Southwest Power Pool

GEN-2010-001
Impact Restudy for
Generator Modification
(Turbine Change)

SPP Generation Interconnection Studies

GEN-2010-001

September 2013

Executive Summary

The GEN-2010-001 interconnection customer has requested a system impact restudy to determine the effects of changing wind turbine generators from the previously studied Suzlon S88 2.1 MW wind turbine generators to the Vestas V100 VCSS 2.0 MW wind turbine generators. Quanta Technology, LLC was commissioned to perform this restudy and its report of the results is attached.

In this restudy the project uses one hundred fifty (150) Vestas V100 VCSS 2.0 MW wind turbine generators for an aggregate power of 300.0MW. The point of interconnection (POI) for GEN-2010-001 is at the proposed Beaver County 345 kV Substation in Beaver County, OK. The interconnection restudy request shows that the Vestas V100 VCSS 2.0MW wind turbine generators will have a reactive capability of 0.98 lagging (providing VARS) and 0.96 leading (absorbing VARS) power factor.

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 V100 VCSS 2.0 MW 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.

A power factor analysis was performed in this study. The facility will be required to maintain a 95% lagging (providing VARs) and 95% leading (absorbing VARs) power factor at the point of interconnection. Due to limited reactive capabilities of the Vestas wind turbines, GEN-2010-001 will need approximately 75 MVAR additional capacitive support to meet the 0.95 leading power factor at the POI. Approximately 12 MVAR of additional inductive support is required in order to compensate for the collector system and transmission line charging effects at the POI when GEN-2010-001 is at low wind or no wind conditions.

With the assumptions outlined in this report and with all the required network upgrades from the GEN-2010-001 GIA in place, GEN-2010-001 with the Vestas V100 VCSS 2.0 MW wind turbine generators should be able to reliably interconnect to the SPP transmission grid.

Nothing in this study should be construed as a guarantee of transmission service. If the customer wishes to obtain deliverability to a specific customer, a separate request for transmission service shall be requested on Southwest Power Pool’s OASIS by the Customer.

GEN-2010-001 System Impact Restudy (Vestas 2.0 MW)

September 13, 2013

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EXECUTIVE SUMMARY

The Southwest Power Pool (SPP), on behalf of a generation interconnection customer, desires a definitive interconnection system impact restudy for a generator interconnection in northwest Oklahoma near Woodward:

- GEN-2010-001. 300 MW windfarm using Vestas VCSS 2.0 MW units connected to a tap of the Hitchland to Woodward 345kV line at the Beaver County Substation.

There are 10 previously queued generators associated with this interconnection request.

SPP requested a stability analysis and power factor analysis for the wind farm in GEN-2010-001. The power factor analysis included the determination of the reactive compensation required to meet a 95% lag/lead power factor at the POI and the compensation needed for zero VAR injection at the POI when GEN-2010-001 is off-line. SPP did not request an Available Transfer Capability (ATC) study as part of this study.

GEN-2010-001 was found to be stable for all conditions studied. The wind turbine generators in GEN-2010-001 have the capability of pre-contingency voltage recovery and the post fault voltage recovery was found to be within the criterion of 0.7 PU to 1.2 PU.

Low Voltage Ride Through (LVRT) analysis shows no generators tripping offline due to low voltage.

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

Power factor analysis indicates that GEN-2010-001 will need to provide leading reactive compensation at the POI under base case and a majority of contingency conditions to maintain voltage at the POI at a 1.00 PU voltage schedule. The power factor analysis identified the need for reactive power at the POI to be between 94.76% leading and 96.6% lagging under the contingency conditions modeled. No single element contingencies tested will require the contribution of reactive power from GEN-2010-001 to exceed a net power factor of 95% lagging to 95% leading at the POI. The power factor at the POI was slightly lower than 95% leading to hold 1.0 PU for the double circuit outage of the Beaver Co to Hitchland 345kV circuits.

GEN-2010-001, which utilizes Vestas turbines with limited VAR capability, will need approximately 75 MVAR of additional capacitive support to meet the 0.95% lagging power factor at the POI. No additional compensation is required to meet 95% leading at the POI. A total of 12.2 MVAR of additional inductive support would be required in order to compensate for the collector system and lead line charging when GEN-2010-001 is off-line such that the VAR flow at the POI is zero.

