GEN-2011-014 Impact Restudy for Generator Modification (Turbine Change)

Generator Interconnection
December 2015

Southwest Power Pool

Executive Summary

The GEN-2011-014 Interconnection Customer has requested a modification to its Interconnection Request. Quanta Technologies (Quanta) was contracted by SPP to perform this system impact restudy to determine the effects of changing wind turbine generators from the previously studied Siemens 3.0MW wind turbine generators (67 machines total) to Vestas V117 3.3MW wind turbine generators (60 machines total).

In this restudy the project uses sixty (60) Vestes V117 GS 3.3MW wind turbine generators for an aggregate power of 198MW. The point of interconnection (POI) for GEN-2011-014 is at the proposed OG&E substation that will tap the Beaver County – Woodward 345kV line, approximately 15 miles east of Beaver County. The Interconnection Customer has provided documentation that shows the Vestas V117 GS 3.3MW wind turbine generators have a reactive capability of 0.863 lagging (providing VARS) and 0.933 leading (absorbing VARS) power factor at full load.

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-2013-002 were used that analyzed the timeframes of 2015 summer, 2015 winter, 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 Vestas V117 GS 3.3MW 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.

Power factor analysis performed for this study indicates that the Generating Facility will be required to maintain the pro-forma 95% lagging (providing vars) and 95% leading (absorbing vars) power factor at the Point of Interconnection Furthermore, the low wind analysis has verified that the project will be required to install approximately 10 Mvar of shunt reactors 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 2013-002 in place, GEN-2011-014 with the Vestas V117 GS 3.3MW 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.

SPP Queue GEN-2011-014 Impact Restudy for Generator Modification

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Revision History:

Revision Number	Date Approved	Approved By	Description
1	*December 18, 2015*		Change description of units. Explain MVAR injection of collector system. Recalculate power factor analysis.

EXECUTIVE SUMMARY

GEN-2011-014 ("Interconnection Customer") has requested an Impact Restudy for Generator Modification through the Southwest Power Pool Tariff. The interconnection request will be studied at 100% of nameplate MW capacity. The modified generator is to be a 198.0 MW wind farm consisting of 60 Vestas 3.3 MW V117 wind turbines. The point of interconnection to the 345 kV system is unchanged.

Short circuit, stability and power factor analyses were performed using 2015 Summer Peak, 2015 Winter Peak, and 2025 Summer Peak conditions. Prior queued projects were included.

Forty-four contingencies were considered, including

- Three-phase 345 kV faults normally cleared, unsuccessfully reclosed and locked out, isolating one or two 345 kV lines.
- Three-phase faults removing a transformer.
- Three-phase 138 and 230 kV faults normally cleared, unsuccessfully reclosed and locked out, isolating a 138 or 230 kV line; single-phase faults following the same sequence.
- Single-phase 345 kV faults with stuck circuit breaker.

Conclusions reached were as follows.

The highest fault current noted is at bus 533040 EVANS N4 (138 kV), while the greatest increase is at Beaver County 345 kV. No location experienced an increase in fault current sufficient to require circuit breakers to be changed from one "preferred rating" to a higher one.

There were no material differences between the 15SP, 15WP and 25SP stability simulations. All units monitored had acceptable stability response, neither pulling out, tripping, nor exhibiting undamped variations, for all faults with the exception of the following.

- Contingency FLT06: 3 phase fault on the G11-14 TAP to Woodward 345 kV lines 1 & 2. This is a very severe contingency and stability issues have been noted in previous studies. It has been found that they can be mitigated by curtailing generation during outages of G11-14 tap to Woodward 345 kV line.
- Contingencies FLT07 and FLT08: 3 phase fault on Hitchland to Finney 345 kV line(s). Four DeWind wind turbines associated with queue GEN-2006-044 at Hitchland 345 kV were tripped off due to over-frequency, at approximately 0.6 seconds into the simulation. SPP considers this a known issue unrelated to the units under study.
- The POI voltage can be maintained at the pre-fault level for the studied faults with MVAR output within the pro forma 95% power factor

