Interface Analysis:

The study also evaluated the impact of the proposed project on constrained interfaces in the MAPP and MISO systems. They are provided for informational purposes only, to identify potential third party flow gate issues for the requested delivery component of the transmission.

Stability Analysis:

The results of the stability analysis indicated that the proposed wind farm does not adversely impact transmission system performance.

Short Circuit Analysis:

Three-phase symmetrical fault current levels were calculated at the point of interconnection and POI vicinity, with and without the GI-0515 project. The short circuit levels were then compared against the minimum breaker rating at those substations. The short circuit levels were found to be within the respective minimum breaker ratings.

Preliminary Cost Estimates for Network Reinforcements

Non-binding good faith cost estimates for Network reinforcements required to mitigate the impacts of GI-0515 project is presented below. These were compiled by Western Area Power Administration and may be further developed and refined in the Facility Study. It should be noted that the information presented below are with Project GI-0515 modeled at the requested levels i.e. with GI-0515 at 130 MW.

GI-0515 Conceptual Cost Estimate

Facility Addition	Quanity	Unit Cost	Total
115 kV 1600 amp bay			
Site Prep	1	$ 73,000	$ 73,000
Circuit Breakers	1	$ 110,000	$ 110,000
Disconnect Switches	3	$ 18,500	$ 55,500
Control	1	$ 94,000	$ 94,000
Bus System	1	$ 108,000	$ 108,000
Steel & Footings	1	$ 208,000	$ 208,000
Upgrades to Increase Eagle Butte-Faith-Maurine 115 to 120 MVA			
Uprates to Eagle Butte Terminal (Breaker 362)			
EB breaker bushing CT uprate from 400:5 to 600:5	1	$ 1,000	$ 1,000
EB bus work capable of minimum of 900 amps (max wintr cond lmt)	1	$ 50,000	$ 50,000
EB-MA Relay Load Limit to 145 MVA (110% of 132 MVA)	1	$ 1,000	$ 1,000
Uprates to Faith Tap			
FH bus work capable of minimum of 900 amps (max wntr cond lmt)	1	$ 50,000	$ 50,000
Uprates to Maurine Terminal (Breaker 1462)			
Verify MA line disconnects capable of minimum of 600 amps	2	$ 1,000	$ 2,000
Verify MA bus work capable of minimum of 600 amps	1	$ 1,000	$ 1,000
Upgrades to Increase Eagle Butte-Oahe 115 to 120 MVA			
Uprates to Eagle Butte Terminal (Breaker 162)			
EB breaker bushing CT uprate from 400:5 to 600:5	1	$ 1,000	$ 1,000
EB-OA Relay Load Limit to 145 MVA (110% of 132 MVA)	1	$ 1,000	$ 1,000
Uprates to Oahe Terminal (1262 Breaker)			
OA breaker bushing CT uprate from 300:5 and 400:5 to 600:5	1	$ 1,000	$ 1,000
Verify OA line disconnects capable of minimum of 600 amps	2	$ 1,000	$ 2,000
Verify OA bus work capable of minimum of 600 amps	1	$ 1,000	$ 1,000
20% Contingency Adder			$ 151,900
Total GI-0515 Conceptual Cost Estimate			$ 911,400

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1. INTRODUCTION

Basin Electric Power Co-operative (BEPC) commissioned ABB Inc., to perform a System Impact Study for the interconnection of Project GI-0515, a 130 MW generation (Net) comprising of 88 x 1.5 MW GE wind turbines to Eagle Butte 115 kV Substation, about 10 miles from the Cheyenne River Project substation, in Ziebach & Dewey County, SD. Figure 1.1 gives the location of the proposed wind farm on a geographic transmission map. Figure 1.2 gives the proposed project interconnection diagram along with the Collector System information. This report discusses the study details and the results.

Fig. 1.1 Approximate Location of Proposed Wind Farm (CEII)

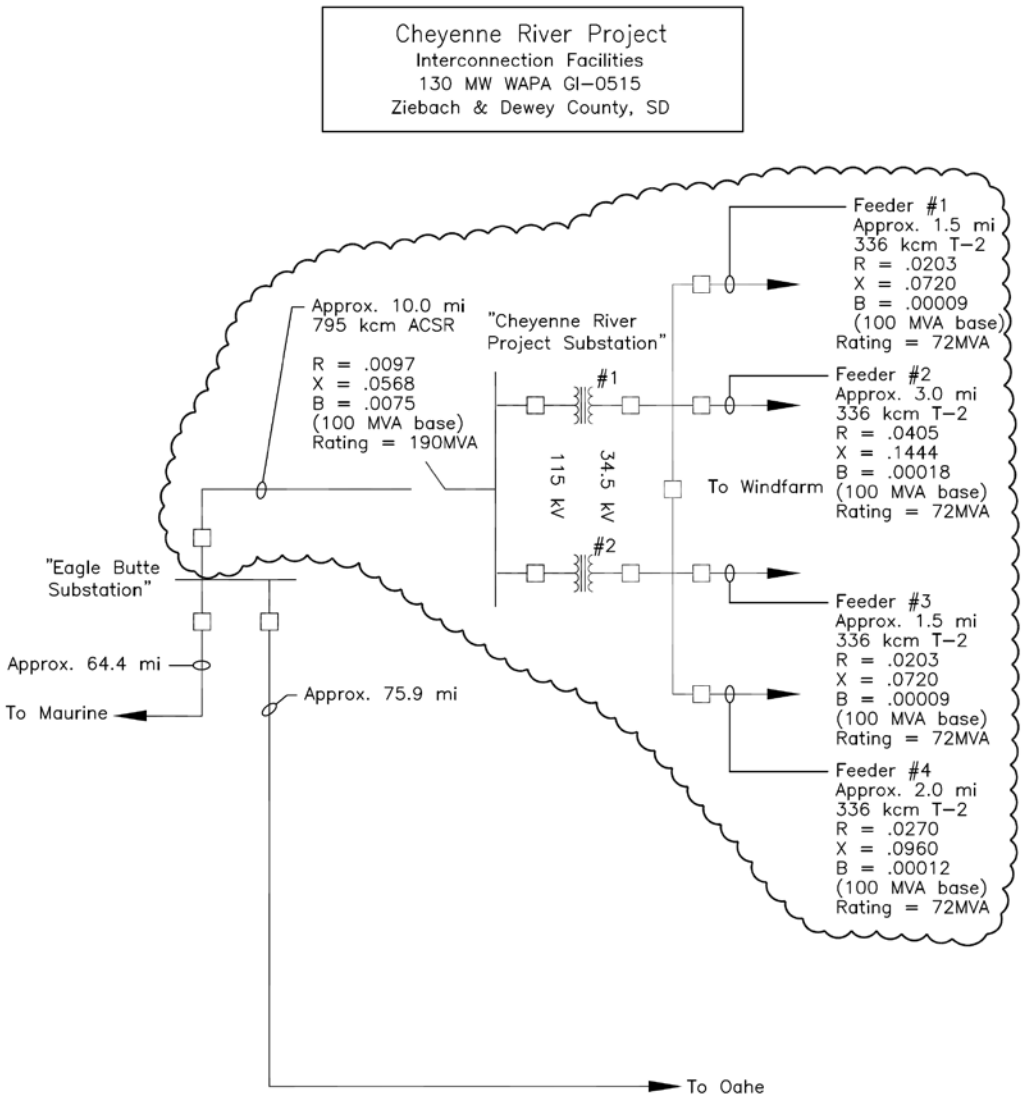

Fig. 1.2 Proposed Interconnection Details for GI-0515

2. STUDY METHODOLOGY

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 GI-0515 project on thermal loading of transmission facilities under system intact conditions was evaluated by comparing transmission system power flows with and without the GI-0515 project. For this purpose, full ac power flow solutions were used.

All facilities rated 110 kV and above were monitored in Northern MAPP (areas 600, 608, 618, 626, 640 and 652). The criteria to flag thermal overload is 90% of continuous facility rating (Rate A in PSS/E).

MAPP DRS Guidelines were used to identify Significantly Affected Facilities (SAF). According to these guidelines, all overloaded facilities that have a TDF (Transfer Distribution Factor) greater than 5% of the generation addition (without plant vs. with plant) were flagged as significantly affected facilities.

N-1 Contingency Analysis:

The contingency description file for this study consisted of single branches as well as multiple-circuit and multi-terminal outages in Northern MAPP. All facilities rated 110 kV and above were monitored in Northern MAPP.

