GEN-2015-098
Impact Restudy for Generator Modification (Turbine Change)

August 2016
Generator Interconnection

Southwest Power Pool

Revision History

Date	Author	Change Description
08/24/2016	SPP	GEN-2015-098 Impact Restudy for Generator Modification (Turbine Change) issued.

Executive Summary

The GEN-2015-098 Interconnection Customer has requested a modification to its Interconnection Request. SPP has performed this system impact restudy to determine the effects of changing wind turbine generators from the previously studied GE 2.0MW wind turbine generators (50 machines total) to GE 2.3MW wind turbine generators (43 machines total).

In this restudy the project uses forty-three (43) GE 2.3MW wind turbine generators for an aggregate power of 98.9MW. The point of interconnection (POI) for GEN-2015-098 is at the Western Area Power Administration (WAPA) Beaver Hill 230kV Substation. The Interconnection Customer has provided documentation that shows the GE 2.3MW wind turbine generators have a reactive capability of 0.95 lagging (providing VARS) and 0.95 leading (absorbing VARS) power factor.

This study was performed to determine whether the request for modification is considered Material. To determine this, study models that included Interconnection Requests through DISIS-2015-002 were used that analyzed the timeframes of 2016 winter, 2017 summer, and 2025 summer models.

The restudy showed that no stability problems were found during the summer and the winter peak conditions as a result of changing to the GE 2.3MW wind turbine generators. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A. The requested modification is not considered Material.

A power factor analysis and a low-wind/no-wind condition analysis were performed for this modification request. The facility will be required to maintain a 95% lagging (providing VARs) and 95% leading (absorbing VARs) power factor at the POI. Additionally, the project will be required to install approximately 10 Mvar of reactor shunts on its substation 34.5kV bus(es). This is necessary to offset the capacitive effect on the transmission network caused by the project's transmission line and collector system during low-wind/no-wind conditions.

With the assumptions outlined in this report and with all the required network upgrades from the DISIS 2015-002 in place, GEN-2015-098 with the GE 2.3MW wind turbine generators should be able to interconnect reliably to the SPP transmission grid.

It should be noted that this study analyzed the requested modification to change generator technology, manufacturer, and layout. Powerflow analysis was not performed. This study analyzed many of the most probable contingencies, but it is not an all-inclusive list and cannot account for every operational situation. It is likely that the customer may be required to reduce its generation output to 0 MW, also known as curtailment, under certain system conditions to allow system operators to maintain the reliability of the transmission network.

Nothing in this study should be construed as a guarantee of transmission service or delivery rights. If the customer wishes to obtain deliverability to final customers, a separate request for transmission service must be requested on Southwest Power Pool's OASIS by the customer.

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I. Introduction

GEN-2015-098 Impact Restudy is a generation interconnection study performed to study the impacts of interconnecting the project shown in Table I-1. This restudy evaluates the requested modification to change from fifty (50) GE 2.0MW wind turbine generators to forty-three (43) GE 2.3MW wind turbine generators.

Table I-1: Interconnection Request

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2015-098	98.9	GE 2.3MW [Forty-three (43) generators]	Mingusville 230kV

The prior-queued, equally-queued and lower queued requests shown in Table I-2 were included in this study and the wind farms were dispatched to 100% of rated capacity.

Table I-2: Prior and Later Queued Interconnection Requests

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2005-008IS	50	WT3 generic wind (659294)	Edgeley 115kV (Pomona 115kV)
GEN-2006-015IS	50	WT3 generic wind (659273)	Marshall 115kV
GEN-2007-015IS	100	WT3 generic wind (659366)	Hilken 230kV
GEN-2007-027IS	99	WT3 generic wind (659010)	Bismarck-Garrison 230kV #1
GEN-2009-026IS	110	GENROU (659403)	Dickinson-Heskett 230kV
GEN-2010-007IS	172.5	GENROU (659407)	Antelope Valley 345kV
GEN-2012-006IS	125.01	GENROU (659162/659163/ 659192)	Williston-Charlie Creek 230kV
GEN-2014-004IS	384.2	GE 1.7MW (659125)	Charlie Creek 345kV
GEN-2014-006IS	125	GENSAL (659431, ‘A1’-‘A6’/659432, ‘B1’-‘B6’)	Williston 115kV
GEN-2014-010IS	150	Vestas V110 2.0MW (659141)	Neset 115kV
GEN-2014-014IS	151.5	GE 1.7MW (659453)	Belfield-Rhame 230kV
GEN-2015-046	300	Vestas V110 2.0MW (584873)	Tande 345kV
GEN-2015-091	101.2	GE 2.3MW (585263)	Daglum 230kV
GEN-2015-096	150	GE 2.0MW (585313)	Daglum 230kV

Table I-3: Prior and Later Queued MISO Interconnection Requests

Request	Capacity (MW)	Generator Model	Point of Interconnection
G359	150	WT3 generic wind (661995)	MDU 230kV system near Ellendale
G380	150	WT1 generic wind (620115)	Rugby 115kV
G408	12	WT1 generic wind (600059)	Tap McHenry-Souris 115kV
G502	50.6	W4GUR (608603)	Milton Young 230kV
G645	50	GENROU (625025, '1')	Ladish 115kV
G723	10	GENSAL (661046)	Heskett 115kV
G752	150	WT3 generic wind (661989)	Tap Bison-Hettinger 230kV
G788	49	GENROU (615015, '1')	Ladish 115kV
G830	99	GENCLS (10648)	GRE-McHenry 115kV
J003	20	WT3 generic wind (661317)	Baker 115kV
J249	180	WT3 generic wind (661999)	MDU Tatanka 230kV
J262	100	GENCLS (11104)	Jamestown 345kV
J263	100	GENCLS (11108)	Jamestown 345kV
J316	150	GENCLS (11115)	MDU Ellendale-Tatanka 230kV line

The study included a stability analysis of the interconnection request. Contingencies that resulted in a prior-queued project tripping off-line, if any, were re-run with the prior-queued project's voltage and frequency tripping relays disabled. Also a low-wind/no-wind analysis was performed on this project since it is a wind farm. The analyses were performed on three seasonal models, the modified versions of the 2016 winter peak, the 2017 summer peak, and the 2025 summer peak cases.

The stability analysis determines the impacts of the new interconnecting project on the stability and voltage recovery of the nearby systems and the ability of the interconnecting project to meet FERC Order 661A. If problems with stability or voltage recovery are identified, the need for reactive compensation or system upgrades is investigated. The three-phase faults and the single line-to-ground faults listed in Table III-1 were used in the stability analysis.

Power factor analysis results are in Appendix B

The low-wind/no-wind analysis determines the capacitive effect at the POI caused by the project's collector system and transmission line capacitance. A shunt reactor size was determined to offset the capacitive effect and to maintain zero Mvar flow at the POI when the plant generators and capacitors are off-line such as might be seen in low-wind or no-wind conditions.

II. Facilities

A one-line drawing for the GEN-2015-098 generation interconnection request is shown in Figure II-1. The POI is the WAPA Beaver Hill 230kV substation.