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1 INTRODUCTION

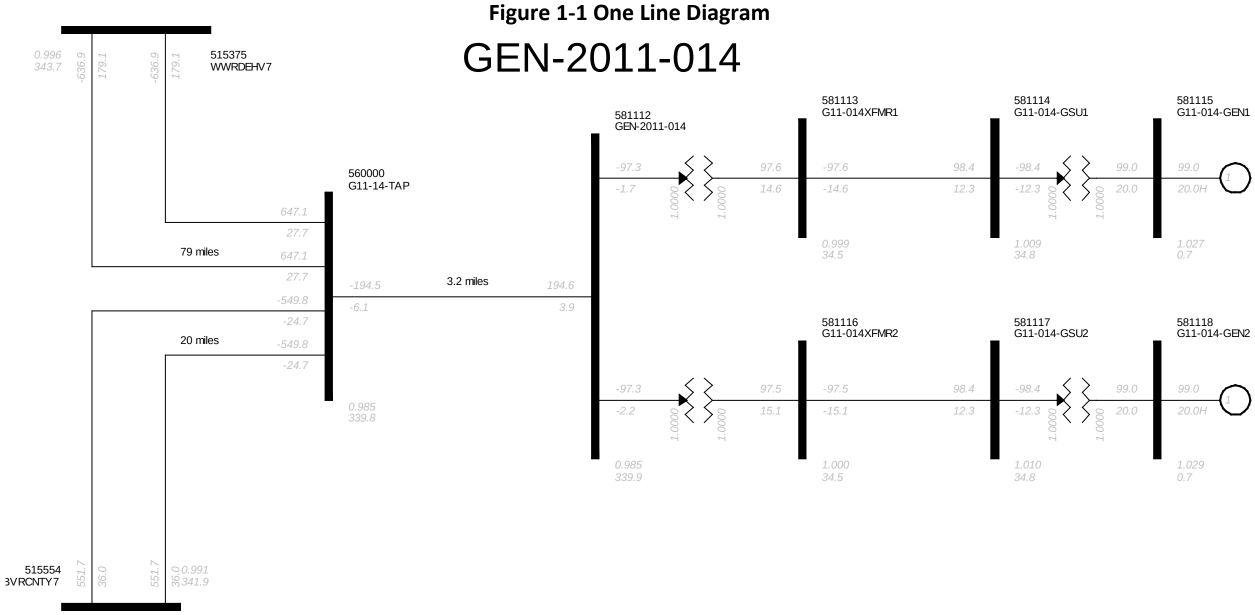
GEN-2011-014 (“Interconnection Customer”) has requested an Impact Restudy for Generator Modification through the Southwest Power Pool Tariff. The interconnection request will be studied at 100% of nameplate MW capacity. The interconnection request will be studied using generator manufacturer and configuration as described below.

Table 1-1-1 Generation Interconnection Requests

Request	Size (MW)	Wind Turbine Model	Point of Interconnection
GEN-2011-014	198.0	Vestas V117 3.3MW (581115, 581118)	Tap on Beaver to Woodward 345kV line (560000)

A one line diagram is shown in Figure 1-1.

Figure 1-1 One Line Diagram



2 METHODOLOGY

2.1 Study Assumptions

1. Quanta Technology ("The Consultant") was provided with three saved cases for this study:
    a. 2015 Summer Peak case (15SP),
    b. 2015 Winter Peak case (15WP), and
    c. 2025 Summer Peak case (25SP)
2. Each case has been built with the SPP footprint displaced by the new generation interconnection request(s) listed in Table 1-1.
3. The three study cases will also contain the prior queued projects listed in Table 2-1. As illustrated in Figure 1-1, these queued projects are represented in the power flow as one or two equivalent machines at the buses shown, with the MW output shown divided between them. Each such machine has an appropriately sized equivalent transformer up to the 34kV level and an equivalent 34.5 kV line to the substation bus. This representation was provided as a part of the power flow case.
4. Each saved case was built and tested using PSSE version 32.2.0.
5. The contingencies are described in the fault definitions listed in Table 2-2.
6. There should not be any special modeling required of line relays in these cases, except for the special modeling related to the wind-turbine tripping.
7. SPP provided the powerflow cases with all prior queued projects in the model. All study and previous queued information is considered CONFIDENTIAL.
8. The study was performed in accordance with "Southwest Power Pool Disturbance Performance Requirements" (Appendix A as appended to the scope).

Table 2-1 Prior Queued Projects

Request	Size (MW)	Wind Turbine Model Bus number	Point of Interconnection
GEN-2002-008	240	GE 1.5MW (523121, 523122, 523123)	Hitchland 345kV (523097)
GEN-2002-009	79.8	Suzlon 2.1MW (523201)	Hansford 115kV (523195)
GEN-2003-020	159	GE 1.5 MW (523941, 523942)	Carson Co. 115kV (523924)
GEN-2006-020S	20	D8.2 2.0MW (579138)	Tap on Hitchland – Sherman Tap 115kV line (560200)
GEN-2006-044	370	DeWind D9.2 2.0MW (523107, 522809, 522811, 522812)	Hitchland 345kV (523097)
GEN-2007-046	199.5	Vestas V100/V110 2.0MW (523170, 523171)	Hitchland 115kV (523093)
GEN-2008-047	300	GE 1.7MW (573506, 573510)	Beaver County 345kV (515554)
GEN-2010-001	300	GE 1.85MW (578545, 578548)	Beaver County 345kV (515554)
GEN-2010-014	358.8	Siemens SWT 2.3MW (576400, 576410)	Hitchland 345kV (523097)
GEN-2011-022	299	Siemens 2.3MW (581153, 581154)	Hitchland 345kV (523097)
ASGI-2011-002	10	DeWind D8.2 2.0MW (523354)	Herring 115kV (523359)
GEN-2013-030	298.2	Suzlon S97 2.1MW (583763, 583766)	Beaver County 345kV (515554)

.

2.2 Model Modifications by Consultant

G59REL protection models associated with four DeWind D9 wind turbines at Queue GEN-2006-044 tripped off on over-frequency (OF) for selected contingencies. Discussion with SPP personnel determined that this is a known problem not associated with the project under study.

2.3 Short circuit analysis

An analysis of three-phase (positive sequence) fault duty was performed on the 2025 summer peak case using Aspen ® software, extending five buses out from the point of interconnection of the study generator. A PSS®E RAWD file was imported for this purpose; zero sequence model data was not available.

2.4 Stability analysis

A stability analysis was performed simulating the contingencies listed in Table 2-3. Version 32 of the PSS®E software marketed by Siemens PTI was used for this analysis.