Contingency analysis was performed using activity ACCC of PSS/E. The contingencies were solved with phase shifters and transformer taps enabled. Thermal violations were flagged based on the Rate A data for facilities (from PSS/E). Post-contingency power flows in excess of 90% of Rate A were flagged. Non-convergent contingencies from these analyses (primarily due to switching back and forth of transformer taps and switched shunts) were solved manually and their violations were appended to the ACCC results. Facility loadings with and without the GI-0515 project were tabulated and compared.

As in the system intact analysis, MAPP DRS Guidelines were used to identify Significantly Affected Facilities (SAF). Facilities with a TDF greater than 3% were included in the SAF list.

2.1.2 Voltage Analysis

Voltages at Northern MAPP buses rated 110 kV and above were monitored for possible voltage violations. Voltages that were outside the values shown in Table 2.1 were flagged. In accordance with MAPP DRS Guidelines, those buses that have a voltage change of more than 0.01 p.u. (without plant vs. with plant) are considered significantly affected.

Table 2.1: Voltage Criteria

System	Base kV	System Intact Conditions		N-1 Contingency Conditions	
		Max (pu)	Min (pu)	Max (pu)	Min (pu)
MAPP	110-500 kV	1.05	0.95	1.10	0.90
MP (area 608)	110-500 kV	1.05	1.00	1.05	0.95
MP Western Division (area 610)	110-230 kV	1.05	0.96	1.05	0.92
OTP (area 626)	230-345 kV	1.05	0.97	1.10	0.92
	110-115 kV	1.07	0.97	1.10	0.92
NPPD (area 640)	110-345 kV	1.05	0.95	1.10	0.90
WAPA (area 652)	110-345 kV	1.05	1.00	1.10	0.90

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 was used for this purpose.

2.3 Stability Analysis

The purpose of the stability analysis is to determine whether the MAPP system would meet stability criteria following commissioning of the proposed GI-0515 project. To that end, faults were simulated in Northern MAPP to assess the impact of the proposed project on transmission system stability. Preliminary solutions were identified and tested for faults that resulted in stability criteria violations.

2.4 Short-Circuit Analysis

The purpose of short-circuit analysis is to determine fault current levels at the point of interconnection, both before and after the addition of the proposed wind farm. In order to facilitate the fault current calculations, a set of pre- and post-project short-circuit models were developed. Three-phase faults were simulated at the point of interconnection and the impact of the GI-0515 project on the increase in fault currents was determined.

3. STEADY STATE ANALYSIS

3.1 Model Development

The pre-project case for this analysis was developed starting from year 2010 summer peak and off-peak cases included in the NMORWG 2010 study package ("pkg2010-1-05-2010"). The following modifications were made to this "Base Model".

The dispatch assumptions for prior-queued generator interconnections that were included in the study models are tabulated below (Table 3.1).

Table 3.1 Dispatch Assumptions for Prior-queued Projects: Steady State Analysis

Bus	Queue #	Size	Steady State	
			Off-peak (MW)	Peak (MW)
67399	G132	180	180	180
67255	GI-0615	50	Off	Off
67295	GI-0508	50	49.5	49.5
67292	GI-0208	41	40.5	40.5
67293	GI-0209	41	40.5	40.5
66881	GM0200	60	Off	Off
63165	G291	21	21	21
67393	G767	20	Off	Off
67274	GI-0316	120	Off	Off
68378	G380	150	150	150
63087	G408	12	12	12
66883	GM0300	41	Off	Off
66985	GM0500	358	Off	Off
67157	GI-0503	100	100	100
67157	GI-0720	16	Off	Off
61603	G502	51	50.6	50.6
61606	GS659	50	Off	Off
99359***	G359	150	150	30
63003***	G531	68	68**	68**
66903***	GI-0512	50	49.5	49.5

** Net output; the gross generation is 75 MW

*** New bus numbers – for generators added to the starting cases; i.e. not represented in the 2010 package power flow

The generating units at Big Stone and Oahe were dispatched at maximum; for the summer off-peak case, URGE levels were used whereas for the summer peak case, CRUISE levels were used (Table 3.2):

Table 3.2 Dispatch Details for Big Stone and Oahe Units

Bus	Queue #	Size (Gross MW)	Steady State	
			Off-peak (URGE_Net-MW)	Peak (CRUISE_Net-MW)
63315	Big Stone	495	475	475
66520	Oahe	684	714	587

It may be noted that for the summer peak load conditions, we used a normal dispatch scenario where Oahe unit #7 is turned off. However, in order to verify the impacts, if any of Oahe #7 on the facility loading impacts in the interconnection vicinity, we performed a sensitivity analysis on the near-term summer peak conditions by dispatching Oahe unit #7 at its CRUISE level (Oahe #7 was re-dispatched against generation at Ft. Randall).

The CT #1 at Groton was turned on for summer peak load conditions; it was also dispatched in the summer off-peak case as a proxy for a proposed 100 MW wind farm in the same location as the Groton CT. Groton CT #2 was dispatched in peak load case and was assumed offline for off-peak conditions. The Groton CTs were re-dispatched against MISO foot-print generation[1].

The Ft. Thompson and Edgeley units were modeled and re-dispatched against MISO foot-print generation.

The Rapid City DC tie was modeled at 200 MW, in the West – East direction. This was re-dispatched against MISO foot-print generation.

[1] Generation east of Twin Cities within: Area 356: Ameren, Area 359: Cilco, Area 208: Cinergy, Area 360: CWLP, Area 211: LGEE, Area 650: Lincoln Electric System, Area 218: CONS, Area 361: SIPC, Area 202: FE, Area 217: NIPS

Table 3.3 Additional Model Information

Bus #	Name	Power Flow Analysis	
		2010 Summer Peak	2010 Summer Off-peak
67273, Unit 1	Groton CT	120	120
67273, Unit 2	Groton CT	120	Offline
67293	Ft. Thompson	40.5	40.5
67292	Edgeley	40.5	40.5
67268	RCDC	200 MW West - East	200 MW West - East

- The North Dakota peak load level was maintained at 3400 MW in the summer peak case, which reflects the 2010 summer peak loading condition. The summer off-peak power flow case had an ND load of 68.2%
- Square Butte DC was dispatched at 500 MW
- NDEX was maintained at 2148 MW in the summer off-peak case (this reflects the assumed present limit of 2080 MW plus 68 MW for a proposed net generation at Stanton (G531)); the NDEX value in the summer peak case was 475 MW.

For summer off-peak condition, the "setexports" IPLAN program was run to fix the NDEX at 2148 MW, MHEX to 2175 MW and MWEX to 1525 MW. The switched capacitors at Groton 115 kV (2x30 MVAR) and the 75 MVAR capacitor at Watertown 230 kV were assumed on-line for the summer off-peak cases (this is in agreement with DRS 12/8/04 motion for NDEX >= 2080 MW)

The *GI-0515* case was developed from the *pre-project cases* by adding the 130 MW (net) wind farm, connected to the Eagle Butte 115 kV Substation, about 10 miles from the Cheyenne River Project substation, in Ziebach & Dewey County, SD. The proposed GI-0515 output was dispatched against "MISO Foot print" generation. The power flow summaries for the cases developed for this study are given in Appendix A.

3.1.1 Modeling of Proposed Wind farm

The proposed wind farm consists of 88, GE 1.5 MW wind turbine generators of DFIG technology; assuming about 2 MW losses in the collector system, the net output is 130 MW. These wind turbine generators were represented in the power flow as 4 equivalent units each with 33 MW output, at 575 V was connected to the 34.5 kV substation via two 80 MVA, 115/34.5 kV transformers connected to the Eagle Butte 115 kV Substation. In the power flow, the wind farm was set to regulate the 34.5 kV side voltage to 1.0 p.u; the 115/34.5 kV transformer tap settings were adjusted suitably in system intact power flow. With this adjustment, the POI voltage was 1.03 pu and power factor was unity. For all subsequent analysis, the transformer taps were locked.

3.2 System Intact

The system intact analysis did not indicate any thermal overloads in POI vicinity for summer peak load conditions. However, for the summer off-peak load condition of year 2010, a loading of up to 103% was noted on Oahe 230/115 kV transformer, in Post-GI0515 case. The pre-project loading on this transformer was 49%.

Table 3.4 lists the significantly affected facility loadings for system intact conditions for without and with the proposed wind farm. The facility overloads with TDF of >5% are included along with a comparison of facility loadings expressed both in MVA and in percent on Rate A without and with the proposed wind farm.