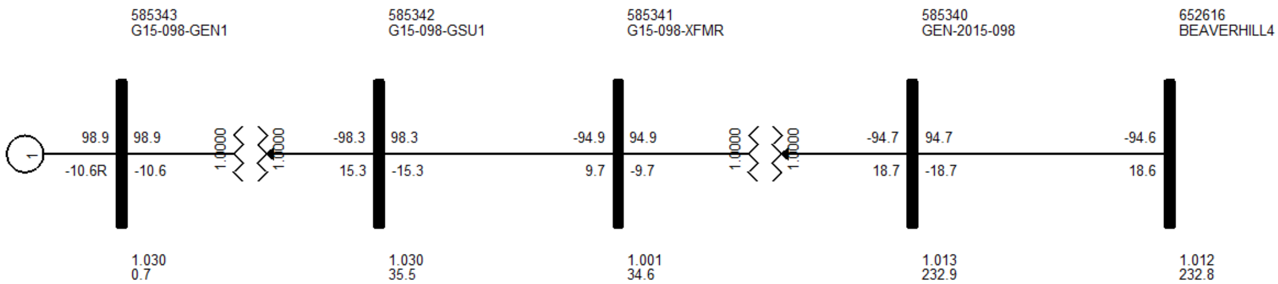

Figure II-1: GEN-2015-098. One-line Diagram

III. Stability Analysis

Transient stability analysis is used to determine if the transmission system can maintain angular stability and ensure bus voltages stay within planning criteria bandwidth during and after a disturbance while considering the addition of a generator interconnection request.

Model Preparation

Transient stability analysis was performed using modified versions of the 2015 series of Model Development Working Group (MDWG) dynamic study models including the 2016 winter peak, the 2017 summer peak, and the 2025 summer peak seasonal models. The cases are then loaded with prior queued interconnection requests and network upgrades assigned to those interconnection requests. Finally the prior queued and study generation are dispatched into the SPP footprint. Initial simulations are then carried out for a no-disturbance run of twenty (20) seconds to verify the numerical stability of the model.

Disturbances

Fifty-one (51) contingencies were identified for use in this study and are listed in Table III-1. These contingencies included three-phase faults and single-phase line faults at locations defined by SPP. Single-phase line faults were simulated by applying fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice.

Except for transformer faults, the typical sequence of events for a three-phase and a single-phase fault is as follows:

1. apply fault at particular location
2. continue fault for five (5) cycles, clear the fault by tripping the faulted facility
3. after an additional twenty (20) cycles, re-close the previous facility back into the fault
4. continue fault for five (5) additional cycles
5. trip the faulted facility and remove the fault

Transformer faults are typically modeled as three-phase faults, unless otherwise noted. The sequence of events for a transformer fault is as follows:

1. apply fault for five (5) cycles
2. clear the fault by tripping the affected transformer facility (unless otherwise noted there will be no re-closing into a transformer fault)