Fault clearing times were 5 cycles for all faults. If reclosing occurred, faulted transmission lines were reclosed into the fault 20 cycles after the initial clearing, then cleared and locked out after one more 5 cycle interval. Faulted transformers were not reclosed.

As the study project is a wind farm using induction, not synchronous, machines, the formal rotor angle oscillation damping requirements of Appendix A of the Scope did not apply. However rotor angles of synchronous machines over 100 MW in the monitored areas (numbers 520, 524, 525, 526, 531, 534 and 536) were plotted and checked for loss of synchronism or persistent oscillations.

Speed, electrical power output, reactive power output and terminal voltage were plotted for all of the queued wind projects listed in Table 2-1.

Table 2-3 Fault Descriptions

Cont. No.	Cont. Name	Description
1	FLT01-3PH	3 phase fault on the Beaver County (515554) to Hitchland (523097) 345kV line ckt1, near Beaver County. a. Apply fault at the Beaver County 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 c	FLT02-3PH	3 phase fault on the Beaver County (515554) to Hitchland (523097) 345kV line circuits 1&2, near Beaver County. a. Apply fault at the Beaver County 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 2	FLT03-3PH	3 phase fault on the G11-14-TAP (560000) to Beaver County (515554) 345kV line ckt1, near G11-14-TAP. a. Apply fault at the G11-14-TAP 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	FLT04-3PH	3 phase fault on the G11-14-TAP (560000) to Beaver County (515554) 345kV line ckt 1&2, near G11-14-TAP. a. Apply fault at the G11-14-TAP 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 1	FLT05-3PH	3 phase fault on the G11-14-TAP (560000) to Woodward (515375) 345kV line ckt1, near G11-14-TAP. a. Apply fault at the G11-14-TAP 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 2	FLT06-3PH	3 phase fault on the G11-14-TAP (560000) to Woodward (515375) 345kV line ckt 1&2, near G11-14-TAP. a. Apply fault at the G11-14-TAP 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.
7 2	FLT07-3PH	3 phase fault on the Hitchland (523097) to Finney (523853) 345kV line ckt1, near Hitchland. a. Apply fault at the Hitchland 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.
8	FLT08-3PH	3 phase fault on the Hitchland (523097) to Potter County (523961) 345kV line ckt1, near Hitchland. a. Apply fault at the Hitchland 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.

Cont. No.	Cont. Name	Description
9 1	FLT09-3PH	3 phase fault on the Hitchland (523097) 345kV to Hitchland (523095) 230kV/(523091) 13.2kV transformer ckt1, near Hitchland 345kV. a. Apply fault at the Hitchland 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
10	FLT10-3PH	3 phase fault on the Hitchland (523095) 230kV to Hitchland (523093) 115kV/(523092) 13.2kV transformer ckt1, near Hitchland 230kV. a. Apply fault at the Hitchland 230kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
11	FLT11-3PH	3 phase fault on the Finney (523853) to Holcomb (531449) 345kV line ckt1, near Finney. a. Apply fault at the Finney 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.
12	FLT12-3PH	3 phase fault on the Finney (523853) to Lamar (599950) 345kV line ckt1, near Finney. a. Apply fault at the Finney 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.
13	FLT13-3PH	3 phase fault on the Holcomb (531449) to Setab (531465) 345kV line ckt1, near Holcomb. a. Apply fault at the Holcomb 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.
14	FLT14-3PH	3 phase fault on the Holcomb (531449) to Buckner (531501) 345kV line ckt, near Holcomb. a. Apply fault at the Holcomb 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.
15	FLT15-3PH	3 phase fault on the Holcomb (531449) 345kV to Holcomb (531448) 115kV/(531450) 13.8kV transformer ckt1, near Holcomb 345kV. a. Apply fault at the Holcomb 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
16	FLT16-3PH	3 phase fault on the Potter County (523961) 345kV to Potter County (523959) 230kV/(523957) 13.2kV transformer ckt1, near Potter County 345kV. a. Apply fault at the Potter County 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
17	FLT17-3PH	3 phase fault on the Woodward (515375) to Border (515458) 345kV line ckt1, near Woodward. a. Apply fault at the Woodward 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.
18	FLT18-3PH	3 phase fault on the Woodward (515375) to Thistle (539801) 345kV line ckt1, near Woodward. a. Apply fault at the Woodward 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.

Cont. No.	Cont. Name	Description
19	FLT19-3PH	3 phase fault on the Woodward (515375) to Thistle (539801) 345kV line ckt 1&2, near Woodward. a. Apply fault at the Woodward 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.
20	FLT20-3PH	3 phase fault on the Woodward (515375) to G11-051-TAP (562075) 345kV line ckt1, near Woodward. a. Apply fault at the Woodward 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.
21	FLT21-3PH (2025SP only)	3 phase fault on the Woodward (515375) to G11-051-TAP (562075) 345kV line ckt 1&2, near Woodward. a. Apply fault at the Woodward 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.
22	FLT22-3PH	3 phase fault on the Woodward (515375) 345kV to Woodward (515376) 138kV/(515799) 13.8kV transformer ckt1, near Woodward 345kV. a. Apply fault at the Woodward 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
23	FLT23-3PH	3 phase fault on the Border (515458) to Tuco (525832) 345kV line ckt1, near Border. a. Apply fault at the Border 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.
24	FLT24-3PH	3 phase fault on the Thistle (539801) to Wichita (515375) 345kV line ckt1, near Thistle. a. Apply fault at the Thistle 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.
25	FLT25-3PH	3 phase fault on the Thistle (539801) to Wichita (515375) 345kV line ckt 1&2, near Thistle. a. Apply fault at the Thistle 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.
26	FLT26-3PH	3 phase fault on the Thistle (539801) to Clark County (539800) 345kV line ckt1, near Thistle. a. Apply fault at the Thistle 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.
27	FLT27-3PH	3 phase fault on the Thistle (539801) to Clark County (539800) 345kV line ckt 1&2, near Thistle. a. Apply fault at the Thistle 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.