Table 3.4 Significantly Impacted Facilities: Thermal Overloads – summer off-Peak system intact Condition, 2010

LIMITING ELEMENT	RATING (MVA)	Loading				DF (%)
		Pre-GI515 (% on Rate A)	Post-GI515 (% on Rate-A)	Pre-GI515 (MVA)	Post-GI515 (MVA)	
66519 OAHE 4 230 66520 OAHE 7 1	107.0	49.0	103.0	55.4	110.3	41.5

The impact on bus voltages was not significant. Figure 3.1 to 3.4 show the power flow and voltage in the vicinity of the plant for pre-and post-project GI-0515 conditions.

3.3 N-1 Conditions

N-1 Contingency Analysis included single branch and selected multi-element contingencies on facilities rated 110 kV and above. Single branch contingencies in WAPA, GRE, MH, MP, OTP, and XEL as well as multiple outages in the Dakotas were considered for this analysis. All facilities rated 110 kV and above were monitored in the WAPA, OTP, GRE, MP, XEL and NPPD control areas. Contingencies were solved using activity ACCC of PSS/E. Phase shifters and transformer taps were enabled. The subsystem definitions, contingencies for the analysis and the monitored element details are included in Appendix B.

Non-convergent contingencies from these analyses (primarily due to switching back and forth of transformer taps and switched shunts) were solved manually and their violations were appended to the ACCC results. Thermal violations were flagged based on continuous facility rating (Rate A in PSS/E). Post-contingency power flows in excess of 90% of the Rate A were recorded. Facility loadings with and without GI-0515 Wind Farm were tabulated and compared. The criterion used to flag thermal overloads is 100% of Rate A. Significantly Affected Facilities (SAF) was identified based on the following criteria:

All overloaded facilities with a TDF (Transfer Distribution Factor) greater than 3% (with respect to the generation addition; without Wind Farm vs. with the wind farm) were flagged as significantly affected facilities.

As in the system intact analysis, all Northern MAPP buses rated 110 kV and above, were monitored for possible post-contingency voltage violations. Bus voltages that were outside the values shown in Table 2.1 were flagged as violations. Those buses with a voltage change greater than 0.01 p.u. (without Wind Farm vs. with Wind Farm) are included in the SAF list.

Figure 3.1: System intact power flow for Pre-GI-0515condition – Summer Peak **(CEII)**

Figure 3.2: System intact power flow for Post-GI-0515condition – Summer Peak **(CEII)**

Figure 3.3: System intact power flow for Pre-GI-0515condition – Summer Off-peak **(CEII)**

Figure 3.4: System intact power flow for Post-GI-0515condition – Summer Off-peak **(CEII)**

3.3.1 Impact on Facility Loading

The following facilities were significantly affected based on the DRS guidelines and can be attributed to the proposed project interconnection:

Eagle Butte – Faith – Maurine 115 kV line: This overhead line, which is one of the outlets for proposed wind farm with the POI at Eagle Butte 115 kV showed a loading of 117 MVA for summer peak and 119 MVA for summer off-peak load conditions for the loss of Eagle Butte – Oahe 115 kV. The Rate-A for this facility is only 77 MVA due to a bus jumper restriction at the Faith 115 kV substation. The emergency rating (Rate-C in PSSE) and Conductor rating (Rate-B in PSSE) for this facility are respectively 77 MVA and 143 MVA.

Eagle Butte – Oahe 115 kV: A second outlet from Eagle Butte with a normal continuous rating of 80 MVA, this overhead line showed a post-contingency loading of 117 MVA for summer peak and 119 MVA for summer off-peak load conditions for the outage of the other outlet, namely Eagle Butte – Faith 115 kV. The Rate-C (emergency) and Rate-B (conductor) values for this facility are 88 MVA and 143 MVA.

Oahe 115/230 kV Transformer: This transformer was overloaded for both peak and off-peak load conditions. However, no overloads were noted in the pre-project cases. For the post-project case under summer peak conditions, this transformer showed a loading of 110% (120 MVA) for the outage of Faith – Eagle Butte - Maurine 115 kV based on 107 MVA rating. This post-project N-1 loading is however below the emergency rating of 134 MVA. The pre-project loading for the same contingency was only 15%. For summer off-peak load conditions, this transformer showed a loading of 137.6% (147.3 MVA) for the same outage. The post-project loading of summer off-peak load condition is higher than the emergency rating of 134 MVA. The pre-project loading for this contingency was only 42.8%.

Maurine 115/230 kV Transformer: A marginal loading of 101%, based on 100 MVA rating was indicated, for the outage of Eagle Butte – Oahe 115 kV. The post-project loading of peak load condition is however below the emergency rating of 125 MVA. No overload was noted for summer off-peak condition.

Ft. Thompson – Oahe 230 kV: There are 4 circuits between Ft. Thompson and Oahe 230 kV substations (2 circuits on each tower). The loading on these circuits increased from a pre-project value of about 106% to 115% (based on 318 MVA rating) in post-project conditions, for a tower outage, which takes out two circuits between these substations. The emergency rating is 350 MVA and the conductor rating is 440 MVA. This is not identified as an injection related constraint.

Tables 3.5 and 3.6 list the significantly affected facilities for contingency conditions, without and with the proposed wind farm. These tables list the limiting facilities and associated contingencies that cause overloads, along with a comparison of facility loadings expressed both in MVA and in

percent on Rate A without and with the proposed wind farm. Overloads were also observed on several other facilities. These are not listed in Tables 3.5 and 3.6 as they were not deemed injection related constraints in the context of this system impact study. However these overloads (listed in Appendix C) will be addressed if they appear during the transmission service approval process for this project.

For the summer peak conditions, there was no significant voltage impact. However, for summer off-peak loading conditions, there several buses which had a bus voltage impact of 0.01 pu or higher. Upon close evaluation, these buses found to be electrically far away from the POI vicinity. The post-contingency bus voltages in the pre- and post-project conditions are given in Appendix C.

Mitigation of the interconnection related impacts is summarized in Section 9 of this report.

3.4 Sensitivity Analysis with Oahe Generating Unit #7

The analysis in Sections 3.2 and 3.3 reflect the normal operating scenario for the summer peak load conditions – with Oahe generating unit #7 (at 230 kV) turned off. However, it is important to evaluate any impact on the facilities in the GI-0515 POI vicinity, if Oahe #7 is dispatched fully. Therefore a sensitivity analysis was performed to identify incremental impacts thereof due to GI-0515. The Oahe #7 generation was re-dispatched against Ft. Randall generation.

With the Oahe #7 dispatched fully at the CRUISE level (Gross Pmax = 97 MW), about 3 MW from Oahe #7 output flows on Oahe transformer (and reducing the transformer flow from 68 MVA to 65 MVA; the power flow on Oahe 230/115 kV transformer is from 115 kV to the 230 kV level.) whereas 92 MW flows on the 230 kV network.

Next, we performed an N-1 contingency analysis with Oahe #7 fully dispatched. This analysis showed very little change on the facility loadings in the interconnection vicinity. In fact, the Oahe 230/115 kV loading reduced from 120.5 MVA (without Oahe #7) to 118 MVA with Oahe #7 dispatched at full.

In summary, Oahe #7 does not significantly impact the flows on the Oahe 230/115 kV transformer and the Eagle Butte-Faith-Maurine 115 kV line. In fact, there is a slight reduction in Oahe transformer loading, with the Oahe #7 dispatched fully. A side-by-side comparison of the impact of Oahe #7 dispatch on nearby facility loadings are shown in Table 3.7.