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1. INTRODUCTION

The Southwest Power Pool (hereafter referred to as SPP) commissioned Quanta Technology to restudy the impact of a GEN-2010-001. GEN-2010 is in northwest Oklahoma in Beaver County.

The site studied is:

- GEN-2010-001. 300 MW windfarm using Vestas VCSS 2.0 MW units connected to the Beaver County Substation in the Woodward to Hitchland 345kV line in Beaver County Oklahoma.

SPP did not request an Available Transfer Capability (ATC) study.

SPP requested a stability analysis for all of the generation and a power factor analysis for the windfarm in GEN-2010-001. Quanta Technology performed a dynamics study and a power factor study utilizing SPP's list of faults as follows:

1. Determine the ability of the generators to remain in synchronism following three phase and single line to ground faults.
2. Determine the ability of the wind farm to meet FERC Order 661A (low voltage ride through and wind farm recovery to pre-fault voltage) with and without additional reactive power support.
3. Determine the amount of reactive compensation to be supplied by the wind farm facility as determined by a proxy VAR generator modeled at the Point of Interconnection (POI) to maintain a scheduled bus voltage of 1.0 PU for the transmission line and transformer outages specified in the GEN-2010-001 restudy.
4. Determine the amount of reactive compensation required to meet a 95% lag/lead power factor at the POI.
5. Determine the amount of reactive compensation such that the VAR flow at the POI was zero when GEN-2010-001 is off-line.

The results of the study are given in the following sections.

2. STUDY METHODOLOGY

SPP provided 2014 summer peak and 2014 winter peak load flow cases in PSS/E format. Table 2-1 below shows the total demand and generation in the monitored areas.

Table 2-1 Description of Study Areas

Area #	Area Name	2014 Summer Peak		2014 Winter Peak	
		Load (MW)	Generation (MW)	Load (MW)	Generation (MW)
520	AEPW	10,448.1	9,430.4	7,975.4	7,083.3
524	OKGE	6,550.7	7,301.1	4,603.7	4,993.1
525	WFEC	1,449.0	1,278.5	1,334.6	1,082.2
526	SPS	6,136.2	8,233.4	4,594.2	6,055.9
527	OMPA	371.6	44.1	210.9	169.6
531	MIDW	391.8	228.5	282.2	228.5
534	SUNC	1,201.6	1,456.4	777.6	997.0
536	WERE	5,916.4	5,857.4	3,943.2	4,247.4

2.1 POWER FACTOR ANALYSIS

The wind turbine generators of GEN-2010-001 were modeled off-line and replaced by a 300 MW proxy generator at the 345kV POI. The G08-047 windfarm, which shares a common POI with GEN-2010-001, was also modeled off-line and replaced by a second 300 MW proxy generator at the 345kV POI. A high capacity continuously variable VAR generator with a voltage schedule of 1.0 PU was modeled at the POI. The reactive capability requirements at the POI were determined for the list of contingencies shown in

Table 2-2 and allocated to GEN-2010-001 on a pro-rata basis based on the MW output of the windfarms connected at the POI.

The Vestas 2.0MW wind turbine generators have a power factor range from 0.98 lagging (supplying VARS) to 0.96 leading (absorbing VARS). The units were set to maximum lag and then maximum lead to determine if additional reactive compensation was required to meet the 95% power factor requirements at the POI. Reactors and capacitors were added to the 34.5kV collector buses until the power factor at the POI was equal to 95% leading or lagging respectively.

The reactive compensation required to off-set the charging of the collector system and lead line was calculated by modeling GEN-2010-001 off-line and calculating the size of reactors placed at the 34.5kV collector buses which would result in zero VAR flow at the 345kV POI. This reactive compensation was not included, that is it was modeled off-line, in the calculation of reactive requirements for the base case or contingency conditions studied.