Cont. No.	Cont. Name	Description
28	FLT28-3PH	3 phase fault on the Thistle (539801) 345kV to Thistle (539804) 138kV/(539802) 13.8kV transformer ckt1, near Thistle 345kV. a. Apply fault at the Thistle 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
29	FLT29-3PH (2015SP and 2015WP Only)	3 phase fault on the Tatonga (515407) to Northwest (514880) 345kV line ckt1, near Tatonga. a. Apply fault at the Tatonga 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.
30	FLT30-3PH (2025SP Only)	3 phase fault on the Tatonga (515407) to Mathewson (515497) 345kV line ckt1, near Tatonga. a. Apply fault at the Tatonga 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.
31	FLT31-3PH (2025SP Only)	3 phase fault on the Tatonga (515407) to Mathewson (515497) 345kV line ckt 1&2, near Tatonga. a. Apply fault at the Tatonga 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.
32	FLT32-3PH	3 phase fault on the Woodward EHV (515376) to Keenan (514000) 138kV line, near Woodward EHV. a. Apply fault at the Woodward EHV 138kV 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.
33	FLT33-1PH	Single phase fault and sequence like previous
34	FLT34-3PH	3 phase fault on the Woodward EHV (515376) to Woodward (514785) 138kV circuit 1 line, near Woodward EHV. a. Apply fault at the Woodward EHV 138kV 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.
35	FLT35-1PH	Single phase fault and sequence like previous
36	FLT36-3PH	3 phase fault on the Woodward EHV (515376) to Iodine (514796) 138kV line, near Woodward EHV. a. Apply fault at the Woodward EHV 138kV 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.
37	FLT37-1PH	Single phase fault and sequence like previous
38	FLT38-3PH	3 phase fault on the Hitchland (523095) to Ochiltree (523155) 230kV line ckt1, near Hitchland. a. Apply fault at the Hitchland 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.

Cont. No.	Cont. Name	Description
39	FLT39-1PH	Single phase fault and sequence like previous
40	FLT40-3PH	3 phase fault on the Hitchland (523095) to Moore County (523309) 230kV line ckt1, near Hitchland. a. Apply fault at the Hitchland 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.
41	FLT41-1PH	Single phase fault and sequence like previous
42	FLT42-1PH	Woodward 345kV Stuck Breaker a. Apply single phase fault at the Woodward (515375) 345kV bus on the Woodward to GEN-2011-051 Tap (562075) 345kV line ckt1. b. Wait 16 cycles, and then drop Woodward (515375) 345kV to Thistle (539801) 345kV ckt1. c. Trip Woodward to GEN-2011-051 Tap 345kV ckt1 and remove the fault.
43	FLT43-1PH	Beaver Co 345kV Stuck Breaker a. Apply single phase fault at the Beaver County (515554) 345kV bus on the Beaver County to GEN-2011-014 Tap (560000) 345kV line ckt1. b. Wait 16 cycles, and then drop Beaver County (515554) 345kV to Hitchland (523097) 345kV Ckt 1. c. Trip Beaver County to GEN-2011-014 Tap 345kV ckt1 and remove the fault.
44	FLT44-1PH	Hitchland 345kV Stuck Breaker a. Apply single phase fault at the Hitchland (523097) 345kV bus on the Hitchland – Beaver County (515554) 345kV line circuit 1. b. Wait 16 cycles, and then drop Hitchland (523097) 345kV to Hitchland (523095) 230kV/(523091) 13.2 transformer Ckt 1. c. Trip Hitchland to Beaver County 345kV ckt1and remove the fault.

2.5 Power factor analysis

A power factor analysis was performed for the interconnection request, using each of the three power flow models (2015 summer peak, 2015 winter peak, 2025 summer peak). The contingencies considered were those identified in Table 2-3 as three-phase and outaging a single line or transformer.

3 RESULTS

3.1 Short circuit analysis

The three-phase fault currents calculated by Aspen are shown in Table 3-1. The highest fault current noted is at bus 533040 EVANS N4 (138 kV), while the greatest increase is at Beaver County 345 kV. Locations exceeding 36,000 amps and 27,000 amps (i.e., 90% of the capabilities of 40 kA and 30 kA "preferred ratings" of circuit breakers, respectively) are highlighted.