Table 3.5 Significantly Impacted Facilities: Thermal Overloads – Summer Peak Load Conditions, 2010

LIMITING ELEMENT	RATING (MVA)	CONTINGENCY	Loading				DF(%)
			Pre-GI515 (% on Rate-A)	Post-GI515 (% on Rate-A)	Pre-GI515 (MVA)	Post-GI515 (MVA)	
66519 OAHE 4 230 66520 OAHE 7 115 1	107	FTH-EB-MRN	15	112.2	16.4	120	89.1
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	20.5	150.3	12.2	117	80.7
66476 EAGLEBT7 115 66520 OAHE 7 115 1	80	FTH-EB-MRN	15	145	12.2	116.9	80.6
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	21.3	149	12.8	112.3	79.9
66246 MAURIN1T 230 66480 MAURINE7 115 1	100	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	21.3	100.7	12.8	100.7	67.6
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	9	113	7	89.5	62.5
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	9	112.7	5	85	60.6

Table 3.6 Significantly Impacted Facilities: Thermal Overloads – Summer Off-peak Load Conditions, 2010

LIMITING ELEMENT	RATING (MVA	CONTINGENCY	Loading				DF(%)
			Pre-GI515 (% on Rate-A)	Post-GI515 (% on Rate-A)	Pre-GI515 (MVA)	Post-GI515 (MVA)	
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	16.3	153	9.8	119.1	84.1
66476 EAGLEBT7 115 66520 OAHE 7 115 1	80	66243 FAITH 7 115 - 66476 EAGLEBT7 115 ckt 1	12.1	147.5	9.8	118.7	83.8
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	17.1	151.5	10.5	113.6	79.3
66519 OAHE 4 230 66520 OAHE 7 115 1	107	66243 FAITH 7 115 - 66476 EAGLEBT7 115 ckt 1	42.8	137.6	45.8	147.3	78.1
66507 FTTHOMP4 230 66519 OAHE 4 230 1	318	151[2]	105.5	115.3	335.4	359.8	19
66507 FTTHOMP4 230 66519 OAHE 4 230 2	318	151	105.5	115.3	335.4	359.8	19
66507 FTTHOMP4 230 66519 OAHE 4 230 3	318	150[3]	105.9	114.9	336.1	359.6	18
66507 FTTHOMP4 230 66519 OAHE 4 230 4	318	150	105.9	114.9	336.1	359.6	18

[2] Tower Outage – Ft. Thompson – Oahe circuits 3&4

[3] Tower Outage – Ft. Thompson – Oahe circuits 1&2

Table 3.7 Comparison of Facility Loading under N-1 Condition; Summer Peak 2010, With and Without Oahe #7

LIMITING ELEMENT							RATING (MVA)			CONTINGENCY	Facility Loading			
											With Oahe #7		Without Oahe #7	
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	RateA	RateB	RateC		MVA	%	MVA	%
66243	FAITH 7	115	66476	EAGLEBT7	115	1	77	143	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	116.9	150.3	117	150.3
66243	FAITH 7	115	66476	EAGLEBT7	115	1	77	143	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	89.7	113.7	89.5	113
66243	FAITH 7	115	66480	MAURINE7	115	1	77	143	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	111.5	148.7	112.3	148
66243	FAITH 7	115	66480	MAURINE7	115	1	77	143	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	85.9	112.1	85	112
66476	EAGLEBT7	115	66520	OAHE 7	115	1	80	143	88	EB-FTH-MRN	117	145	116.9	145
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	EB-FTH-MRN	118.3	110	120.5	112

3.5 Prior Outage Analysis for Near-term Conditions

The purpose of this task was to determine if the GI-0515 wind farm would place any additional burden on the operation of the system when a facility is out of service (for e.g. maintenance outage). Such knowledge is expected to provide the operators to prepare in advance for a second outage (forced). Issues if any that may be expected from a second outage thereof could as well be addressed with the help of an operating guide or a generation re-dispatch.

For the purpose of this study, we considered the prior outage of following three facilities:

1. Eagle Butte – Faith – Maurine 115 kV
2. Eagle Butte – Oahe 115 kV
3. Oahe unit #1

The prior outage analysis was performed on 2010 summer peak load conditions. For the prior outage of Oahe unit #1, this generating unit (at 115 kV) was re-dispatched against Oahe unit #7 (at 230 kV).

The system intact conditions, i.e. with the prior outage of the respective facilities and prior to a second contingency, showed overloads in the GI-0515 interconnection vicinity. The facilities that were overloaded and the loading percentage are exactly the same as in the N-1 conditions with the respective facility being forced out, which is expected.

Table 3.8 Facility Loading under system intact conditions for Prior Outage Cases, Summer Peak 2010

LIMITING ELEMENT							RATING (MVA)	LOADING (%)		
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	RATE	EB-MRN PO	EB-OHE PO	OAHE#1 PO
66476	EAGLEBT7	115	66520	OAHE 7	115	1	80	145	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	112.2	-	-
66243	FAITH 7	115	66476	EAGLEBT7	115	1	77	-	150.3	-
66243	FAITH 7	115	66480	MAURINE7	115	1	77	-	149	-

A contingency analysis was then performed on each of the above three prior outage cases. The thermal loading issues for the three prior outage cases are discussed below:

For the prior outage of Eagle Butte – Faith – Maurine 115 kV, the Oahe 230/115 kV transformer indicated thermal loading in excess of the 112% system intact loading (Table 3.8). The maximum loading on this transformer was 142%, for the outage of Midland – Irv Simmons 115 kV. The 115 kV substations, namely Oahe, Irv Simmons, Pierrie, Ashtap, Philip, Midland and Wall are supplied through the 230/115 kV transformers at Oahe, Philip, Maurine and New Underwood in addition to the local generation at Oahe 115 kV (Oahe #1). The prior outage of Eagle Butte – Faith – Maurine 115 kV followed by the outage of Midland – Irv Simmons 115 kV (or Midland – Philip 115 kV) will leave all of the above substations except Philip and Wall 115 kV be fed through Oahe 230/115 kV transformer, overloading it above its emergency rating of 134 MVA. The second outage of New Underwood – Maurine 230 kV line showed a loading of 116% (on 100 MVA rating) on 230/115 kV transformer at New Underwood. This loading value

is however below its 125 MVA emergency rating.

The prior outage of Eagle Butte – Oahe 115 kV line indicated a maximum loading of 110% (based on 100 MVA rating) on Maurine 230/115 kV transformer upon the outage of Maurine – Newell 115 kV line. This contingency case loading is below its emergency rating of 125 MVA.

The prior outage of Oahe unit #1 showed a 146% loading on Eagle Butte – Oahe 115kV for the outage of Eagle Butte Oahe 115 kV and a 150% loading on Eagle Butte – Faith – Maurine 115 kV for the outage of Eagle Butte 115 kV. These loading values are same as those recorded for the N-1 conditions. This implies that the prior outage of Oahe unit #1 does not impose any additional operating restrictions, with the GI-0515 in service.

The facility loading for the three prior outage cases are included in Table 3.9.

Mitigation of the interconnection related impacts is summarized in Section 9 of this report.

Table 3.9 Facility Loading under Contingencies, Summer Peak 2010, Prior Outage Cases

LIMITING ELEMENT							RATING (MVA)				LOADING (% on RATE A)		
LFNUM	LFNAM	LFKV	LTNUM	LTNAM	LTKV	LCKT	RATEA	RATEB	RATEC	CONTINGENCY	EB-FTH-MRN	EB-OHE	OAHE1
66476	EAGLEBT7	115	66520	OAHE 7	115	1	80	143	88	EB-FTH-MRN	-	-	145.7
66243	FAITH 7	115	66476	EAGLEBT7	115	1	77	143	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	-	-	150.3
66243	FAITH 7	115	66480	MAURINE7	115	1	77	143	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	-	-	148.7
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66481 MIDLAND7 115 - 66491 IRVSIMM7 115 ckt 1	141.9	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66481 MIDLAND7 115 - 66487 PHILIP 7 115 ckt 1	136.7	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66479 MARTIN 7 115 - 66487 PHILIP 7 115 ckt 1	122.1	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66497 MAURINE4 230 - 66470 BISON 4 230 ckt 1	120.9	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66489 PIERRE 7 115 - 66223 PIERRE 8 69 ckt 1	119.1	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66479 MARTIN 7 115 - 67153 VETALTP7 115 ckt 1	118.4	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66482 MISSION7 115 - 67153 VETALTP7 115 ckt 1	118	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	117	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66520 OAHE 7 115 - 66600 ASHTAP 7 115 ckt 1	115.8	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66491 IRVSIMM7 115 - 66520 OAHE 7 115 ckt 1	114.8	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66481 MIDLAND7 115 - 66263 MIDLAND8 69 ckt 1	113.9	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66482 MISSION7 115 - 64967 ST.FRANC 115 ckt 1	113.8	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66490 RAPIDCY7 115 - 66269 RAPIDCY8 69 ckt 1	113.8	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66496 RUSHMRE7 115 - 66270 RUSHMRE8 69 ckt 1	113.6	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66479 MARTIN 7 115 - 66261 MARTIN19 34.5 ckt 1	113.5	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66487 PHILIP 7 115 - 66268 PHILIP 8 69 ckt 1	113.3	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66311 DUNLAP 7 115 - 64771 CHADRON7 115 ckt 1	113.1	-	-
66519	OAHE 4	230	66520	OAHE 7	115	1	107	107	134	66489 PIERRE 7 115 - 66600 ASHTAP 7 115 ckt 1	113.1	-	-
66246	MAURIN1T	230	66480	MAURINE7	115	1	100	100	125	66480 MAURINE7 115 - 66483 NEWELL 7 115 ckt 1	-	109.5	-
66246	MAURIN1T	230	66480	MAURINE7	115	1	100	100	125	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	-	102.3	-
66246	MAURIN1T	230	66480	MAURINE7	115	1	100	100	125	66483 NEWELL 7 115 - 67262 ELKCRK 7 115 ckt 1	-	102.2	-
66246	MAURIN1T	230	66497	MAURINE4	230	1	100	100	125	66480 MAURINE7 115 - 66483 NEWELL 7 115 ckt 1	-	112	-
66246	MAURIN1T	230	66497	MAURINE4	230	1	100	100	125	66483 NEWELL 7 115 - 67262 ELKCRK 7 115 ckt 1	-	104.5	-
66246	MAURIN1T	230	66497	MAURINE4	230	1	100	100	125	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	-	104.2	-
66266	NUNDRWDT	230	66484	NUNDRWD4	230	1	100	100	125	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	116.6	-	101
66266	NUNDRWDT	230	66485	NUNDRWD7	115	1	100	100	125	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	110.8	-	95