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
1	FLT_01_TANDE3_JUDSON3_345kV_3PH	3 phase fault on the Tande (659336) to Judson (659333) 345kV line, near Tande. a. Apply fault at the Tande 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
2	FLT_02_JUDSON3_PATENTGATE3_345kV_3PH	3 phase fault on the Judson (659333) to Patentgate (659390) 345kV line, near Judson. a. Apply fault at the Judson 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
3	FLT_03_KUMMERRIDGE3_ROUNDUP3_345kV_3PH	3 phase fault on the Kummer Ridge (659387) to Round Up (659384) 345kV line, near Kummer Ridge. a. Apply fault at the Kummer Ridge 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
4	FLT_04_CHARCK3_ROUNDUP3_345kV_3PH	3 phase fault on the Charlie Creek (659183) to Round Up (659384) 345kV line, near Charlie Creek. a. Apply fault at the Charlie Creek 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
5	FLT_05_CHARCK3_ANTELOP3_345kV_3PH	3 phase fault on the Charlie Creek (659183) to Antelope (659101) 345kV line, near Charlie Creek. a. Apply fault at the Charlie Creek 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
6	FLT_06_CHARCK3_BELFELD3_345kV_3PH	3 phase fault on the Charlie Creek (659183) to Belfield (652424) 345kV line, near Charlie Creek. a. Apply fault at the Charlie Creek 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
7	FLT_07_DAGLUM4_BELFELD4_230kV_3PH	3 phase fault on the Daglum (659448) to Belfield (652425) 230kV line, near Daglum. a. Apply fault at the Daglum 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
8	FLT_08_DAGLUM4_RHAME4_230kV_3PH	3 phase fault on the Daglum (659448) to Rhame (659266) 230kV line, near Daglum. a. Apply fault at the Daglum 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
9	FLT_09_BELFELD4_DICKNSN4_230kV_3PH	3 phase fault on the Belfield (652425) to Dickinson (652417) 230kV line, near Belfield. a. Apply fault at the Belfield 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
10	FLT_10_BELFELD4_MEDORA4_230kV_3PH	3 phase fault on the Belfield (652425) to Medora (652413) 230kV line, near Belfield. a. Apply fault at the Belfield 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
11	FLT_11_BELFELD4_SHEART4_230kV_3PH	3 phase fault on the Belfield (652425) to S Heart (659309) 230kV line, near Belfield. a. Apply fault at the Belfield 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
12	FLT_12_RHAME4_BOWMAN4_230kV_3PH	3 phase fault on the Rhame (659266) to Bowman (661010) 230kV line, near Rhame. a. Apply fault at the Rhame 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
13	FLT_13_RHAME4_LTLMISS4_230kV_3PH	3 phase fault on the Rhame (659266) to Little Missouri (659265) 230kV line, near Rhame. a. Apply fault at the Rhame 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
14	FLT_14_BAKER4_MICTYE4_230kV_3PH	3 phase fault on the Baker (661004) to Miles City (652411) 230kV line, near Baker. a. Apply fault at the Baker 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
15	FLT_15_BOWMAN4_HETINGR4_230kV_3PH	3 phase fault on the Bowman (661010) to Hettinger (661047) 230kV line, near Bowman. a. Apply fault at the Bowman 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
16	FLT_16_HEBRON4_MANDAN4_230kV_3PH	3 phase fault on the Hebron (652468) to Mandan (661053) 230kV line, near Hebron. a. Apply fault at the Hebron 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
17	FLT_17_BEAVERHILL4_MEDORA4_230kV_3PH	3 phase fault on the Beaver Hill (652616) to Medora (652413) 230kV line, near Beaver Hill. a. Apply fault at the Beaver Hill 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
18	FLT_18_BEAVERHILL4_DAWSONC4_230kV_3PH	3 phase fault on the Beaver Hill (652616) to Dawson County (652403) 230kV line, near Beaver Hill. a. Apply fault at the Beaver Hill 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
19	FLT_19_DAWSONC4_MICTYE4_230kV_3PH	3 phase fault on the Dawson County (652403) to Miles City (652411) 230kV line, near Dawson County. a. Apply fault at the Dawson County 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
20	FLT_20_DAWSONC4_COALHILL4_230kV_3PH	3 phase fault on the Dawson County (652403) to Coal Hill (652111) 230kV line, near Dawson County. a. Apply fault at the Dawson County 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
21	FLT_21_COALHILL4_FTPECK4_230kV_3PH	3 phase fault on the Coal Hill (652111) to Ft Peck (652405) 230kV line, near Coal Hill. a. Apply fault at the Coal Hill 230kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
22	FLT_22_DAWSONC4_LEWIS7_115kV_3PH	3 phase fault on the Dawson County (652404) to Lewis (661056) 115kV line, near Dawson County. a. Apply fault at the Dawson County 115kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
23	FLT_23_DAWSONC4_FALLON7_115kV_3PH	3 phase fault on the Dawson County (652404) to Fallon (652407) 115kV line, near Dawson County. a. Apply fault at the Dawson County 115kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
24	FLT_24_DAWSONC4_CIRCLE7_115kV_3PH	3 phase fault on the Dawson County (652404) to Circle (652401) 115kV line, near Dawson County. a. Apply fault at the Dawson County 115kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
25	FLT_25_DAWSONC4_GLENDCT7_115kV_3PH	3 phase fault on the Dawson County (652404) to Glendive County (661032) 115kV line, near Dawson County. a. Apply fault at the Dawson County 115kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
26	FLT_26_TANDE3_TANDE4_345_230kV_3PH	3 phase fault on the Tande 345kV (659336) / 230kV (659337) / 13.8kV (659338) transformer, near Tande 345kV ckt 1. a. Apply fault at the Tande 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
27	FLT_27_PATENTGATE3_PATENTGATE7_345_115kV_3PH	3 phase fault on the Patentgate 345kV (659390) / 115kV (659391) / 13.8kV (659392) transformer, near Patentgate 345kV ckt 1. a. Apply fault at the Patentgate 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
28	FLT_28_JUDSON3_JUDSON4_345_230kV_3PH	3 phase fault on the Judson 345kV (659333) / 230kV (659334) / 13.8kV (659335) transformer, near Judson 345kV ckt 1. a. Apply fault at the Judson 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
29	FLT_29_CHARCK3_CHARCK4_345_230kV_3PH	3 phase fault on the Charlie Creek 345kV (659183) / 230kV (659302) / 13.8kV (659319) transformer, near Charlie Creek 345kV ckt 2. a. Apply fault at Charlie Creek 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
30	FLT_30_BELFELD3_BELFELD4_345_230kV_3PH	3 phase fault on the Belfield 345kV (652424) / 230kV (652425) / 13.8kV (652221) transformer, near Belfield 345kV ckt 1. a. Apply fault at the Belfield 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
31	FLT_31_RHAME4_RHAME7_230_115kV_3PH	3 phase fault on the Rhame 230kV (659266) / 115kV (659267) transformer, near Rhame 230kV ckt 1. a. Apply fault at the Rhame 230kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
32	FLT_32_BAKER4_BAKER7_230_115kV_3PH	3 phase fault on the Baker 230kV (661004) / 115kV (661005) / 13.8kV (661901) transformer, near Baker 230kV ckt 1. a. Apply fault at the Baker 230kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
33	FLT_33_BOWMAN4_BOWMAN7_230_115kV_3PH	3 phase fault on the Bowman 230kV (661010) / 115kV (659340) transformer, near Bowman 230kV ckt 1. a. Apply fault at the Bowman 230kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
34	FLT_34_DAWSONC4_DAWSONC7_230_115kV_3PH	3 phase fault on the Dawson County 230kV (652403) / 115kV (652404) / 13.8kV (652211) transformer, near Dawson County 230kV ckt 1. a. Apply fault at the Dawson County 230kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
35	FLT_35_RHAME4PO_BOWMAN4PO_230kV_3PH	**Prior outage** on the Belfield (652425) to Daglum (659448) 230kV line: 3 phase fault on the Rhame (659266) to Bowman (661010) 230kV line, near Rhame 230kV. a. Prior Outage Belfield to Daglum 230kV. b. Apply fault at the Rhame 230kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.
36	FLT_36_PATENTGATE3PO_CHARCK3PO_345kV_3PH	**Prior outage** on the Tande 345kV (659336) / 230kV (659337) / 13.8kV (659338) transformer ckt 1: 3 phase fault on the Patentgate (659390) to Charlie Creek (659183) 345kV line, near Patentgate 345kV. a. Prior Outage Tande 345/230/13.8kV transformer ckt1. b. Apply fault at the Patentgate 345kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.
37	FLT_37_NESET4PO_TIOGA44PO_230kV_3PH	**Prior outage** on the Tande (659336) to Judson (659333) 345kV line: 3 phase fault on the Neset (659138) to Tioga (661084) 230kV line, near Neset 230kV. a. Prior Outage Tande to Judson 345kV. b. Apply fault at the Neset 230kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
38	FLT_38_BELFELD4PO_MEDORA4PO_230kV_3PH	**<u>Prior outage</u>** on the Belfield (652425) to Dickinson (652417) 230kV line: 3 phase fault on the Belfield (652425) to Medora (652413) 230kV line, near Belfield 230kV. a. Prior Outage Belfield to Dickinson 230kV. b. Apply fault at the Belfield 230kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.
39	FLT_39_BELFELD4PO_MEDORA4PO_230kV_3PH	**<u>Prior outage</u>** on the Rhame (659266) to Daglum (659448) 230kV line: 3 phase fault on the Belfield (652425) to Medora (652413) 230kV line, near Belfield 230kV. a. Prior Outage Rhame to Daglum 230kV. b. Apply fault at the Belfield 230kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.
40	FLT_40_DAWSONC4PO_COALHILL4PO_230kV_3PH	**<u>Prior outage</u>** on the Dawson County (652403) to Miles City (652411) 230kV line: 3 phase fault on the Dawson County (652403) to Coal Hill (652111) 230kV line, near Dawson County 230kV. a. Prior Outage Dawson County to Miles City 230kV. b. Apply fault at the Dawson County 230kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.
41	FLT_41_DAWSONC4PO_MICTYE4PO_230kV_3PH	**<u>Prior outage</u>** on the Dawson County 230kV (652403) / 115kV (652404) / 13.8kV (652211) transformer ckt 1: 3 phase fault on the Dawson County (652403) to Miles City (652411) 230kV line, near Dawson County 230kV. a. Prior Outage Dawson County 230/115/13.8kV transformer ckt1. b. Apply fault at the Dawson County 230kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (c) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (c) and remove fault.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
42	FLT_42_JUDSON3PO_JUDSON4PO_345_230kV_3PH	**Prior outage** on the Tande 345kV (659336) / 230kV (659337) / 13.8kV (659338) transformer ckt 1: 3 phase fault on the Judson 345kV (659333) / 230kV (659334) /13.8kV (659335) transformer ckt 1, near Judson 345kV. a. Prior Outage Tande 345/230/13.8kV transformer ckt1. b. Apply fault at the Judson 345kV bus. c. Clear fault after 5 cycles by tripping the faulted transformer.
43	FLT_43_TANDE4SB_NESET4SB_230kV_1PH	**Single phase fault with stuck breaker** on the Tande (659337) to Neset (659138) 230kV line, near Tande. a. Apply fault at the Tande 230kV bus. b. Run 5 cycles, then open Neset end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Tande (659337) 230kV line.
44	FLT_44_PATENTGATE3SB_CHARCK3SB_345kV_1PH	**Single phase fault with stuck breaker** on the Patentgate (659390) to Charlie Creek (659183) 345kV line, near Patentgate. a. Apply fault at the Patentgate 345kV bus. b. Run 5 cycles, then open Charlie Creek end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Patentgate (659390) 345kV line.
45	FLT_45_CHARCK3SB_ROUNDUP3SB_345kV_1PH	**Single phase fault with stuck breaker** on the Charlie Creek (659183) to Round Up (659384) 345kV line, near Patentgate. a. Apply fault at the Charlie Creek 345kV bus. b. Run 5 cycles, then open Round Up end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Charlie Creek (659183) 345kV line.
46	FLT_46_BELFELD4SB_MEDORA4SB_230kV_1PH	**Single phase fault with stuck breaker** on the Belfield (652425) to Medora (652413) 230kV line, near Belfield. a. Apply fault at the Belfield 230kV bus. b. Run 5 cycles, then open Medora end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Belfield (652425) 230kV line.
47	FLT_47_RHAME4SB_LTLMISS4SB_230kV_1PH	**Single phase fault with stuck breaker** on the Rhame (659266) to Little Missouri (659265) 230kV line, near Rhame. a. Apply fault at the Rhame 230kV bus. b. Run 5 cycles, then open Little Missouri end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Rhame (659266) 230kV line.
48	FLT_48_MEDORA4SB_BEAVERHILL4SB_230kV_1PH	**Single phase fault with stuck breaker** on the Medora (652413) to Beaver Hill (652616) 230kV line, near Medora. a. Apply fault at the Medora 230kV bus. b. Run 5 cycles, then open Beaver Hill end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Medora (652413) 230kV line.