Table 3-1 Fault current

Bus No	Bus Name	kV	From G11-14	Without Study Units	With Study Units	Delta Amps	Delta Pct
560000	G11-14-TAP	345	0	11847.7	12915.6	1067.9	9.01%
515554	BVRCNTY7	345	1	12367.5	13742.3	1374.8	11.12%
515375	WWRDEHV7	345	1	18988.0	19344.0	356.0	1.87%
573501	GEN-2008-047	345	2	10745.0	11753.5	1008.5	9.39%
578542	GEN-2010-001	345	2	10409.6	11350.4	940.8	9.04%
523097	HITCHLAND 7	345	2	13658.6	14529.4	870.8	6.38%
582019	GEN-2011-019	345	2	18967.8	19323.1	355.3	1.87%
582020	GEN-2011-020	345	2	18967.8	19323.1	355.3	1.87%
562075	G11-051-TAP	345	2	15859.1	16015.1	156.0	0.98%
515376	WWRDEHV4	138	2	24726.8	24877.5	150.7	0.61%
579351	GEN-2007-062	345	2	8311.3	8365.9	54.6	0.66%
539801	THISTLE7	345	2	15260.8	15302.3	41.5	0.27%
515458	BORDER 7	345	2	4909.0	4919.3	10.3	0.21%
523101	NOBLE_WND 7	345	3	13607.9	14471.8	863.9	6.35%
523112	NOVUS1 7	345	3	13446.3	14285.8	839.5	6.24%
573507	G08-047-HV-1	345	3	9375.3	10124.1	748.8	7.99%
576395	GEN-2010-014	345	3	10330.4	10805.8	475.4	4.60%
523095	HITCHLAND 6	230	3	13888.0	14302.3	414.3	2.98%
581148	GEN-2011-022	345	3	8597.7	8916.8	319.1	3.71%
583110	GEN-2011-051	345	3	15719.3	15872.5	153.2	0.97%
515407	TATONGA7	345	3	15581.2	15667.6	86.4	0.55%
514785	WOODWRD4	138	3	20039.1	20120.7	81.6	0.41%
523961	POTTER_CO 7	345	3	7654.1	7701.6	47.5	0.62%
523853	FINNEY 7	345	3	12785.6	12824.5	38.9	0.30%
579358	G07-062-HV-2	345	3	6376.7	6406.6	29.9	0.47%
515398	OUSPRT 4	138	3	9491.6	9512.3	20.7	0.22%
515394	KEENAN 4	138	3	8947.6	8964.9	17.3	0.19%

539804	THISTLE4	138	3	16276.1	16291.6	15.5	0.10%
539800	CLARKCOUNTY7	345	3	12291.2	12304.6	13.4	0.11%
532796	WICHITA7	345	3	24014.9	24028.3	13.4	0.06%
583090	GEN-2011-049	345	3	4449.9	4458.2	8.3	0.19%
514796	IODINE-4	138	3	7066.5	7074.5	8.0	0.11%
525832	TUCO_INT 7	345	3	13438.7	13441.0	2.3	0.02%
523093	HITCHLAND 3	115	4	17354.8	17545.7	190.9	1.10%
576396	G10-014-XFMR	115	4	12754.7	12940.9	186.2	1.46%
523103	NOBLE_WND 3	115	4	10339.4	10470.5	131.1	1.27%
522801	NOVUS-44	115	4	10244.8	10329.7	84.9	0.83%
523111	NOVUS1 3	115	4	8821.0	8887.3	66.3	0.75%
523959	POTTER_CO 6	230	4	20789.7	20854.5	64.8	0.31%
579253	GEN-2007-021	345	4	13000.5	13060.1	59.6	0.46%
515448	CRSRDSW7	345	4	11154.1	11197.3	43.2	0.39%
531449	HOLCOMB7	345	4	12976.2	13014.9	38.7	0.30%
515497	MATHWSN7	345	4	28604.7	28639.2	34.5	0.12%
523155	OCHILTREE 6	230	4	4264.7	4294.5	29.8	0.70%
579268	GEN-2007-044	345	4	8829.6	8855.9	26.3	0.30%
523309	MOORE_CNTY 6	230	4	6706.2	6730.2	24.0	0.36%
524296	SPNSPUR_WND7	345	4	4700.6	4716.5	15.9	0.34%
531469	SPERVIL7	345	4	14140.3	14154.5	14.2	0.10%
539803	IRONWOOD7	345	4	13669.0	13682.3	13.3	0.10%
539638	FLATRDG3	138	4	14662.9	14674.9	12.0	0.08%
523118	BUFF_DUNES 7	345	4	6922.4	6933.1	10.7	0.15%
583370	GEN-2012-024	345	4	9786.3	9794.7	8.4	0.09%
514782	WODWRD 2	69	4	12091.6	12100.0	8.4	0.07%
582008	GEN-2011-008	345	4	9863.1	9871.3	8.2	0.08%
515785	WINDFRM4	138	4	18440.4	18447.8	7.4	0.04%
533040	EVANS N4	138	4	40732.0	40739.0	7.0	0.02%
532791	BENTON 7	345	4	18946.6	18950.7	4.1	0.02%
514787	DEWEY 4	138	4	6530.2	6533.5	3.3	0.05%
525830	TUCO_INT 6	230	4	23854.7	23857.6	2.9	0.01%
532798	VIOLA 7	345	4	13233.8	13236.5	2.7	0.02%
515363	CENT 4	138	4	3236.5	3238.1	1.6	0.05%
599950	LAMAR7	345	4	2455.6	2457.1	1.5	0.06%
532771	RENO 7	345	4	11894.8	11896.2	1.4	0.01%
532768	EMPEC 7	345	4	16415.0	16415.4	0.4	0.00%
526936	YOAKUM_345	345	4	9329.8	9330.0	0.2	0.00%
511456	O.K.U.-7	345	4	4805.6	4805.7	0.1	0.00%