4. CONSTRAINED INTERFACE ANALYSIS

The purpose of this task was to determine if the GI-0515 wind farm would adversely impact the regional constrained interfaces (PTDF and OTDF interfaces) of the MAPP system. The analysis was performed using the NMORWG DFCALC IPLAN program on the 2010 Summer Peak power flow models with and without GI-0515 wind farm. The interface and flow-gate definitions were obtained from the definition file "ties-NMOR-pkg2010_sp10.txt".

Table 4.1 compares the interface flows for the cases with and without the proposed wind farm. The tables also show the transfer distribution factor (in percent) for the 130 MW power transfer from the proposed project to the sink. For the PTDF interfaces, the impacts > 5% and for OTDF interfaces the impacts > 3% from pre-project condition are shown in this Table.

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 delivery service should the proposed GI-0515 project go forward.

Table 4.1: Impact of the GI-0515 Project on MAPP Constrained Interfaces

INTERFACE	WITHOUT GI-0515 (MW)	WITH GI-0515 (MW)	CHANGE (MW)	TDF (%)
PTDF INTERFACE				
EAUARP	114.9	126	11.1	8.6
PPRZIO	175	186.2	11.1	8.6
GGS	1441.9	1458.7	16.8	12.9
GENTLMREDWIL	279.9	288.5	8.6	6.6
GRIS_LNC	369.7	390.6	21	16.1
COOPER_S	36.6	59.5	22.8	17.6
PR_ISL_BYRON	-82.5	-71.3	11.2	8.6
FTCAL_S	154.3	165.1	10.8	8.3
AHDSTL	279.9	287.1	7.1	5.5
MWEX__	612.7	630.7	18.1	13.9
OTDF INTERFACE				
LEEBYRNELELC	496.1	508.7	12.7	9.8
CDVNELQUA471	575.8	595.7	19.9	15.3
QUDCOR471QUD	276.4	282.6	6.2	4.8
QUDCORNEL471	276.4	282.6	6.2	4.8
ADNZIOPLPZIO	-3.6	8.1	11.7	9

INTERFACE	WITHOUT GI-0515 (MW)	WITH GI-0515 (MW)	CHANGE (MW)	TDF (%)
EAUARPWMPPAD	146.6	157.9	11.3	8.7
EAUARPPRIBYR	105.7	118.4	12.8	9.8
QUA471CDVNEL	579.1	599.1	20	15.4
QUACDVQUA471	824.7	851.7	27	20.8
CHESILNELELC	990.1	1002.5	12.4	9.5
NELELCCHESIL	783.5	798.6	15.2	11.7
PLPZIOCHESIL	289.7	302.5	12.8	9.8
PLPZIOZIOARC	108.1	124	15.9	12.3
NAPFOXNAPKEW	-945.6	-937.9	7.7	5.9
WRWWRNWRWNAP	-128.8	-122.2	6.7	5.1
SJHALKNAIASC	207.5	224.5	17	13.1
IASCLKNASJHA	274.1	290	16	12.3
BYRMLFBYRPVV	59.8	65	5.1	3.9

5. STABILITY ANALYSIS

5.1 Introduction

The purpose of this analysis was to determine whether the MAPP system would meet stability criteria following commissioning of the proposed GI-0515 wind farm. The analyses were performed for year 2010, summer off-peak load conditions. To that end, local and regional contingencies were simulated. Stability analysis was performed on pre- and post-project stability models to compare the impact(s) of the proposed project addition.

The studies were conducted utilizing the NMORWG 2010 study package ("pkg2010-1-05-2010").

The dispatch assumptions for prior-queued generator interconnections that were included in the study models are tabulated below (Table 5.1) and follow from those for GI-0512 study.

Table 5.1 Dispatch Assumptions for prior-queued generation: Stability Analysis

Stability			
Bus	**Queue #**	**Size**	**Off-peak (MW)**
67399	G132	180	180
67255	GI-0615	50	off
67295	GI-0508	50	49.5
67292	GI-0208	41	Off
67293	GI-0209	41	40
66881	GM0200	60	Off
63165	G291	21	16
67393	G767	20	Off
67274	GI-0316	120	Off
68378	G380	150	150
63087	G408	12	12
66883	GM0300	41	Off
66985	GM0500	358	Off
67157	GI-0503	100	Off
67157	GI-0720	16	Off
61603	G502	51	50.6
61606	GS659	50	Off
99359***	G359	150	150
63003***	G531	68**	68**
66903***	GI-0512	50	49.5

** Net output; the gross generation is 75 MW

*** New bus numbers – for generators added to the starting cases; i.e. not represented in the 2010 package power flow

- The North Dakota peak load level was maintained at 3400 MW in the summer peak case, which reflects the 2010 summer peak loading condition. The summer off-peak power flow case had an ND load of about 64.4%
- Square Butte DC was dispatched at 500 MW
- NDEX was maintained at 2148 MW in the summer off-peak case

The "setexports" IPLAN program was run to fix the NDEX at 2148 MW, MHEX to 2175 MW and MWEX to 1525 MW.

The *GI-0515* case was developed from the *pre-GI-0515* case by adding the proposed 130 MW wind farm and dispatching it against "MISO Foot print" generation.

5.1.1 Modeling of the Wind Farm for Stability

The proposed wind farm consists of 88, GE 1.5 MW wind turbine generators of DFIG technology. These wind turbine generators were represented in the power flow as four (4) equivalent units and connected to the 115 kV substation via two 80 MVA, 115/34.5 kV transformer connected to the Eagle Butte 115 kV Substation. For the dynamic representation of the proposed wind farm, the GE 1.5 MW DFIG wind turbine generator model available in PSS/E (8/29/2009 release of the PSS/E GE 1.5 MW DFIG models) was used.

The stability data for the equivalent wind turbine-generator was based on default data provided with the PSS/E DFIG model. The model parameters used in this study are given in Appendix D.

5.2 Results of the Stability Analysis

The disturbances considered for the stability assessment are listed in Table 5.2. Most of these faults simulated are standard faults from the NMORWG study package, except for "local faults" which are disturbances (3-phase faults and single-line-to-ground faults) in the interconnection vicinity.

The results from the stability analysis showed stable performance with no oscillations. The proposed wind farm stayed online during the disturbance and post-disturbance. Voltage recovery was acceptable. No transient voltage violations were noted. A comparison against pre-project performance did not show any degradation in the overall system performance. It may be therefore concluded that the proposed GI-0515 wind farm does not cause any adverse impact on the system stability performance.

The summary tables for the fault scenarios are presented in Appendix E. The stability plots from the simulation are included in Appendix F.