Table III-1: Contingencies Evaluated

Contingency Number and Name		Description
49	FLT_49_DAWSONC4SB_BEAVERHILL4SB_230kV_1PH	**Single phase fault with stuck breaker** on the Dawson County (652403) to Beaver Hill (652616) 230kV line, near Dawson County. a. Apply fault at the Dawson County 230kV bus. b. Run 5 cycles, then open Beaver Hill end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Dawson County (652403) 230kV line.
50	FLT_50_DAWSONC4SB_LEWIS7SB_115kV_1PH	**Single phase fault with stuck breaker** on the Dawson County (652404) to Lewis (661056) 115kV line, near Dawson County. a. Apply fault at the Dawson County 115kV bus. b. Run 5 cycles, then open Lewis end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Dawson County (652404) 115kV line.
51	FLT_51_SQBUTTE4SB_GRESTANTON4SB_230kV_1PH	**Single phase fault with stuck breaker** on the Square Butte (657756) to Stanton (615901) 230kV line, near Square Butte. a. Apply fault at the Square Butte 230kV bus. b. Run 5 cycles, then open Stanton end of the faulted line. c. Run 10 cycles, and then clear the fault and disconnect Square Butte (657756) 230kV line.

Results

The stability analysis was performed and the results are summarized in Table III-2. Based on the stability results and with all network upgrades in service, GEN-2015-098 did not cause any stability problems and remained stable for all faults studied. No generators tripped or went unstable, and voltages recovered to acceptable levels.

Complete sets of plots for the stability analysis are available on request.

Table III-2: Stability Analysis Results

Contingency Number and Name		2015SP	2015WP	2025SP
1	FLT_01_TANDE3_JUDSON3_345kV_3PH	Stable	Stable	Stable
2	FLT_02_JUDSON3_PATENTGATE3_345kV_3PH	Stable	Stable	Stable
3	FLT_03_KUMMERRIDGE3_ROUNDUP3_345kV_3PH	Stable	Stable	Stable
4	FLT_04_CHARCK3_ROUNDUP3_345kV_3PH	Stable	Stable	Stable
5	FLT_05_CHARCK3_ANTELOP3_345kV_3PH	Stable	Stable	Stable
6	FLT_06_CHARCK3_BELFELD3_345kV_3PH	Stable	Stable	Stable
7	FLT_07_DAGLUM4_BELFELD4_230kV_3PH	Stable	Stable	Stable
8	FLT_08_DAGLUM4_RHAME4_230kV_3PH	Stable	Stable	Stable
9	FLT_09_BELFELD4_DICKNSN4_230kV_3PH	Stable	Stable	Stable
10	FLT_10_BELFELD4_MEDORA4_230kV_3PH	Stable	Stable	Stable
11	FLT_11_BELFELD4_SHEART4_230kV_3PH	Stable	Stable	Stable
12	FLT_12_RHAME4_BOWMAN4_230kV_3PH	Stable	Stable	Stable
13	FLT_13_RHAME4_LTLMISS4_230kV_3PH	Stable	Stable	Stable
14	FLT_14_BAKER4_MICTYE4_230kV_3PH	Stable	Stable	Stable
15	FLT_15_BOWMAN4_HETINGR4_230kV_3PH	Stable	Stable	Stable
16	FLT_16_HEBRON4_MANDAN4_230kV_3PH	Stable	Stable	Stable
17	FLT_17_BEAVERHILL4_MEDORA4_230kV_3PH	Stable	Stable	Stable
18	FLT_18_BEAVERHILL4_DAWSONC4_230kV_3PH	Stable	Stable	Stable
19	FLT_19_DAWSONC4_MICTYE4_230kV_3PH	Stable	Stable	Stable
20	FLT_20_DAWSONC4_COALHILL4_230kV_3PH	Stable	Stable	Stable
21	FLT_21_COALHILL4_FTPECK4_230kV_3PH	Stable	Stable	Stable
22	FLT_22_DAWSONC4_LEWIS7_115kV_3PH	Stable	Stable	Stable
23	FLT_23_DAWSONC4_FALLON7_115kV_3PH	Stable	Stable	Stable
24	FLT_24_DAWSONC4_CIRCLE7_115kV_3PH	Stable	Stable	Stable
25	FLT_25_DAWSONC4_GLENDCT7_115kV_3PH	Stable	Stable	Stable
26	FLT_26_TANDE3_TANDE4_345_230kV_3PH	Stable	Stable	Stable
27	FLT_27_PATENTGATE3_PATENTGATE7_345_115kV_3PH	Stable	Stable	Stable
28	FLT_28_JUDSON3_JUDSON4_345_230kV_3PH	Stable	Stable	Stable
29	FLT_29_CHARCK3_CHARCK4_345_230kV_3PH	Stable	Stable	Stable
30	FLT_30_BELFELD3_BELFELD4_345_230kV_3PH	Stable	Stable	Stable
31	FLT_31_RHAME4_RHAME7_230_115kV_3PH	Stable	Stable	Stable
32	FLT_32_BAKER4_BAKER7_230_115kV_3PH	Stable	Stable	Stable
33	FLT_33_BOWMAN4_BOWMAN7_230_115kV_3PH	Stable	Stable	Stable
34	FLT_34_DAWSONC4_DAWSONC7_230_115kV_3PH	Stable	Stable	Stable
35	FLT_35_RHAME4PO_BOWMAN4PO_230kV_3PH	Stable	Stable	Stable
36	FLT_36_PATENTGATE3PO_CHARCK3PO_345kV_3PH	Stable	Stable	Stable
37	FLT_37_NESET4PO_TIOGA44PO_230kV_3PH	Stable	Stable	Stable

Table III-2: Stability Analysis Results

Contingency Number and Name		2015SP	2015WP	2025SP
38	FLT_38_BELFELD4PO_MEDORA4PO_230kV_3PH	Stable	Stable	Stable
39	FLT_39_BELFELD4PO_MEDORA4PO_230kV_3PH	Stable	Stable	Stable
40	FLT_40_DAWSONC4PO_COALHILL4PO_230kV_3PH	Stable	Stable	Stable
41	FLT_41_DAWSONC4PO_MICTYE4PO_230kV_3PH	Stable	Stable	Stable
42	FLT_42_JUDSON3PO_JUDSON4PO_345_230kV_3PH	Stable	Stable	Stable
43	FLT_43_TANDE4SB_NESET4SB_230kV_1PH	Stable	Stable	Stable
44	FLT_44_PATENTGATE3SB_CHARCK3SB_345kV_1PH	Stable	Stable	Stable
45	FLT_45_CHARCK3SB_ROUNDUP3SB_345kV_1PH	Stable	Stable	Stable
46	FLT_46_BELFELD4SB_MEDORA4SB_230kV_1PH	Stable	Stable	Stable
47	FLT_47_RHAME4SB_LTLMISS4SB_230kV_1PH	Stable	Stable	Stable
48	FLT_48_MEDORA4SB_BEAVERHILL4SB_230kV_1PH	Stable	Stable	Stable
49	FLT_49_DAWSONC4SB_BEAVERHILL4SB_230kV_1PH	Stable	Stable	Stable
50	FLT_50_DAWSONC4SB_LEWIS7SB_115kV_1PH	Stable	Stable	Stable
51	FLT_51_SQBUTTE4SB_GRESTANTON4SB_230kV_1PH	Stable	Stable	Stable

NOTE: “- NA -“means the contingency is not applicable

FERC LVRT Compliance

FERC Order #661A places specific requirements on wind farms through its Low Voltage Ride Through (LVRT) provisions. For Interconnection Agreements signed after December 31, 2006, wind farms shall stay on line for faults at the POI that draw the voltage down at the POI to 0.0 pu.