576407	G10-014-XF-2	115	5	12029.3	12192.9	163.6	1.36%
522803	NOVUS-2	115	5	10229.2	10313.7	84.5	0.83%
576397	G10-014-XF-1	115	5	8931.8	9015.4	83.6	0.94%
523131	NBLWND-HV3 3	115	5	7806.0	7878.9	72.9	0.93%
523979	HARRNG_EST 6	230	5	26658.6	26707.2	48.6	0.18%
523195	HANSFORD 3	115	5	10175.8	10223.1	47.3	0.46%
524010	ROLLHILLS 6	230	5	19743.0	19781.2	38.2	0.19%
523090	TEXAS_CNTY 3	115	5	8350.0	8385.0	35.0	0.42%
522804	NOVUS-44-3	115	5	7448.8	7483.7	34.9	0.47%
523130	NBLWND-HV2 3	115	5	5059.3	5087.8	28.5	0.56%
579272	G07-044-HV-2	345	5	8785.3	8811.3	26.0	0.30%
522802	NOVUS-1	115	5	5781.4	5804.9	23.5	0.41%
514901	CIMARON7	345	5	29964.1	29986.6	22.5	0.08%
523160	FRISCO_WND 3	115	5	6889.7	6910.8	21.1	0.31%
523154	OCHILTREE 3	115	5	5693.0	5713.4	20.4	0.36%
523308	MOORE_E 3	115	5	10540.1	10559.7	19.6	0.19%
514880	NORTWST7	345	5	29523.3	29542.8	19.5	0.07%
523174	GOODWELLWND3	115	5	7490.3	7509.2	18.9	0.25%
579480	GEN-2008-124	230	5	19765.9	19784.3	18.4	0.09%
531501	BUCKNER7	345	5	10815.4	10830.0	14.6	0.13%
562701	GEN-2006-006	345	5	14028.2	14042.1	13.9	0.10%
531448	HOLCOMB3	115	5	23808.4	23822.1	13.7	0.06%
539809	IRONWOOD 1 7	345	5	13565.7	13578.7	13.0	0.10%
531465	SETAB 7	345	5	7941.4	7949.6	8.2	0.10%
524267	BUSHLAND 6	230	5	10075.5	10083.6	8.1	0.08%
520999	MOORLND4	138	5	18752.5	18759.6	7.1	0.04%
533041	EVANS S4	138	5	40650.6	40657.5	6.9	0.02%
582708	G-2011-008-1	345	5	8839.3	8845.7	6.4	0.07%
539695	SPEARVL6	230	5	12699.8	12705.8	6.0	0.05%
539631	FLATRWD3	138	5	9679.4	9684.7	5.3	0.05%
560242	G11-017-TAP	345	5	9887.6	9892.9	5.3	0.05%
514715	WOODRNG7	345	5	16242.8	16247.5	4.7	0.03%
582016	GEN-2011-016	345	5	7628.7	7632.6	3.9	0.05%
581005	GEN-2011-007	345	5	9308.9	9312.2	3.3	0.04%
521096	WOODWRD2	69	5	10398.6	10401.9	3.3	0.03%
532986	BENTON 4	138	5	28311.1	28314.2	3.1	0.01%
533390	MAIZEW 4	138	5	27541.0	27544.0	3.0	0.01%
539674	BARBER 4	138	5	8041.1	8044.0	2.9	0.04%
521065	TALOGA 4	138	5	6544.0	6546.9	2.9	0.04%

525840	ANTELOPE_1 6	230	5	23655.3	23658.1	2.8	0.01%
523869	CHAN/TASCOS6	230	5	3849.7	3852.3	2.6	0.07%
525461	NEWHART 6	230	5	11006.2	11008.7	2.5	0.02%
532794	ROSEHIL7	345	5	18213.5	18216.0	2.5	0.01%
539759	SPRVL 3	115	5	11710.7	11713.2	2.5	0.02%
514781	CEDARAV2	69	5	6127.4	6129.5	2.1	0.03%
533065	SG12COL4	138	5	22475.2	22477.3	2.1	0.01%
533075	VIOLA 4	138	5	20927.0	20929.1	2.1	0.01%
525213	SWISHER 6	230	5	10383.1	10385.1	2.0	0.02%
533416	RENO 3	115	5	30182.2	30184.2	2.0	0.01%
515543	RENFROW7	345	5	12002.4	12004.4	2.0	0.02%
514776	NEWGRTP2	69	5	5833.1	5835.0	1.9	0.03%
525524	TOLK_EAST 6	230	5	29408.0	29409.1	1.1	0.00%
539668	HARPER 4	138	5	5695.0	5696.0	1.0	0.02%
525828	TUCO_INT 3	115	5	20249.3	20250.2	0.9	0.00%
515786	FPLWIND4	138	5	6099.2	6100.0	0.8	0.01%
511468	L.E.S.-7	345	5	11454.7	11455.5	0.8	0.01%
514822	SOUTHRD4	138	5	3854.8	3855.5	0.7	0.02%
515390	TLGAWND4	138	5	2948.3	2948.9	0.6	0.02%
526337	JONES 6	230	5	25137.3	25137.8	0.5	0.00%
532792	FR2EAST7	345	5	6246.1	6246.6	0.5	0.01%
532769	LANG 7	345	5	16227.8	16228.2	0.4	0.00%
526161	CARLISLE 6	230	5	14315.8	14316.2	0.4	0.00%
532797	WOLFCRK7	345	5	14750.7	14751.1	0.4	0.00%
532773	SUMMIT 7	345	5	10633.1	10633.5	0.4	0.00%
583340	GEN-2012-020	230	5	9266.4	9266.7	0.3	0.00%
526935	YOAKUM 6	230	5	18633.4	18633.6	0.2	0.00%
532770	MORRIS 7	345	5	12354.9	12355.0	0.1	0.00%
532774	SWISVAL7	345	5	16139.7	16139.8	0.1	0.00%
527896	HOBBS_INT 7	345	5	9205.1	9205.1	0.0	0.00%