Table 5.2: List of Faults for Stability Analysis

Fault Code	Fault Description	System Location
	Regional Faults	
ac1	4 cy slgf @ avs 345 on broadland line, avs brkr 4596 stk; clr @ 10 cy by tripping fltd line & oliver-mercer load	N. Dakota
ac3	4 cycle 3 phase fault at antelope valley 345 clear the antelope valley-broadland 345 kV line	N. Dakota
ac4	4 cy slgf @ avs 345 on broadland line, avs brkr 4692 stk clr @ 10 cy by tripping fltd line	N. Dakota
ag1	Single line to ground fault with breaker fail at Leland Olds on the Ft. Thompson 345 kV line	N. Dakota
ag3	Three phase fault at Leland Olds on the Ft. Thompson 345 kV line.	N. Dakota
eb3	4.5 cy 3 ph flt @ center 345 on jamestown line clr center-jamestown 345 kV line	N. Dakota
ec3	5 cy 3 ph flt @ center 230 on heskett line clr center-heskett 230 kV line	N. Dakota
ef9	4 cycle 3 phase fault at stanton 230 clear the stanton-coal creek-mchenry 230 kV line	N. Dakota
el3	5 cy 3 ph flt @ center 230 on square butte line clr center-square butte 230 kV line	N. Dakota
ei2	Permanent bipole fault on the CUDC line. Both Coal Creek units tripped at 0.28 sec.	N. Dakota
eq1	4.5 cy slgf @ coal creek on pole 1, brkr 61rb1 stk clr @ 11 cy by tripping fltd pole & bus 1,cross trip ccs 2	N. Dakota
fdk	5 cycle slgf @ Square Butte-Stanton, breaker 18 stuck, Square Butte dc bipole blocked @ 1 cycle. Clear @ 11 cycles by tripping Square Butte-Stanton and Young #2, ramp Square Butte dc pole 1 > 275 @ 17 cycles.	N. Dakota
fds	5.0 cy 3 ph flt @ square butte 230 on stanton line clr square butte end at 4 cy, stanton end at 5 cy	N. Dakota
fdl	5 cycle slgf @ Square Butte-Stanton, breaker 17 stuck, Square Butte dc bipole blocked @ 1 cycle. Clear @ 12 cycles by tripping Square Butte-Stanton and Young #2, ramp Square Butte dc back @ 17 cycles.	N. Dakota
pcs	Single line to ground fault with breaker fail at King with 8P6 stuck.	Prony
pct	Eau-Claire - Arpin 345 kV line trip without a fault.	Prony
pys	Single line to ground fault with breaker fail at Prairie Island with 8H9 stuck.	Prony
pyt	Prairie Island-Byron 345 kV line trip without a fault.	Prony
	Local Faults	
da3	6 cycle 3 phase fault at Eagle Butte 115 kV Bus Clear the Eagle Butte - Faith 115 kV line	S. Dakota
db3	6 cycle 3 phase fault at Eagle Butte 115 kV Bus Clear the Eagle Butte - Oahe 115 kV line	S. Dakota
dc3	5 cycle, 3-ph fault on Maurine - New Underwood 230 kV @ Maurine; Clear the fault, trip Maurine - New Underwood 230 kV	S. Dakota
dd3	5 cycle, 3-ph fault on Oahe-PhilipTap-New Underwood 230 kV @ Oahe; Clear the fault, trip Oahe-PhilipTap-New Underwood 230 kV	S. Dakota
dh3	6 cycle, 3phase fault on Oahe - Eagle Butte 115 kV @ Oahe 115 kV; Clear fault, trip Oahe - Eagle Butte 115 kV	S. Dakota

Fault Code	Fault Description	System Location
yss	6 cycle, slgf on Oahe-Eagle Butte 115 kV; bkr 1262 stuck; open bkrs #1462, 1362, 1162, 1062; at 15 cycles; clear fault, trip Oahe-Ash Tap, Oahe-Irv Simmons, Oahe 115/230 kV TR, Oahe unit #1	S. Dakota

6. SHORT CIRCUIT ANALYSIS

After establishing the Pre-GI0515 short-circuit case (08sc-102208.sav), the proposed project was added to create the post-project short-circuit case.

Based on information provided by GE, during severe close-by 3-phase faults and at full power, the crow-bar protection operates, shorting the converter and rendering the DFIG a traditional induction generator. This represents a worst case scenario and the short-circuit current contribution of the wind turbine can then be taken as 5 p.u. Based on this assumption we assigned a Zsorce value of 0.2 p.u for the equivalent wind turbine units in the power flow. For the purposes of this analysis, classical fault assumptions were used with a pre-fault voltage of 1.0 p.u. The proposed wind farm was modeled as a 4 equivalent generators, along with the collector system and 2x34.5/230 kV GSU at the POI (Eagle Butte 115 kV).

Three-phase symmetrical fault current levels were calculated at the point of interconnection and POI vicinity. A comparison of the fault currents in the pre- and post-project cases are given below along with the minimum breaker ratings:

Table 6.1 Comparison of Fault Currents – Pre- and Post-Project Cases

Bus			Min. Breaker Rating (A)	Fault Current (A)		
#	Name	kV		Pre-GI0515	Post-GI0515	Incremental
66613	GI-0515 POI	115	N/A	-	2260	-
66476	Eagle Butte	115	20,000	1816	2512	696
66520	Oahe	115	25,000	7878	8089	211
66480	Maurine	115	20,000	3114	3310	196
66489	Pierre	115	20,000	6148	6273	125
66491	Irv Simmons	115	20,000	6179	6304	125
66519	Oahe	230	25,000	12064	12163	99
66497	Maurine	230	31,500	2087	2164	77

From Table 6-1, it may be noted that the short circuit levels at the substations in the vicinity are within the respective breaker ratings (minimum).

7. OUT-YEAR ANALYSIS

As part of this study, an analysis (power flow only) of the future system conditions depicting summer peak load conditions for the year 2016 was also performed. The most notable changes in the study area for this future year include the proposed addition of approximately 268 MW of new load (Keystone Pumping load) distributed along transmission corridor extending from Montana (Miles City area) to South Dakota (Maurine – Philip – Midland – Whitten – Gregory), a new transmission line (Big Bend – Whitten 115 kV), transformer upgrades (Belfield, Leland Olds, New Underwood, Oahe, Philip) and static capacitors for power factor correction at the pumping load substations. Considering these potential changes to the transmission in the POI vicinity, an evaluation of the peak load conditions for year 2016 (Summer) was performed, with the GI-0515 in service. Two scenarios were studied – i) Without the Keystone additions, and ii) With the Keystone additions. Both the system intact as well as N-1 contingencies were evaluated. The thermal loading on facilities in the POI vicinity and bus voltages outside the acceptable band (refer Table 2.1) was flagged for violations.

7.1 Analysis without Keystone Additions

This scenario does not include the Keystone pumping loads and the associated network upgrades; the pre-project case was prepared starting from "sp16aa.sav" in the 2010 study package. Next, the prior-queued projects and other model assumptions (same as in the near-term conditions) were included to create the pre-project case – "nxl-sp16aa.sav"; to this pre-project case, the GI-0515 project was added and the case was named "n15-sp16aa.sav". The system intact conditions did not indicate any overloads in the POI vicinity. Next, contingency analysis was performed on these two cases and results were compared. Thermal overloads were noted for N-1 conditions (Table 7.1). It may be noted that the maximum loadings on the two outlets, namely Eagle Butte – Faith - Maurine 115 kV and Eagle Butte – Oahe 115 kV and the Oahe 115/230 kV transformer (see red highlights in Table 7.1) are comparable to those seen in near-term conditions. There were no voltage problems.

7.2 Analysis with Keystone Additions

The pre-project case was named "key-sp16aa.sav". The GI-0515 project was added to the pre-project case to obtain the post-project case ("k15-sp16aa.sav"). The system intact conditions did not indicate any overloads in the POI vicinity. However it was found that the Eagle Butte – Faith – Maurine 115 kV line was loaded to 93% of its continuous rating (77 MVA). This is an increase from a previous (i.e. pre-Keystone addition case) value of 83%. This increase in power flow after Keystone additions is due to a re-distribution of the power; with the new network configuration, more of GI-0515 output now flows towards Maurine. For the N-1 conditions, though the maximum loading on the 115 kV facilities out of Eagle Butte did not change (from the case without the Keystone additions), these facilities showed thermal overloads for several contingencies in the Dakotas and Nebraska (Table 7.2). It may further be noted that due to the transformer upgrades at Oahe and Leland Olds, the loading problems that were reported earlier (see Table 7.1) are now resolved.