Table 2-2 Steady State Contingency Descriptions

Cont. No.	Description
FLT01	Outage the Beaver County (580500) to Hitchland (523097) 345kV
FLT03	Outage the Beaver County (580500) to Woodward (515375) 345kV
FLT05	Outage the Hitchland (523097) to Finney (523853) 345kV
FLT07	Outage the Hitchland (523097) to Potter County (523961) 345kV
FLT09	Outage the Woodward (515375) to Tatonga (515407) 345kV
FLT11	Outage the Woodward (515375) to Border (515458) 345kV
FLT13	Outage the Woodward (515375) to Thistle (539801) 345kV
FLT15	Outage the Border (515458) to Tuco Int (525832) 345kV
FLT17	Outage the Finney (583853) to Holcomb (531449) 345kV
FLT19	Outage the Finney (583853) to Lamar (599950) 345kV
FLT21	Outage the Hitchland (523095) to Ochiltree (523155) 230kV
FLT23	Outage the Hitchland (523095) to Moore County (523309) 230kV
FLT25	Outage the Moore County (523309) to Potter County (523959) 230kV
FLT27	Outage the Woodward (515376) to Woodward (514785) 138kV
FLT29	Outage the Woodward (515376) to Iodine (514796) 138kV
FLT31	Outage the Woodward (515376) to Keenan (515394) 138kV
FLT33	Outage the Woodward (515376) to OU Spirit (515398) 138kV
FLT35	Outage the Hitchland (523093) to Texas County (523090) 115kV
FLT37	Outage the Hitchland (523093) to DWS Frisco (523160) 115kV
FLT39	Outage the Hitchland (523093) to Hansford (523195) 115kV
FLT41	Outage the Hitchland 345kV (523097) to the Hitchland 230kV (523095)/13.2kV (523091) transformer
FLT42	Outage the Woodward 345kV (515375) to the Woodward 138kV (515376)/13.8kV (515799) transformer
FLT43	Outage the Potter County 345kV (523961) to the Potter County 230kV (523959)/13.2kV

Cont. No.	Description
	(523957) transformer
FLT44	Outage the Ochiltree 230kV (523155) to the Ochiltree 115kV (523154)/13.2kV (523151) transformer
FLT45	Outage the Moore County 230kV (523309) to the Moore County 115kV (523308)/13.2kV (523302) transformer
FLT46	Double circuit outage on Beaver County (580500) to Hitchland (523097) 345kV line, ckt1&2
FLT47	Double circuit outage on Beaver County (580500) to Woodward (515375) 345kV line, ckt1&2
FLT48	Double circuit outage on Woodward (515375) to Thistle (539801) 345kV line, ckt1&2

2.2 DYNAMIC ANALYSIS

The study areas shown in Table 2-1 were monitored in the dynamic analysis.

The transmission line and transformer faults were simulated and synchronous machine rotor angles and wind turbine generator speeds were monitored to check whether synchronism is maintained following fault removal.

All line faults were simulated in the following fashion:

1. Apply fault to a line near one of its buses.
2. Clear fault after five (5) cycles by tripping the faulted line.
3. Wait 20 cycles and reclose the tripped line into the fault.
4. Leave fault on for five (5) cycles, then trip the line and remove the fault.

Note that the above line faults were simulated in three phase (3PH) and single line to ground (1PH) versions as specified in the contingency list provided.

All transformer and double-circuit faults were simulated in the following fashion:

1. Apply fault at the identified bus terminals of the transformer or double circuit lines.
2. Clear fault after five (5) cycles by tripping the faulted transformer or double circuit.

Note that no reclosing was considered for the above transformer and double-circuit faults.