3.2 Stability analysis

Plots of the dynamic response of the study unit for the faults described in Table 2-3 are included in Appendix A of this report. This Appendix is subdivided into parts for 15 SP, 15 WP and 25 SP conditions. Appendix B, provided as a separate document, plots the rotor angles of all synchronous machines over 100 MW in the monitored areas (numbers 520, 524, 525, 526, 531, 534 and 536) as well as the speed, electrical power output, reactive power output and terminal voltage for all of the queued wind projects listed in Table 2-1. The plots for queued wind projects are plotted by turbine vendor and model; this was done because the vendor-supplied dynamic ("user") models have different units of measure for turbine speed.

- DeWind D8 and D9
- GE 1.5 MW
- GE 1.7 and 1.85 MW
- Siemens
- Suzlon
- Vestas 2.0
- Vestas 100 and 117

All units monitored had acceptable response, neither pulling out, tripping, nor exhibiting undamped variations, with the exception of the following. There were no material differences between the 15SP, 15WP and 25SP simulations.

3.2.1 Contingencies presenting special issues

3.2.1.1 Contingency FLT06: 3 phase fault on the G11-14 TAP to Woodward 345 kV lines 1 & 2

The study unit's response to this fault is plotted on page 6 of each part of Appendix A. Speed, electrical power and reactive power output, and terminal voltage fluctuate significantly at most of the queued wind farm projects tracked following the final switching steps modeled and terminal voltage not only fluctuates but gradually declines toward the tripping level. This is a very severe contingency, a three-phase fault at the POI of GEN2011-014 tripping two lines of four lines, then reclosing, tripping again and locking out. We are advised by SPP that past studies have revealed stability issues for this contingency, but that they can be mitigated by curtailing generation during line outages.

3.2.1.2 Contingencies FLT07 and FLT08: 3 phase fault on Hitchland to Finney 345 kV line(s)

Four DeWind wind turbines associated with queue GEN-2006-044 have a POI at Hitchland 345 kV. (See plots on pages 85 and 99 of each part of Appendix B.) These units were tripped off by their G59REL protection models due to over-frequency, at approximately 0.6 seconds into the simulation. SPP considers this a known issue. Several corrective strategies, discussed in Appendix C, were attempted to enable these wind turbines to ride through the contingencies without tripping and allow valid evaluation of the response of the system as a whole.

In any case, the unit under study is not responsible for this problem.

3.3 Power factor analysis

Table 3-2 tabulates the VAR injections and power factors as measured at the 345 kV POI of the plant. Yellow highlighting indicates the lowest power factor (greatest VARs drawn from the 345 kV POI) , and blue highlighting indicates the highest power factor (least VARs). Gray shading indicates cases having a power factor below 70.71%, equivalent to requiring more MVAR than the MW output of the unit. Asterisks indicate cases requiring adjustments to obtain convergence.

- The 15 SP power flow case for FLT20 for GEN-2011-014 required locking the phase shifting transformers at Whiteshell (on the Ontario – Manitoba interface) to obtain convergence.
- The 15 WP power flows for FLT10 and FLT38 required minor changes to converge:
    - 15 WP FLT10 converged when one capacitor at Goodwell Wind was locked on.
    - 15 WP FLT38 converged when OCHILTREE transformer tap locked.
- Tatonga to Mathewson, the line faulted in FLT30, is not in the 15 SP and 15 WP cases. Tatonga to Northwest, faulted in FLT29, is not in the 25 SP case. Those faults were not simulated for the power factor analysis for these seasons.

Key findings of the power factor analysis are:

- An interconnection customer is required to maintain the standard pro-forma power factor requirement of 95% leading (absorbing) to 95% lagging (supplying) at the point of interconnection. This may require capacitor banks or other reactive compensation, depending on the customer's detailed design of the collector and lead line system.
- The unloaded collector system injects MVAR into the POI, the amount dependent upon the POI bus voltage. Under summer 2015 conditions the 34.5 kV collector system for the turbines modeled as machine 1 injects 3.3 MVAR into its stepup transformer, while the grid for machine 2 injects 3.9 MVAR. The radial 345 kV line from the substation to the tap injects another 2.8 MVAR, for a total of 10.0 MVAR.
- The POI voltage can be maintained at the pre-fault level for the studied faults with MVAR output within the pro forma 95% power factor.