Contingencies 17 and 18 in Table III-2 simulated the LVRT contingencies. GEN-2015-098 met the LVRT requirements by staying on line and the transmission system remaining stable.

IV. Power Factor Analysis

A subset of the stability faults was used as power flow contingencies to determine the power factor requirements for the wind farm to maintain scheduled voltage at the POI. The voltage schedule was set equal to the voltages at the POI before the project is added, with a minimum of 1.0 per unit. A fictitious reactive power source replaced the study project to maintain scheduled voltage during all studied contingencies. The MW and Mvar injections from the study project at the POI were recorded and the resulting power factors were calculated for all contingencies for summer peak and winter peak cases. The most leading and most lagging power factors determine the minimum power factor range capability that the study project must install before commercial operation.

Per FERC and SPP Tariff requirements, if the power factor needed to maintain scheduled voltage is less than 0.95 lagging, then the requirement is limited to 0.95 lagging. The lower limit for leading power factor requirement is also 0.95. If a project never operated leading under any contingency, then the leading requirement is set to 1.0. The same applies on the lagging side.

The power factor analysis showed a need for reactive capability by the study project at the POI. The final power factor requirement in the Generator Interconnection Agreement (GIA) will be the pro-forma 0.95 lagging to 0.95 leading at the POI, and this requirement is shown in Table IV-1. The detailed power factor analysis tables are in Appendix B. Since the GE 2.3MW wind turbines, as studied, have a reactive capability of 0.95 lagging and 0.95 leading, the generation facility may require external capacitor banks or other reactive equipment (such as the +/- 0.90 power factor option for the GE 2.3MW wind turbines) to meet the power factor requirement at the POI. The results are shown in **Appendix B: Power Factor Analysis**.

Table IV-1: Power Factor Requirements [a]

Request	Size (MW)	Generator Model	Point of Interconnection	Final PF Requirement at POI	
				Lagging [b]	Leading [c]
GEN-2015-098	98.9	GE 2.3MW	Mingusville 230kV	0.95[d]	0.95[e]

Notes:

a. The table shows the minimum required power factor capability at the point of interconnection that must be designed and installed with the plant. The power factor capability at the POI includes the net effect of the generators, transformers, line impedances, and any reactive compensation devices installed on the plant side of the meter. Installing more capability than the minimum requirement is acceptable.

b. Lagging is when the generating plant is supplying reactive power to the transmission grid, like a shunt capacitor. In this situation, the alternating current sinusoid “lags” behind the alternating voltage sinusoid, meaning that the current peaks shortly after the voltage.

c. Leading is when the generating plant is taking reactive power from the transmission grid, like a shunt reactor. In this situation, the alternating current sinusoid “leads” the alternating voltage sinusoid, meaning that the current peaks shortly before the voltage.

d. Electrical need is lower, but PF requirement limited to 0.95 by FERC order.

e. The most leading power factor determined through analysis was 1.00.

V. Low Wind Analysis

Interconnection requests for wind generation projects that interconnect on the SPP system are analyzed for the capacitive charging effects during reduced generation conditions (unsuitable wind speeds, curtailment, etc.) at the generation site.

Model Preparation

The project generators and capacitors (if any), and all other wind projects that share the same POI, were turned off in the base case. The resulting reactive power injection into the transmission network comes from the capacitance of the project's transmission lines and collector cables. This reactive power injection is measured at the POI. Shunt reactors were added at the study project substation low voltage bus to bring the Mvar flow into the POI down to approximately zero.

Results

A final shunt reactor requirement for each of the studied interconnection requests is shown in **Table V-1**. One line drawings used in the analysis are shown in **Appendix D: Low Wind Compensation Analysis**.

Table V-1: Summary of Shunt Reactor Requirements

Request	Capacity	POI	Approximate Shunt Reactor Required
GEN-2015-098	98.9MW	Mingusville 230kV	10 Mvar

The results shown are for the 2025 summer case. The other two cases (2016 winter and 2017 summer) were almost identical since the generation plant design is the same in all cases.

VI. Short Circuit Analysis

Results

The short circuit analysis was performed on the 2025 Summer Peak power flow case using the PSS/E ASCC program. Since the power flow model does not contain negative and zero sequence data, only three-phase symmetrical fault current levels were calculated at the point of interconnection up to and including five levels away. The following pages list the results of the analysis. The results are shown in **Appendix E: Short Circuit Analysis**.

VII. Conclusion

The SPP GEN-2015-098 Impact Restudy evaluated the impact of interconnecting the project shown below in Table VII-1.

Table VII-1: Interconnection Request

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2015-098	98.9	GE 2.3MW [forty-three (43) generators]	Mingusville 230kV

With all Base Case Network Upgrades in service, previously assigned Network Upgrades in service, and required capacitor banks in service, the GEN-2015-098 project was found to remain on line, and the transmission system was found to remain stable for all conditions studied. The requested modification is not considered Material.

A low-wind/no-wind condition analysis was performed for this modification request. The project will be required to install a total of approximately 10 Mvar of reactor shunts on its substation 34.5kV buses. This is necessary to offset the capacitive effect on the transmission network cause by the project's transmission line and collector system during low-wind or no-wind conditions.

Low Voltage Ride Through (LVRT) analysis showed the study generators did not trip offline due to low voltage when all Network Upgrades are in service.

All generators in the monitored areas remained stable for all of the modeled disturbances.

Any changes to the assumptions made in this study, for example, one or more of the previously queued requests withdraw, may require a re-study at the expense of the Customer.

Nothing in this System Impact Study constitutes a request for transmission service or confers upon the Interconnection Customer any right to receive transmission service.