Table 2-3 Fault Descriptions

Fault No.	Description
1,2	Fault the Beaver County (580500) to Hitchland (523097) 345kV (3phase, 1phase)
3,4	Fault the Beaver County (580500) to Woodward (515375) 345kV (3phase, 1phase)
5,6	Fault the Hitchland (523097) to Finney (523853) 345kV (3phase, 1phase)
7,8	Fault the Hitchland (523097) to Potter County (523961) 345kV (3phase, 1phase)
9,10	Fault the Woodward (515375) to Tatonga (515407) 345kV (3phase, 1phase)
11,12	Fault the Woodward (515375) to Border (515458) 345kV (3phase, 1phase)
13,14	Fault the Woodward (515375) to Thistle (539801) 345kV (3phase, 1phase)
15,16	Fault the Border (515458) to Tuco Int (525832) 345kV (3phase, 1phase)
17,18	Fault the Finney (583853) to Holcomb (531449) 345kV (3phase, 1phase)
19,20	Fault the Finney (583853) to Lamar (599950) 345kV (3phase, 1phase)
21,22	Fault the Hitchland (523095) to Ochiltree (523155) 230kV (3phase, 1phase)
23,24	Fault the Hitchland (523095) to Moore County (523309) 230kV (3phase, 1phase)
25,26	Fault the Moore County (523309) to Potter County (523959) 230kV (3phase, 1phase)
27,28	Fault the Woodward (515376) to Woodward (514785) 138kV (3phase, 1phase)
29,30	Fault the Woodward (515376) to Iodine (514796) 138kV (3phase, 1phase)
31,32	Fault the Woodward (515376) to Keenan (515394) 138kV (3phase, 1phase)
33,34	Fault the Woodward (515376) to OU Spirit (515398) 138kV (3phase, 1phase)
35,36	Fault the Hitchland (523093) to Texas County (523090) 115kV (3phase, 1phase)
37,28	Fault the Hitchland (523093) to DWS Frisco (523160) 115kV (3phase, 1phase)
39,40	Fault the Hitchland (523093) to Hansford (523195) 115kV (3phase, 1phase)
41	Fault the Hitchland 345kV (523097) to the Hitchland 230kV (523095)/13.2kV (523091) transformer (3 phase)
42	Fault the Woodward 345kV (515375) to the Woodward 138kV (515376)/13.8kV (515799) transformer (3 phase)
43	Fault the Potter County 345kV (523961) to the Potter County 230kV (523959)/13.2kV (523957) transformer (3 phase)
44	Fault the Ochiltree 230kV (523155) to the Ochiltree 115kV (523154)/13.2kV (523151) transformer (3 phase)
45	Fault the Moore County 230kV (523309) to the Moore County 115kV (523308)/13.2kV (523302) transformer (3 phase)
46	Double circuit fault on Beaver County (580500) to Hitchland (523097) 345kV line, ckt1&2 (3 phase)
47	Double circuit fault on Beaver County (580500) to Woodward (515375) 345kV line, ckt1&2 (3 phase)
48	Double circuit fault on Woodward (515375) to Thistle (539801) 345kV line, ckt1&2 (3 phase)

In order to simulate 1PH faults, equivalent reactance[1] were determined to be applied at the faulted buses. Table 2-4 presents equivalent reactors used in the transient stability study.

Table 2-4 Equivalent Reactors (MVAR) for Single Line to Ground Faults

Fault No.	Faulted Bus #	2014 Summer Peak	2014 Winter Peak
2,4	580500	-4790	-4742
6,8	523097	-5220	-5200
10,12,14	515375	-6105	-5921
16	515458	-1990	-1958
18,20	523853	-4158	-4104
22,24	523095	-3432	-3445
26	523309	-1685	-1743
28,30,32,34	515376	-3897	-3825
36,38,40	523093	-1728	-1732

Another important aspect of the dynamic analysis was to check FERC Order 661A compliance. The turbine generators were monitored to determine whether they stayed connected to the grid (Low Voltage Ride Through - LVRT) following the faults defined in Table 3-1. The wind farm capability of post-fault voltage recovery at the POI was also checked.

3. PROJECT DESCRIPTION

Following is a table of the proposed generators in Group 8.

Table 3-1: Points of Interconnection for Group 8

Request	Size (MW)	Turbine Model	Point Of Interconnection		
			Common Name	Bus #	Name in Model
GEN-2010-001	300	Vestas VCSS	Beaver County	580500	BEAVER CO 345

[1] The equivalent reactance were calculated when the voltage at the faulted bus dropped to 0.60 pu.

All of the one-line diagrams use this following color code for nominal voltages:

Red **345 kV**

Black **lower voltage levels**

Following is the one-line diagram of the interconnection GEN-2010-001. All voltages and line flows are from the 2014 summer peak base case.