Table 7.1 Facility Loading under N-1 Condition; Summer Peak 2016, With and Without GI-0515 – No Keystone Additions

LIMITING ELEMENT	RATING (MVA	CONTINGENCY	Loading				DF(%)
			Pre-GI515 (% on Rate-A)	Post-GI515 (% on Rate-A)	Pre-GI515 (MVA)	Post-GI515 (MVA)	
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	19.4	**146.3**	14.9	114.5	76.6
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	6.9	109.8	5.4	86.7	62.5
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	210	24.3	100.1	18.8	79	46.3
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	18.4	**145.8**	14.3	111.3	74.6
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	4.5	109.4	3.5	84.2	62.1
66476 EAGLEBT7 115 66520 OAHE 7 115 1	80	66476 EAGLEBT7 115 - 66480 MAURINE7 115 ckt 1	19	**141.9**	14.84	114.3	76.5
66519 OAHE 4 230 66520 OAHE 7 115 1	107	66476 EAGLEBT7 115 - 66480 MAURINE7 115 ckt 1	9	**106.8**	10.08	114.3	80.2
67105 LELANDO3 345 67201 LELND1TY 345 1	250	67202 LELND2TY 345 - 67106 LELANDO4 230 ckt 1	140.4	142.3	350.9	355.7	3.7
67105 LELANDO3 345 67201 LELND1TY 345 1	250	67105 LELANDO3 345 - 67202 LELND2TY 345 ckt 1	140.4	142.3	350.9	355.7	3.7
67201 LELND1TY 345 67106 LELANDO4 230 1	250	67202 LELND2TY 345 - 67106 LELANDO4 230 ckt 1	140.4	142.3	350.9	355.7	3.7
67201 LELND1TY 345 67106 LELANDO4 230 1	250	67105 LELANDO3 345 - 67202 LELND2TY 345 ckt 1	140.4	142.3	350.9	355.7	3.7

Table 7.2 Facility Loading under N-1 Conditions, Summer Peak 2016, With and Without GI-0515 – With Keystone Additions

LIMITING ELEMENT	RATING (MVA	CONTINGENCY	Loading				DF(%)
			Pre-GI515 (% on Rate-A)	Post-GI515 (% on Rate-A)	Pre-GI515 (MVA)	Post-GI515 (MVA)	
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	19.9	**146.6**	14.9	115	77
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	45.8	117.0	35.5	92.5	43.8
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	5.0	110.5	3.9	87.6	64.4
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	67101 ANTELOP3 345 - 67183 CHAR.CK3 345 ckt 1	28.1	106.1	20.8	83.1	47.9
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66484 NUNDRWD4 230 - 67271 RCSERCAP 230 ckt 1	27.1	105.7	20.9	84	48.5
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	67268 RCDCEAST 230 - 67271 RCSERCAP 230 ckt 1	27.2	105.7	21	83.9	48.4
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66573 STEGALL4 230 - 67206 STGXFMR4 230 ckt 1	27.7	105.6	21.1	83.5	48
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	67135 STEGALL3 345 - 67207 STEGALTY 345 ckt 1	27.7	105.6	21.1	83.5	48
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	67207 STEGALTY 345 - 67206 STGXFMR4 230 ckt 1	27.7	105.6	21.1	83.5	48
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	67269 RCDCWEST 230 - 67270 RCGENWST 230 ckt 1	27.4	104.6	21.3	82.9	47.4
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66424 BELFELD3 345 - 67183 CHAR.CK3 345 ckt 1	23.6	102.1	17.7	80.8	48.5
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66220 BELFELDT 345 - 66424 BELFELD3 345 ckt 1	23.5	102	17.7	80.8	48.5
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66220 BELFELDT 345 - 66425 BELFELD4 230 ckt 1	23.6	101.8	17.8	80.5	48.2
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66425 BELFELD4 230 - 67915 RHAME 4 230 ckt 1	26.4	101.8	20.6	80.6	46.2
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	66476 EAGLEBT7 115 - 66259 EAGLEBE8 69 ckt 1	22.2	101.5	17.6	81.1	48.8
66243 FAITH 7 115 66476 EAGLEBT7 115 1	77	67131 LARAMIE3 345 - 67118 LARAM31G 24 ckt 1	23.1	100.1	18	79.2	47.1
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66476 EAGLEBT7 115 - 66520 OAHE 7 115 ckt 1	18.9	**146.2**	14.4	113.1	75.9
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66484 NUNDRWD4 230 - 66497 MAURINE4 230 ckt 1	44.3	116.5	34.8	90.3	42.7
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66519 OAHE 4 230 - 66520 OAHE 7 115 ckt 1	3.7	109.8	2.9	85.9	63.8
66243 FAITH 7 115 66480 MAURINE7 115 1	77	67101 ANTELOP3 345 - 67183 CHAR.CK3 345 ckt 1	27.8	105.8	20.4	80	45.8
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66484 NUNDRWD4 230 - 67271 RCSERCAP 230 ckt 1	25.9	105.1	20	82.5	48.1
66243 FAITH 7 115 66480 MAURINE7 115 1	77	67268 RCDCEAST 230 - 67271 RCSERCAP 230 ckt 1	25.9	105.0	20.1	82.5	48
66243 FAITH 7 115 66480 MAURINE7 115 1	77	67135 STEGALL3 345 - 67207 STEGALTY 345 ckt 1	26.8	105.0	20.4	81.7	47.2
66243 FAITH 7 115 66480 MAURINE7 115 1	77	67207 STEGALTY 345 - 67206 STGXFMR4 230 ckt 1	26.8	105.0	20.4	81.7	47.2

LIMITING ELEMENT	RATING (MVA	CONTINGENCY	Loading				DF(%)
			Pre-GI515 (% on Rate-A)	Post-GI515 (% on Rate-A)	Pre-GI515 (MVA)	Post-GI515 (MVA)	
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66573 STEGALL4 230 - 67206 STGXFMR4 230 ckt 1	26.8	105.0	20.3	81.6	47.2
66243 FAITH 7 115 66480 MAURINE7 115 1	77	67269 RCDCWEST 230 - 67270 RCGENWST 230 ckt 1	25.9	104.0	20.2	81.1	46.8
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66424 BELFELD3 345 - 67183 CHAR.CK3 345 ckt 1	23.1	101.5	17.3	79	47.5
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66220 BELFELDT 345 - 66424 BELFELD3 345 ckt 1	23.1	101.5	17.3	79	47.5
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66220 BELFELDT 345 - 66425 BELFELD4 230 ckt 1	23.0	101.3	17.3	78.7	47.2
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66425 BELFELD4 230 - 67915 RHAME 4 230 ckt 1	24.7	101.3	19.4	78.8	45.7
66243 FAITH 7 115 66480 MAURINE7 115 1	77	66476 EAGLEBT7 115 - 66259 EAGLEBE8 69 ckt 1	21.8	100.9	17.2	79.7	48.1
66476 EAGLEBT7 115 66520 OAHE 7 115 1	80	66476 EAGLEBT7 115 - 66480 MAURINE7 115 ckt 1	19	**141.8**	14.84	114.3	76.5

7.3 Constrained Interface Analysis

The purpose of this task was to determine if the GI-0515 wind farm would adversely impact the regional constrained interfaces (PTDF and OTDF interfaces) of the MAPP system, considering the year 2016 conditions.. The analysis was performed using the NMORWG DFCALC IPLAN program on the 2016 Summer Peak power flow models with and without GI-0515 wind farm. The interface and flow-gate definitions were obtained from the definition file "ties-NMOR-pkg2010_sp16.txt".

Table 7.3 compares the interface flows for the cases with and without the proposed wind farm. The tables also show the transfer distribution factor (in percent) for the 132 MW power transfer from the proposed project to the sink. For the PTDF interfaces, the impacts > 5% and for OTDF the impacts > 3% from pre-project condition are shown in this Table.

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 delivery service should the proposed GI-0515 project go forward.

Table 7.3: Impact of the GI-0515 Project on MAPP Constrained Interfaces – 2016 Summer Peak

INTERFACE	WITHOUT GI-0515 (MW)	WITH GI-0515 (MW)	CHANGE (MW)	TDF (%)
PTDF INTERFACE				
EAUARP	145	157.8	12.7	9.8
GGS	1395.1	1410.4	15.3	11.8
GENTLMREDWIL	240.7	249.4	8.7	6.7
GRIS_LNC	224.8	251.6	26.8	20.6
COOPER_S	-7.3	17.8	25.1	19.3
PR_ISL_BYRON	-8	2.3	10.3	7.9
FTCAL_S	-8.6	-1.3	7.3	5.6
AHDSTL	152	158.9	6.9	5.3
MWEX__	400.5	419	18.4	14.2
OTDF INTERFACE				
LEEBYRNELELC	1068.9	1083.3	14.4	11.1
CDVNELQUA471	383.7	405.9	22.2	17.1
QUDCOR471QUD	183.4	191.9	8.5	6.5
QUDCORNEL471	183.4	191.9	8.5	6.5
EAUARPWMPPAD	158.8	171.5	12.7	9.7
EAUARPPRIBYR	144.8	157.8	13	10