APPENDIX A

PLOTS

Available on request

APPENDIX B

POWER FACTOR ANALYSIS

GEN 2015-098 Turbine Restudy POI – BEAVERHILL4 230.00 237.444900513 (652616)		2016 Winter Voltage = 1.03237 pu				2017 Summer Voltage = 1.02666 pu				2025 Summer Voltage = 1.016957 pu			
Cont. No.	Contingency Name	Power at POI	VARS at POI	Power Factor		Power at POI	VARS at POI	Power Factor		Power at POI	VARS at POI	Power Factor	
0	FLT_00_NoFault	98.9	-8.75352	0.996106	LEAD	98.9	-8.0354	0.99676	LEAD	98.9	-10.9549	0.993921	LEAD
1	FLT_01_TANDE3_JUDSON3_345kV_3PH	98.9	-7.86629	0.996852	LEAD	98.9	-7.69417	0.99697	LEAD	98.9	-10.8219	0.994067	LEAD
2	FLT_02_JUDSON3_PATENTGATE3_345kV_3PH	98.9	-8.75766	0.996102	LEAD	98.9	-6.62191	0.99776	LEAD	98.9	-10.4886	0.994423	LEAD
3	FLT_03_KUMMERRIDGE3_ROUNDUP3_345kV_3PH	98.9	-8.57605	0.996261	LEAD	98.9	-7.20392	0.99738	LEAD	98.9	-10.1443	0.994781	LEAD
4	FLT_04_CHARCK3_ROUNDUP3_345kV_3PH	98.9	-7.46443	0.997164	LEAD	[redacted]				98.9	-10.0838	0.994842	LEAD
5	FLT_05_CHARCK3_ANTELOP3_345kV_3PH	98.9	-7.79498	0.996908	LEAD	98.9	-6.18277	0.99802	LEAD	98.9	-9.41169	0.995502	LEAD
6	FLT_06_CHARCK3_BELFELD3_345kV_3PH	98.9	0.52952	0.999986	LAG	98.9	2.71957	0.99962	LAG	98.9	-1.26861	0.999918	LEAD
7	FLT_07_DAGLUM4_BELFELD4_230kV_3PH	98.9	-11.8147	0.99294	LEAD	[redacted]							
8	FLT_08_DAGLUM4_RHAME4_230kV_3PH	98.9	7.66204	0.997012	LAG	98.9	9.14776	0.99575	LAG	98.9	9.824841	0.995102	LAG
9	FLT_09_BELFELD4_DICKNSN4_230kV_3PH	98.9	-6.56548	0.997804	LEAD	98.9	-5.88883	0.99822	LEAD	98.9	-8.7769	0.996085	LEAD
10	FLT_10_BELFELD4_MEDORA4_230kV_3PH	98.9	-20.9969	0.978198	LEAD	98.9	-18.2272	0.98348	LEAD	98.9	-17.5367	0.984641	LEAD
11	FLT_11_BELFELD4_SHEART4_230kV_3PH	[redacted]											
12	FLT_12_RHAME4_BOWMAN4_230kV_3PH	98.9	-7.32034	0.997272	LEAD	98.9	-6.05126	0.99813	LEAD	98.9	-13.6282	0.990639	LEAD
13	FLT_13_RHAME4_LTLMISS4_230kV_3PH	98.9	-4.82763	0.998811	LEAD	98.9	-5.63722	0.99839	LEAD	98.9	3.382669	0.999416	LAG
14	FLT_14_BAKER4_MICTYE4_230kV_3PH	98.9	-5.86519	0.998246	LEAD	98.9	-8.06105	0.99665	LEAD	98.9	1.135857	0.999934	LAG
15	FLT_15_BOWMAN4_HETINGR4_230kV_3PH	98.9	-9.02574	0.995862	LEAD	98.9	-7.09362	0.99748	LEAD	98.9	-13.3644	0.990993	LEAD
16	FLT_16_HEBRON4_MANDAN4_230kV_3PH	98.9	-5.97221	0.998182	LEAD	98.9	-5.47324	0.99842	LEAD	98.9	-7.93878	0.996794	LEAD
17	FLT_17_BEAVERHILL4_MEDORA4_230kV_3PH	98.9	-14.5355	0.989372	LEAD	98.9	-11.032	0.99386	LEAD	98.9	-14.0651	0.990038	LEAD
18	FLT_18_BEAVERHILL4_DAWSONC4_230kV_3PH	98.9	1.38613	0.999902	LAG	98.9	-1.71354	0.99985	LEAD	98.9	-1.63548	0.999863	LEAD
19	FLT_19_DAWSONC4_MICTYE4_230kV_3PH	98.9	-0.65072	0.999978	LEAD	98.9	2.97848	0.99957	LAG	98.9	-1.39948	0.9999	LEAD
20	FLT_20_DAWSONC4_COALHILL4_230kV_3PH	98.9	3.77276	0.999273	LAG	98.9	6.12709	0.99806	LAG	98.9	-6.29506	0.99798	LEAD
21	FLT_21_COALHILL4_FTPECK4_230kV_3PH	98.9	-7.49378	0.997142	LEAD	98.9	-6.27206	0.99795	LEAD	98.9	-7.28369	0.997299	LEAD
22	FLT_22_DAWSONC4_LEWIS7_115kV_3PH	98.9	-9.10107	0.995793	LEAD	98.9	-7.55824	0.99702	LEAD	98.9	-11.0594	0.993806	LEAD
23	FLT_23_DAWSONC4_FALLON7_115kV_3PH	98.9	-8.11151	0.996653	LEAD	98.9	-5.46973	0.99844	LEAD	98.9	-6.12508	0.998088	LEAD

GEN 2015-098 Turbine Restudy POI – BEAVERHILL4 230.00 237.444900513 (652616)		2016 Winter Voltage = 1.03237 pu				2017 Summer Voltage = 1.02666 pu				2025 Summer Voltage = 1.016957 pu			
Cont. No.	Contingency Name	Power at POI	VARS at POI	Power Factor		Power at POI	VARS at POI	Power Factor		Power at POI	VARS at POI	Power Factor	
24	FLT_24_DAWSONC4_CIRCLE7_115kV_3PH	98.9	-12.6204	0.991956	LEAD	98.9	-10.5491	0.99439	LEAD	98.9	-12.8512	0.991663	LEAD
25	FLT_25_DAWSONC4_GLENDCT7_115kV_3PH	98.9	-8.00184	0.996743	LEAD	98.9	-5.99675	0.99817	LEAD	98.9	-7.66101	0.997013	LEAD
26	FLT_26_TANDE3_TANDE4_345_230kV_3PH	98.9	-6.44993	0.99788	LEAD	98.9	-6.31166	0.99797	LEAD	98.9	-8.50849	0.99632	LEAD
27	FLT_27_PATENTGATE3_PATENTGATE7_345_115kV_3PH	[redacted]											
28	FLT_28_JUDSON3_JUDSON4_345_230kV_3PH	98.9	-9.10892	0.995785	LEAD	98.9	-8.31938	0.99641	LEAD	98.9	-11.1632	0.99369	LEAD
29	FLT_29_CHARCK3_CHARCK4_345_230kV_3PH	98.9	-8.72276	0.996133	LEAD	98.9	-7.90147	0.99684	LEAD	98.9	-10.913	0.993967	LEAD
30	FLT_30_BELFELD3_BELFELD4_345_230kV_3PH	98.9	-7.68459	0.996995	LEAD	98.9	-6.80014	0.99765	LEAD	98.9	-9.80128	0.995125	LEAD
31	FLT_31_RHAME4_RHAME7_230_115kV_3PH	98.9	-8.75352	0.996106	LEAD	98.9	-8.0354	0.99676	LEAD	98.9	-10.9549	0.993921	LEAD
32	FLT_32_BAKER4_BAKER7_230_115kV_3PH	98.9	-8.92872	0.995949	LEAD	98.9	-8.04877	0.99675	LEAD	98.9	-11.4412	0.993375	LEAD
33	FLT_33_BOWMAN4_BOWMAN7_230_115kV_3PH	98.9	-8.75352	0.996106	LEAD	98.9	-8.0354	0.99676	LEAD	98.9	-10.9549	0.993921	LEAD
34	FLT_34_DAWSONC4_DAWSONC7_230_115kV_3PH	98.9	-17.2173	0.985183	LEAD	98.9	-22.9759	0.97406	LEAD	98.9	-28.3066	0.961397	LEAD