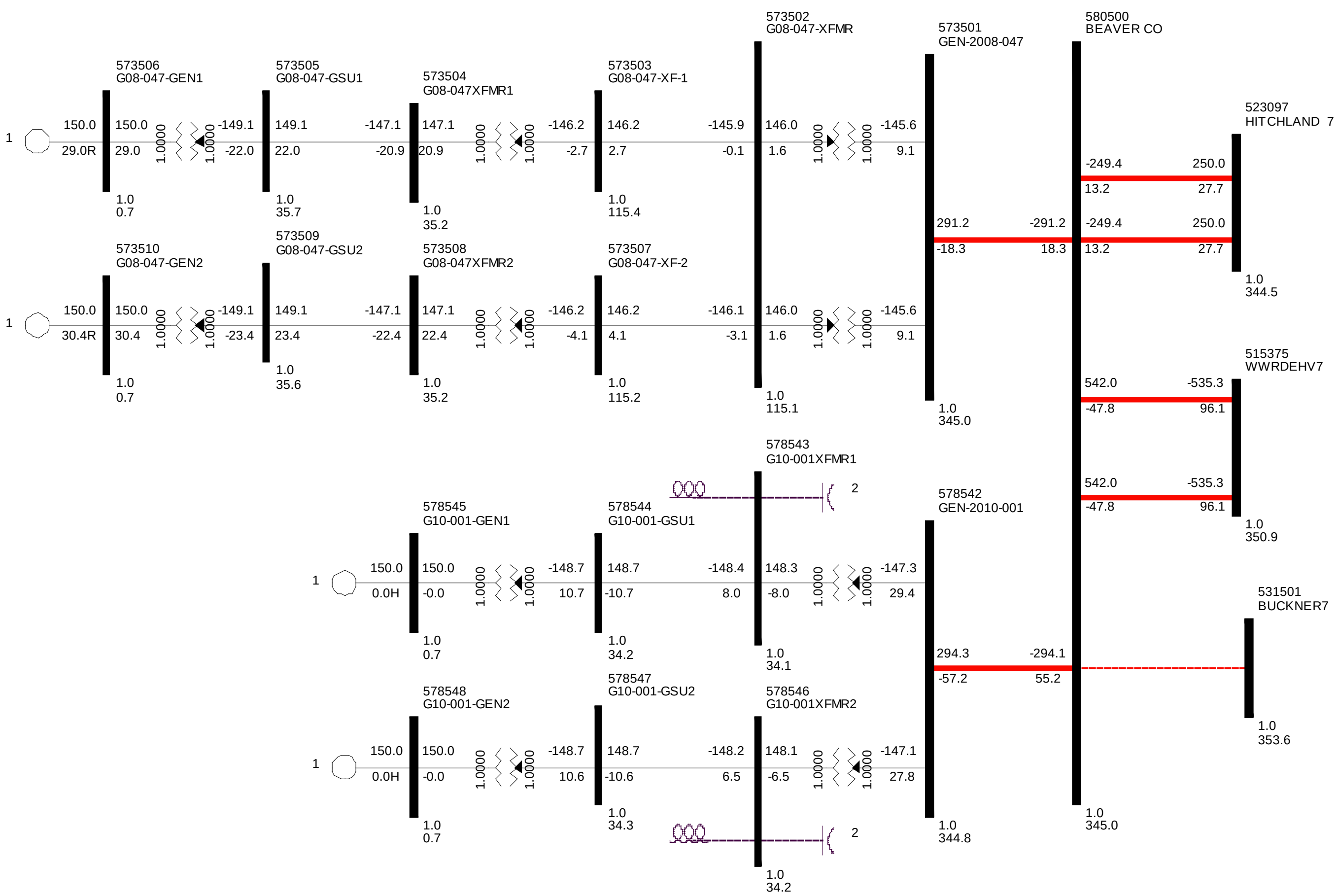


Figure 1 GEN-2010-001 One-Line Diagram

The site of the interconnection for GEN-2010-001 is in northwest Oklahoma in Beaver County.