INTERFACE	WITHOUT GI-0515 (MW)	WITH GI-0515 (MW)	CHANGE (MW)	TDF (%)
QUA471CDVNEL	386	408.3	22.3	17.2
QUACDVQUA471	541.2	572.4	31.2	24
ZIOARCZIOPLP	73.3	78.1	4.8	3.7
CHESILNELELC	1033.4	1046.5	13.1	10.1
NELELCCHESIL	983.2	999.6	16.4	12.6
PLPZIOCHESIL	446	456.6	10.6	8.2
PLPZIOZIOARC	337.2	346.1	8.8	6.8
NAPFOXNAPKEW	-958.4	-950.8	7.6	5.9
WRWWRNWRWNAP	27.5	33.8	6.3	4.9
SJHALKNAIASC	178.7	196.6	17.9	13.8
IASCLKNASJHA	252.1	269	16.9	13

8. SUMMARY OF ISSUES

The interconnection of GI-0515 wind farm showed significant impact on the thermal loading of the facilities in the interconnection vicinity:

Eagle Butte – Faith – Maurine 115 kV: This transmission line, which is one of the two outlets for GI-0515 indicated a maximum loading of 119 MVA during N-1 conditions (2010 summer off-peak load conditions; outage of the second outlet, Eagle Butte – Oahe 115 kV) which translates into 153% on 77 MVA rating (Rate-A in PSS/E). The loading under summer peak conditions was slightly lower (150%). The maximum pre-project loading was 21 MVA.

Eagle Butte – Oahe 115 kV: This is the second outlet for GI-0515 wind farm output. The outage of Eagle Butte – Faith – Maurine 115 kV caused a loading of 119 MVA (i.e. 148% on 80 MVA rating) for summer off-peak load conditions. The loading under summer peak conditions was slightly lower (145%). The maximum pre-project loading was 15 MVA.

Oahe 230/115 kV transformer: This transformer indicated a loading of 110 MVA under system intact, summer off-peak load conditions for year 2010 in the post-project case. The continuous rating of this transformer is 107 MVA and therefore the loading is 103%. The pre-project loading was 55 MVA (49%). During N-1 contingencies, a maximum loading of 147 MVA was noted (outage of Eagle Butte – Faith – Maurine 115 kV during summer off-peak load conditions, year 2010). The corresponding loading for summer peak load conditions was 120 MVA. The maximum pre-project loading was 43 MVA. The prior outage of Eagle Butte – Faith – Maurine 115 kV line followed by the outage of Irv Simmons – Midland 115 kV line indicated a loading of 142% (i.e. 152 MVA).

9. MITIGATION OF ISSUES

In this section, the mitigation options for the issues caused by interconnection of GI-0515 project are discussed. There are two options to mitigate the thermal loading problems:

1. Establish Operating guideline(s) – Reduce the GI-0515 output to ensure the relevant facilities are loaded within their respective operating limit, or
2. Capacity upgrade of the overloaded facilities

9.1 Establish Operating Guideline(s)

The Eagle Butte – Faith – Maurine 115 kV transmission line is currently operated with a 77 MVA capacity limit due to restrictions imposed by equipment limitations at the Faith 115 kV substation. The maximum thermal loading on this facility was 119 MVA under N-1 contingencies. Therefore loading problem on this facility needs mitigation. Based on a 84% distribution factor (with respect to the GI-0515 generation injection at Eagle Butte), the project output will need to be reduced by 52 MW (i.e. to 80 MW wind farm output) so that the loading on this line is within the 77 MVA emergency rating.

The Eagle Butte – Oahe 115 kV line is currently operated with an 80 MVA continuous capacity and an emergency capacity of 88 MVA. The maximum thermal loading on this facility was 119 MVA under N-1 contingencies. Based on an 84% distribution factor, the project output will need to be reduced by 39 MW (i.e. to 93 MW wind farm output) in order to limit the facility loading within the 88 MVA emergency rating.

A system intact loading of 110 MVA was noted on the 230/115 kV transformer at Oahe, for the summer off-peak conditions. In order to maintain the loading on this transformer within its continuous rating of 107 MVA, the GI-0515 output would need to be reduced by about 8 MW on a continuous basis. For N-1 conditions, this transformer can be loaded up to 134 MVA (i.e. emergency rating). In view of the maximum N-1 loading of 152 MVA (loss of Eagle Butte – Faith – Maurine 115 kV followed by a second outage of Irv Simmons – Midland 115 kV), the GI-0515 output will need to be reduced to 113 MW.

The following tables (Tables 9.1 and 9.2) give the most limiting overloads and the maximum allowable injection from GI-0515 for various operating conditions. It should be noted that these reductions are approximate and were calculated based on the respective TDFs.

Table 9.1 Operating Guideline for Mitigation of Thermal Overloads – System Intact and N-1 Contingencies

Facility	Rating (MVA)			Loading (MVA)		Loading (% on Rate A)		Loading (% on Rate C)	TDF (%)	Contingency	Condition	Max. Allowable Injection at the POI (MW)	Mitigation Facility Upgrade
	Rate A	Rate B	Rate C	Pre-project	Post-project	Pre-project	Post-project	Post-project					
Oahe 230/115 kV Transformer	107.0	107.0	134.0	55.4	110.3	49.0	103.0	82.2	41.5	System Intact	2010 su op	124.0	Upgrade transformer to 115 MVA normal / 150 MVA emergency
Oahe 230/115 kV Transformer	107.0	107.0	134.0	45.8	147.3	42.8	137.6	109.9	78.1	L/O Eagle Butte - Faith - Maurine 115 kV line	2010 su op	113.0	Upgrade transformer to 115 MVA normal / 150 MVA emergency
Eagle Butte - Oahe 115 kV line	80.0	143.0	88.0	9.8	118.7	12.1	147.5	134.1	83.8	L/O Eagle Butte - Faith - Maurine 115 kV line	2010 su op	93.0	Upgrade terminal equipment
Eagle Butte - Faith - Maurine 115 kV line	77.0	143.0	77.0	9.8	119.1	12.7	153.1	153.1	84.1	L/O Eagle Butte - Oahe 115 kV line	2010 su op	80.0	Upgrade terminal equipment

Table 9.2 Operating Guideline for Mitigation of Thermal Overloads – Prior Outage and Contingencies (2010 Summer Peak)

Facility	Rating (MVA)			Loading (MVA)		Loading (% on Rate A)		Loading (% on Rate C)	TDF (%)	Contingency	Prior-Outage	Max. Allowable injection at POI (MW)	Mitigation Facility Upgrade
	Rate A	Rate B	Rate C	Pre-project	Post-project	Pre-project	Post-project	Post-project					
Oahe 230/115 kV Transformer	107.0	107.0	134.0	27.1	151.8	25.3	141.9	113.3	94.5	L/O Midland-Irv Simmons 115 kV line	EB-FTH-MRN	113.0	Upgrade transformer to 115 MVA normal / 155 MVA emergency
Eagle Butte - Oahe 115 kV line	80.0	143.0	88.0	12.1	116.9	15.4	145.7	132.5	79.4	L/O Eagle Butte - Faith - Maurine 115 kV line	Oahe #1	97.0	Upgrade terminal equipment
Eagle Butte - Faith - Maurine 115 kV line	77.0	143.0	77.0	12.1	116.9	16.0	150.3	150.3	79.4	L/O Eagle Butte - Oahe 115 kV line	Oahe #1	82.0	Upgrade terminal equipment

9.2 Capacity Upgrade of Facilities

As an alternative to operating the proposed wind farm project at reduced output, the overloaded facilities could be upgraded to operate with a higher capacity (that would eliminate the thermal loading problems).

In the case of the two outlet lines, namely Eagle Butte – Faith – Maurine 115 kV and Eagle Butte – Oahe 115 kV lines, the maximum loading was 119 MVA under N-1 conditions whereas the usable capacity on these lines are only 77 MVA and 88 MVA respectively. Therefore the capacity upgrade should be such that these facilities can be loaded to at least 120 MVA.

The Oahe transformer is however earmarked for an upgrade in the year 2016 depending on the Keystone project moving forward. The Oahe transformer is expected to have a capacity of 250 MVA (continuous) with an emergency capability of 312 MVA. Until the Keystone project is implemented (which will also include an upgrade of the Oahe transformer), the GI-0515 may be operated with a reduced output (113 MW). However, if the Keystone project does not materialize or if the developer seeks to operate at the proposed full output, then the Oahe 230/115 kV transformer will have to be upgraded prior to the project (GI-0515) commissioning in order to mitigate the potential overload problem.