Table 3-2 Power factor analysis results at GEN-2011-014 POI

	MVAR			Power Factor (pu		
FAULT	15SP	15WP	25SP	15SP	15WP	25SP
FLT01-3PH	3.3	9.5	-1.3	0.9999	0.9989	1.0000
FLT03-3PH	6.2	12.5	1.6	0.9995	0.9981	1.0000
FLT05-3PH	16.3	23.4	13	0.9967	0.9933	0.9979
FLT07-3PH	40.3	53.0	26.5	0.9805	0.9669	0.9911
FLT08-3PH	15.9	22.2	10.1	0.9969	0.9940	0.9987
FLT09-3PH	2.2	8.1	-2.5	0.9999	0.9992	0.9999
FLT10-3PH	2.6	7.3	-3.7	0.9999	0.9993	0.9998
FLT11-3PH	42.6	42.6	28.5	0.9783	0.9783	0.9898
FLT12-3PH	0.2	8.3	-4.8	1.0000	0.9991	0.9997
FLT13-3PH	6.0	11.8	1.0	0.9996	0.9983	1.0000
FLT14-3PH	14.3	19.3	10.5	0.9975	0.9954	0.9986
FLT15-3PH	-0.4	5.0	-5.5	1.0000	0.9997	0.9996
FLT16-3PH	13.3	19.6	7.6	0.9978	0.9953	0.9993
FLT17-3PH	5.5	9.8	-0.9	0.9996	0.9988	1.0000
FLT18-3PH	-0.4	6	-5.4	1.0000	0.9996	0.9996
FLT20-3PH	8.7	14.5	-1.8	0.9991	0.9974	1.0000
FLT22-3PH	0.7	7.1	-4.0	1.0000	0.9994	0.9998
FLT23-3PH	1.9	6.2	-3.5	1.0000	0.9995	0.9998
FLT24-3PH	-0.4	6.0	-5.4	1.0000	0.9996	0.9996
FLT26-3PH	3.2	9.6	-2.0	0.9999	0.9989	0.9999
FLT28-3PH	0.3	7.0	-4.3	1.0000	0.9994	0.9998
FLT29-3PH	0.8	6.3	#N/A	1.0000	0.9995	#N/A
FLT30-3PH	#N/A	#N/A	-4.7	#N/A	#N/A	0.9997
FLT32-3PH	0.7	7.1	-4.0	1.0000	0.9994	0.9998
FLT34-3PH	2.4	8.6	-3.3	0.9999	0.9991	0.9999
FLT36-3PH	1.1	7.6	-4.0	1.0000	0.9993	0.9998
FLT38-3PH	2.9	9.1	-2.6	0.9999	0.9990	0.9999
FLT40-3PH	3.8	10.7	0.3	0.9998	0.9986	1.0000

- 15 WP FLT10 converged when one capacitor at Goodwell Wind was locked on.
- 15 WP FLT38 converged when OCHILTREE transformer tap were locked.
- 15 SP FLT20 converged when phase shifters at Whiteshell were locked.

Regulating the POI voltage to pre-contingency levels in the study cases, the most lagging scenario (FLT11-3PH, Summer 2015) require GEN-2011-014 to supply 201 MW and 53 MVAR at the generator buses (0.9669 lagging power factor), while the most leading scenario (FLT15-3PH, Summer 2025) requires GEN-2011-014 to supply 201 MW and absorb 5.5 MVAR at the generator buses (0.9996 leading power factor), which are both well within the ± 0.95 power factor capabilities of the turbines.

4 CONCLUSIONS

4.1 Short circuit analysis

The highest fault current noted is at bus 533040 EVANS N4 (138 kV), while the greatest increase is at Beaver County 345 kV.

No location experienced an increase in fault current sufficient to require circuit breakers to be changed from one "preferred rating" to a higher one.

4.2 Stability analysis

All units monitored had acceptable response, neither pulling out, tripping, nor exhibiting undamped variations, with the exception of the following.

- Contingency FLT06: 3 phase fault on the G11-14 TAP to Woodward 345 kV lines 1 & 2
- Contingencies FLT07 and FLT08: 3 phase fault on Hitchland to Finney 345 kV line(s)

The former is a very severe contingency and stability issues have been noted in previous studies. It has been found that they can be mitigated by curtailing generation during outages of either G11-14 tap to Woodward 345 kV line.

In contingencies FLT07 and FLT08, four DeWind wind turbines associated with queue GEN-2006-044 at Hitchland 345 kV were tripped off by their G59REL protection models due to over-frequency, at approximately 0.6 seconds into the simulation. SPP considers this a known issue unrelated to the units under study.

There were no material differences between the 15SP, 15WP and 25SP simulations.

4.3 Power factor analysis

The POI voltage can be maintained at the pre-fault level for the studied faults with MVAR output within the pro forma 95% power factor.

4.4 Summary

There are no fault current issues associated with the unit. The stability issues seen are known problems, either manageable by redispatch during line outages or associated with the protection module of units elsewhere.

APPENDIX A -- PLOTS OF SPEED, PELEC, QELEC, ETERM OF THE STUDY UNIT

15 SP Cases

15 WP Cases

25 SP Cases

APPENDIX B -- PLOTS OF RESPONSE OF OTHER QUEUED UNITS AND MAJOR SYNCHRONOUS MACHINES (REDACTED)

Plots are provided for 15 SP, 15 WP and 25 SP cases (approximately 570 pages each).