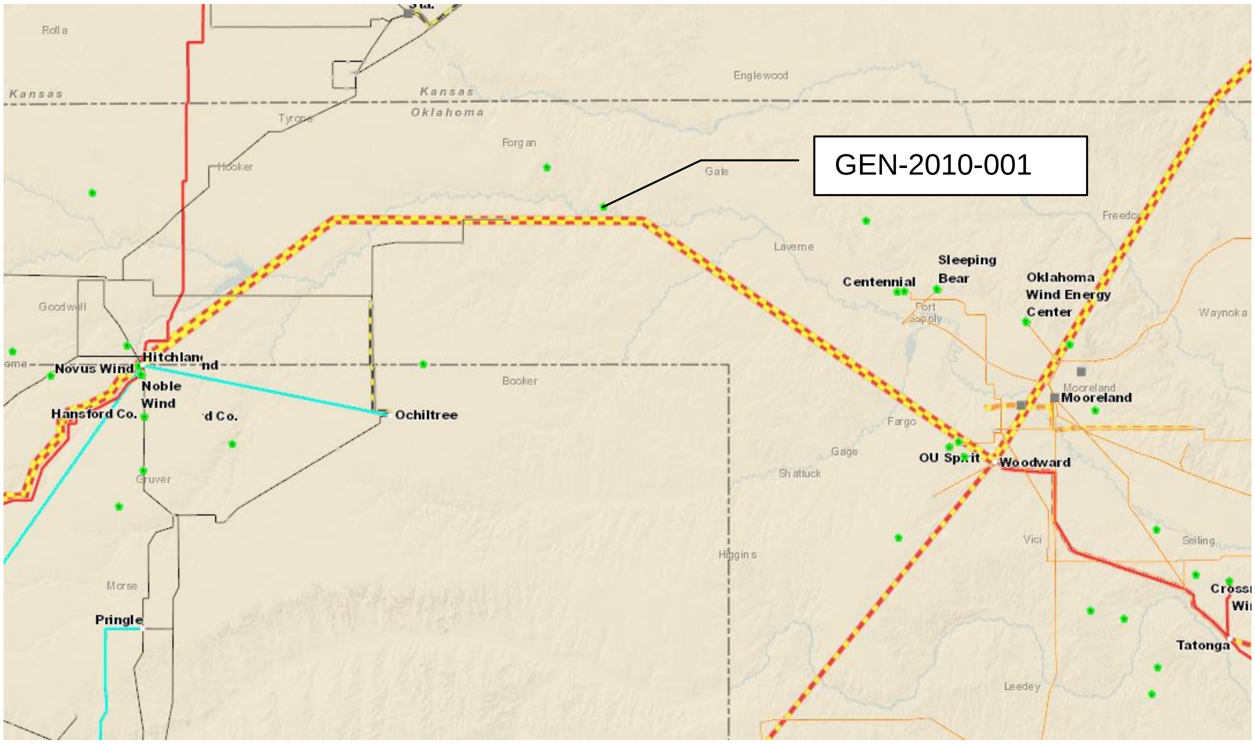


Figure 2 Geographical Location of GEN-2010-001

The following is the detailed description of the wind project GEN-2010-001.

GEN-2010-001

- Wind farm rating
  - Active power capability: 300 MW

- Interconnection:
  - Location: Radial 345kV lead line from Beaver County Substation
  - Generation facility substation transformer (Two step-up transformers)
    - MVA: Rate 100/133/166 MVA each
    - Voltage: 345kV/34.5kV
    - Z: 9.5% on 100 MVA each

- Wind turbine:
  - Number: 150 total
  - Manufacturer: Vestas
  - Type: 2.0 MW V100 VCSS
  - Machine terminal voltage: 700V
  - Rated power: 300 MW total

- Power factor: 0.98 lagging (supplying VARS) to 0.96 leading (absorbing VARS)
- Frequency: 60Hz
- Generator step-up transformer (2 wire equivalent)
  - MVA: 157.5
  - Voltage: 34.5/0.7kV
  - X: 7.44% on 100 MVA

4. POWER FACTOR RESULTS

Table 4-1 and Table 4-2 indicate the reactive capacity attributed to GEN-2010-001 at the POI to maintain a scheduled voltage of 1.0 PU for base case and contingency conditions based on the 2014 summer and 2014 winter peak cases provided. The power factor analysis identified the range of reactive power at the POI to be between 94.76% leading and 96.6% lagging under the contingency conditions modeled. For the network conditions studied, no single circuit contingencies tested will require the contribution of reactive power from GEN-2010-001 to exceed a net power factor of 95% lagging (supplying VARs to the network) to 95% leading (absorbing VARs from the network) at the POI. The double circuit outage of the Beaver County to Hitchland 345kV lines would require a leading power factor of 94.76% allocated to GEN-2010-001 at the POI to maintain 1.0 PU voltage.

GEN-2010-001 will need approximately 75 MVAR of additional capacitive support to achieve a 0.95% lagging power factor at the POI. The capacitance was assumed to be divided equally between the two 34.5kV collector buses. The results are shown in Figure 3. No additional reactive compensation was required to meet a 95% leading power factor at the POI.

The reactive compensation required to off-set the charging of the collector system and lead line was calculated by modeling GEN-2010-001 off-line and calculating the amount of inductive capacity required at the 34.5kV collector buses which would result in zero VAR flow at the 345kV POI. The results are shown in Figure 4. A total of 12.2 MVAR of inductive support would be needed to off-set the line charging of the 34.5kV collector system and the 345kV lead line. This reactive compensation was not included, modeled off-line, in the calculation of reactive requirements for the base case or contingency conditions studied.