APPENDIX C

PROJECT MODELS

GEN-2015-098 (GE 2.3MW)

```
@! ---------- Bus Data ----------
BAT_SPLT,652616,585340,'GEN-2015-098', 230.0,;
BAT_BUS_DATA_2,585340,1,652,1602,652, 230.000,,,'GEN-2015-098',;
BAT_BUS_DATA_2,585341,1,652,1602,652,  34.500,,,'G15-098-XFMR1',;
BAT_BUS_DATA_2,585342,1,652,1602,652,  34.500,,,'G15-098-GSU1',;
BAT_BUS_DATA_2,585343,2,652,1602,652,   0.690,,,'G15-098-GEN1',;
@!
@! ----------- Generator Data -----------
BAT_PLANT_DATA,585343,     0, 1.030,,;
@! 100%
  BAT_MACHINE_DATA_2,585343,'1',1,,,,,0,  98.90,,  32.50686, -32.50686,  98.90, 0.000, 105.000, 0.00000, 0.80000,,,,,,,, 1.00,;
@! 20%
@!BAT_MACHINE_DATA_2,585343,'1',1,,,,,0,  19.79,,   6.50137,  -6.50137,  98.90, 0.000, 105.000, 0.00000, 0.80000,,,,,,,, 1.00,;
@!
@! ----------- Transformer Data -----------
BAT_TWO_WINDING_DATA_3,585340,585341,'1',1,,,,,,33,,,,1,0,1,2,1, 0.00297, 0.09495,  95.000,,,,,, 120.000, 120.000,,,,,,,,,,,,,,,,;
BAT_TWO_WINDING_DATA_3,585342,585343,'1',1,,,,,, 5,,,,1,0,1,2,1, 0.00760, 0.05700, 111.800,,,,,, 111.800, 111.800,,,,,,,,,,,,,,,,;
@!
@! ----------- Collector Cable Data -----------
BAT_BRANCH_DATA,585341,585342,'1',1,,,,,, 0.03621, 0.04932, 0.09902,,,,,,,,  0.0,,,,,;
@!
@! ----------- Transmission Line Data from Substation to POI -----------
BAT_BRANCH_DATA,652616,585340,'1',1,,,,,, 0.00058, 0.00153, 0.00279,,,,,,,, 0.095,,,,,;
@!

585343 'USRMDL' 1  'GEWTG2'  1 1 4 18 3 5
       0   43        0       0
       2.3000     0.80000     0.50000     0.90000      1.2200      1.2000
       2.0000     0.40000     0.80000      10.000     0.20000E-01   0.0000
       0.0000     0.50000     0.16700     0.90000     0.92500      0.0000    /
585343 'USRMDL' 1  'GEWTE2'  4 0 12 67 18 9
       585343        0            0             1             0             0
       0        0            0             1             0             0
       0.15000       2.000      1.0000      0.0000      0.0000     0.50000E-01   3.0000
       0.60000      1.1200     0.40000E-01  0.43600     -0.43600      1.1000     0.20000E-01
       0.45000           -0.45000        60.000          0.10000          0.90000
       1.1000          40.000          0.50000         1.4500           0.50000E-01
       0.50000E-01        1.0000          0.15000         0.96000           0.99600
       1.0040           1.0400          1.00000         1.0000           1.00000
       0.40000           1.0000          0.20000         1.0000           0.25000
       -1.0000           14.0000         25.000          3.0000           -0.90000
       8.0000            0.2000         10.000          1.0000           1.7000
       1.22              1.2500          5.0000          0.0000           0.0000
       0.000             0.25000E-02      1.0000          5.5000           0.10000
       -1.0000            0.10000         0.0000          0.10000          -0.10000
       0.70000           0.12000         -0.12000    /
585343 'USRMDL' 1  'GEWTT1'       5    0    1    5    4    3   0
       3.2200       0.0000       0.0000       1.8800       1.5000    /
0 'USRMDL'  0 'GEWGC1' 8    0    3    6    0    4
       585343      '1 ' 0
       9999.0       5.0000       30.000       9999.0       9999.0
       30.000    /
0 'USRMDL'  0 'GEWTA1'       8    0    3    9    1    4
       585343      '1 '   0
       20.000       0.0000       27.000      -4.0000       0.0000       1.2250
       53.500       104.00       1200.0    /
0 'USRMDL'  0 'GEWTP1'       8    0    3    10    3    3
       585343      '1 '   0
```

```
      0.30000     150.00     25.000     3.0000     30.000
      -4.0000     27.000    -10.000     10.000     1.0000   /
0 'USRMDL'  0 'GEWPLT' 8  0  2  0  0  17          585343     '1 '    /
/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.20000     5.0000      1.00000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.40000     5.0000      1.70000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.60000     5.0000      2.20000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.75000     5.0000      3.0000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.85000     5.0000      10.0000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.90000     5.0000      600.0000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.00000     1.1010      1.000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.00000     1.1500     0.5000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.00000     1.17500     0.2000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.00000     1.2000      0.1000     0.80000E-01/
0 'USRMDL'  0  'VTGTPA' 0 2 6 4 0 1
   585343      585343  '1 '      0 0 0
   0.00000     1.3000      0.0100     0.80000E-01/
/
0 'USRMDL' 0 'FRQTPA' 0 2 6 4 0 1
    585343   585343   '1'   0 0 0
    57.0 63.0  10.0 0.08 /
0 'USRMDL' 0 'FRQTPA' 0 2 6 4 0 1
    585343   585343   '1'   0 0 0
    54.0 100.0   1.0 0.08 /
0 'USRMDL' 0 'FRQTPA' 0 2 6 4 0 1
    585343   585343   '1'   0 0 0
    51.0 66.0  0.25 0.08 /
/
```

APPENDIX D

LOW WIND COMPENSATION ANALYSIS

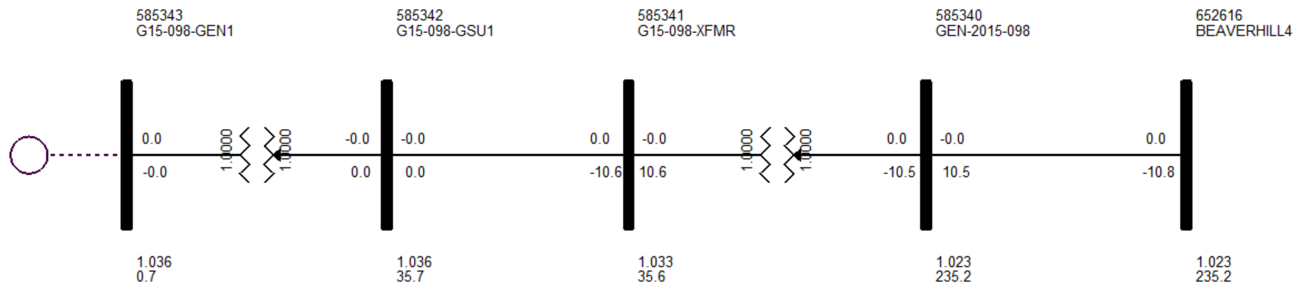

Figure E-1: GEN-2015-098 with generators off and no shunt reactors

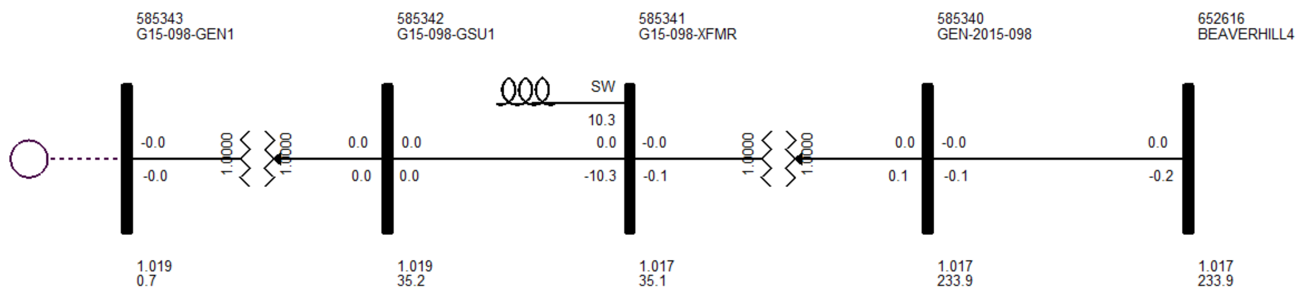

Figure E-2: GEN-2015-098 with generator turned off and shunt reactor added to the low side of the substation 230/34.5kV transformer

APPENDIX E

SHORT CIRCUIT ANALYSIS

PSS®E-32.2.0 ASCC SHORT CIRCUIT CURRENTS TUE, AUG 23 2016 15:30
2015 MDWG FINAL WITH 2013 MMWG, UPDATED WITH 2014 SERC & MRO
MDWG 2025S WITH MMWG 2024S, MRO & SERC 2025 SUMMER

OPTIONS USED:
- FLAT CONDITIONS
  - BUS VOLTAGES SET TO 1 PU AT 0 PHASE ANGLE
  - GENERATOR P=0, Q=0
  - TRANSFOMRER TAP RATIOS=1.0 PU and PHASE ANGLES=0.0
  - LINE CHARGING=0.0 IN +/-/0 SEQUENCE
  - LOAD=0.0 IN +/- SEQUENCE, CONSIDERED IN ZERO SEQUENCE
  - LINE/FIXED/SWITCHED SHUNTS=0.0 AND MAGNETIZING ADMITTANCE=0.0 IN +/-/0 SEQUENCE
  - DC LINES AND FACTS DEVICES BLOCKED
  - TRANSFORMER ZERO SEQUENCE IMPEDANCE CORRECTIONS IGNORED

THREE PHASE FAULT
X---------- BUS ----------X /I+/ AN(I+)
652616 [BEAVERHILL4 230.00] AMP 3902.9 -83.66
585340 [GEN-2015-098230.00] AMP 3821.1 -83.36
652403 [DAWSONC4 230.00] AMP 4228.8 -83.37
652413 [MEDORA 4 230.00] AMP 5047.9 -84.07
652617 [BEAVERHILL8 57.000] AMP 2149.6 -87.41
585341 [G15-098-XFMR34.500] AMP 11763.8 -86.26
652111 [COALHILL4 230.00] AMP 2333.9 -84.24
652211 [DAWSONC9 13.200] AMP 31745.9 -85.36
652404 [DAWSONC7 115.00] AMP 7714.0 -82.11
652411 [MI CTYE4 230.00] AMP 2773.0 -83.36
652425 [BELFELD4 230.00] AMP 9132.6 -85.44
585342 [G15-098-GSU134.500] AMP 9481.9 -80.24
652110 [KPS11-CH9 6.9000] AMP 34510.9 -85.81
652217 [MI CTYE9 13.800] AMP 13643.1 -86.01
652220 [BELFELD29 13.800] AMP 24564.6 -87.36
652221 [BELFELD9 13.800] AMP 22675.8 -89.27
652401 [CIRCLE 7 115.00] AMP 2218.3 -69.54
652405 [FTPECK 4 230.00] AMP 2352.5 -84.34
652407 [FALLON 7 115.00] AMP 3102.6 -76.81
652412 [MI CTYE7 115.00] AMP 3886.1 -83.85
652417 [DICKNSN4 230.00] AMP 6630.5 -83.98
652424 [BELFELD3 345.00] AMP 6559.2 -85.60
659309 [S HEART 4230.00] AMP 9132.6 -85.44
659448 [DAGLUM 4230.00] AMP 6395.1 -85.27
661004 [BAKER 4 230.00] AMP 3131.5 -83.47
661032 [GLENDCT7 115.00] AMP 6198.5 -80.74
661056 [LEWIS 7 115.00] AMP 5667.4 -78.18
11160 [J405 13.800] AMP 28736.8 -87.33
585260 [GEN-2015-091230.00] AMP 6362.3 -85.27
652121 [KPS12-CR7 115.00] AMP 1954.8 -71.15
652131 [KPS13-OF7 115.00] AMP 2260.1 -78.33
652213 [FALLON 8 69.000] AMP 1036.5 -85.99
652214 [FALLON 9 12.470] AMP 1129.0 -87.66
652219 [MI CTYE8 57.000] AMP 4269.2 -87.70
652394 [TERRY TAP 115.00] AMP 2820.9 -77.10
652395 [SHIRLEY TAP 115.00] AMP 2989.4 -79.19

652406 [FTPECK 7 115.00] AMP 3783.2 -83.07
652414 [FTPECK4G 13.800] AMP 19228.2 -86.53
652415 [FTPECK5G 13.800] AMP 19228.2 -86.53
652418 [DKSN-ND7 115.00] AMP 5886.7 -83.17
652451 [RICHLND7 115.00] AMP 5600.0 -77.23
652468 [HEBRON 4 230.00] AMP 5118.5 -83.75
659183 [CHAR.CK3 345.00] AMP 10626.6 -86.12
659197 [DICKNSON 913.800] AMP 15049.3 -85.76
659265 [LTLMISS4 230.00] AMP 3293.7 -83.61
659266 [RHAME 4 230.00] AMP 4025.4 -84.03
659306 [S HEART 7115.00] AMP 2197.0 -88.19
659450 [GI1414 4230.00] AMP 3476.4 -85.51
661005 [BAKER 7 115.00] AMP 3569.4 -83.04
661033 [CABINCR7 115.00] AMP 3119.5 -79.30
661055 [LEWIS71G 13.800] AMP 24874.2 -86.33
661100 [GLNDCT1G 13.800] AMP 20710.9 -87.10
661101 [GLNDCT2G 13.800] AMP 27756.7 -88.29
661901 [BAKER 9 13.800] AMP 11799.4 -86.02
910007 [G12_012IST 115.00] AMP 2488.2 -73.34
585261 [G15-091-XFMR34.500] AMP 11036.3 -87.89
585310 [GEN-2015-096230.00] AMP 2811.6 -84.88
652120 [KPS12-CR9 6.9000] AMP 14144.8 -80.27
652130 [KPS13-OF9 6.9000] AMP 14915.9 -83.66
652409 [WOLFPT 7 115.00] AMP 3463.8 -78.49
652410 [FTPECK3G 13.800] AMP 21364.6 -86.41
652611 [KPS10-FP7 115.00] AMP 1376.8 -82.75
652651 [FAIRVIEW 7 115.00] AMP 4806.9 -74.62
659101 [ANTELOP3 345.00] AMP 16410.9 -87.41
659124 [G14_004IS_1 34.500] AMP 45461.7 -88.64
659180 [KOCH 7 115.00] AMP 3874.6 -75.67
659182 [CHAR.CK7 115.00] AMP 14074.7 -85.80
659211 [CHARCREEK 1913.800] AMP 23841.1 -87.99
659263 [LTLMISS7 115.00] AMP 1812.0 -87.20
659267 [RHAME 7 115.00] AMP 3084.4 -86.83
659302 [CHAR.CK4 230.00] AMP 11360.4 -85.97
659318 [CHARCREEK 2913.800] AMP 23051.9 -88.41
659319 [CHARCREEK 3913.800] AMP 30588.0 -88.76
659384 [ROUNDUP 3345.00] AMP 8826.2 -86.01
659390 [PATENTGATE 3345.00] AMP 6301.3 -86.89
659400 [NDSUNFLWR 4230.00] AMP 4604.2 -83.88
659451 [GI1414 934.500] AMP 15292.9 -87.34
661010 [BOWMAN 4 230.00] AMP 3548.4 -83.78
661019 [MATHSON7 115.00] AMP 5517.4 -82.11
661024 [WDICKSN7 115.00] AMP 4884.5 -82.64
661034 [KPS14-BAK7 115.00] AMP 3225.7 -80.68
661053 [MANDAN 4 230.00] AMP 14277.4 -84.12
661070 [N ENGLN7 115.00] AMP 3233.7 -78.99
661300 [BAKER 8 60.000] AMP 3092.4 -83.96
910005 [G12_012IS_1 34.500] AMP 8241.4 -73.47