Table 4-1: P.F. at POI with VAR Generator, 2014 Summer Peak

Cont. No.	Voltage @ POI (PU)	Power Factor GEN-2010-001 @ POI				
		P	Q	MVA	PF	Lead/ Lag
Base Case	1.00	300	-37.1	302.3	99.24	Lead
FLT01	1.00	300	-42.6	303.0	99.01	Lead
FLT03	1.00	300	27.8	301.3	99.57	Lag
FLT05	1.00	300	34.9	302.0	99.33	Lag
FLT07	1.00	300	-18.5	300.6	99.81	Lead
FLT09	1.00	300	-32.6	301.8	99.42	Lead
FLT11	1.00	300	-38.4	302.4	99.19	Lead
FLT13	1.00	300	-29.9	301.5	99.51	Lead
FLT15	1.00	300	-35.7	302.1	99.3	Lead
FLT17	1.00	300	61.1	306.2	97.99	Lag
FLT19	1.00	300	-38.3	302.4	99.2	Lead
FLT21	1.00	300	-34.5	302.0	99.35	Lead
FLT23	1.00	300	-35.8	302.1	99.3	Lead
FLT25	1.00	300	-32	301.7	99.44	Lead
FLT27	1.00	300	-36.2	302.2	99.28	Lead
FLT29	1.00	300	-37	302.3	99.25	Lead
FLT31	1.00	300	-32.7	301.8	99.41	Lead
FLT33	1.00	300	-37.5	302.3	99.23	Lead
FLT35	1.00	300	-35.7	302.1	99.3	Lead
FLT37	1.00	300	-34.1	301.9	99.36	Lead
FLT39	1.00	300	-37.2	302.3	99.24	Lead
FLT41	1.00	300	-36.6	302.2	99.26	Lead
FLT42	1.00	300	-37.1	302.3	99.25	Lead
FLT43	1.00	300	-27.7	301.3	99.58	Lead
FLT44	1.00	300	-37.1	302.3	99.24	Lead
FLT45	1.00	300	-43.4	303.1	98.97	Lead
FLT46	1.00	300	-101.2	316.6	**94.76**	Lead
FLT47	1.00	300	80.3	310.6	96.6	Lag
FLT48	1.00	300	-32.8	301.8	99.41	Lead

Table 4-2: P.F. at POI with VAR Generator, 2014 Winter Peak

Cont. No.	Voltage @ POI (PU)	Power Factor of Wind Generator GEN-2010-001 @ POI				
		P	Q	MVA	PF	Lead/ Lag
Base Case	1.00	300	-36.6	302.2	99.26	Lead
FLT01	1.00	300	-37.9	302.4	99.21	Lead
FLT03	1.00	300	29	301.4	99.53	Lag
FLT05	1.00	300	42	302.9	99.03	Lag
FLT07	1.00	300	-14.4	300.3	99.89	Lead
FLT09	1.00	300	-30.2	301.5	99.5	Lead
FLT11	1.00	300	-40.8	302.8	99.09	Lead
FLT13	1.00	300	-28.6	301.4	99.55	Lead
FLT15	1.00	300	-37.9	302.4	99.21	Lead
FLT17	1.00	300	43.5	303.1	98.96	Lag
FLT19	1.00	300	-33.5	301.9	99.38	Lead
FLT21	1.00	300	-32.9	301.8	99.4	Lead
FLT23	1.00	300	-29.6	301.5	99.52	Lead
FLT25	1.00	300	-33.8	301.9	99.37	Lead
FLT27	1.00	300	-34.6	302.0	99.34	Lead
FLT29	1.00	300	-35	302.0	99.32	Lead
FLT31	1.00	300	-33	301.8	99.4	Lead
FLT33	1.00	300	-36	302.2	99.29	Lead
FLT35	1.00	300	-34.8	302.0	99.33	Lead
FLT37	1.00	300	-33.2	301.8	99.39	Lead
FLT39	1.00	300	-35.1	302.0	99.32	Lead
FLT41	1.00	300	-34.8	302.0	99.33	Lead
FLT42	1.00	300	-35.5	302.1	99.31	Lead
FLT43	1.00	300	-29	301.4	99.54	Lead
FLT44	1.00	300	-35.5	302.1	99.31	Lead
FLT45	1.00	300	-37.5	302.3	99.23	Lead
FLT46	1.00	300	-98.3	315.7	95.03	Lead
FLT47	1.00	300	73.5	308.9	97.12	Lag
FLT48	1.00	300	-33.7	301.9	99.37	Lead

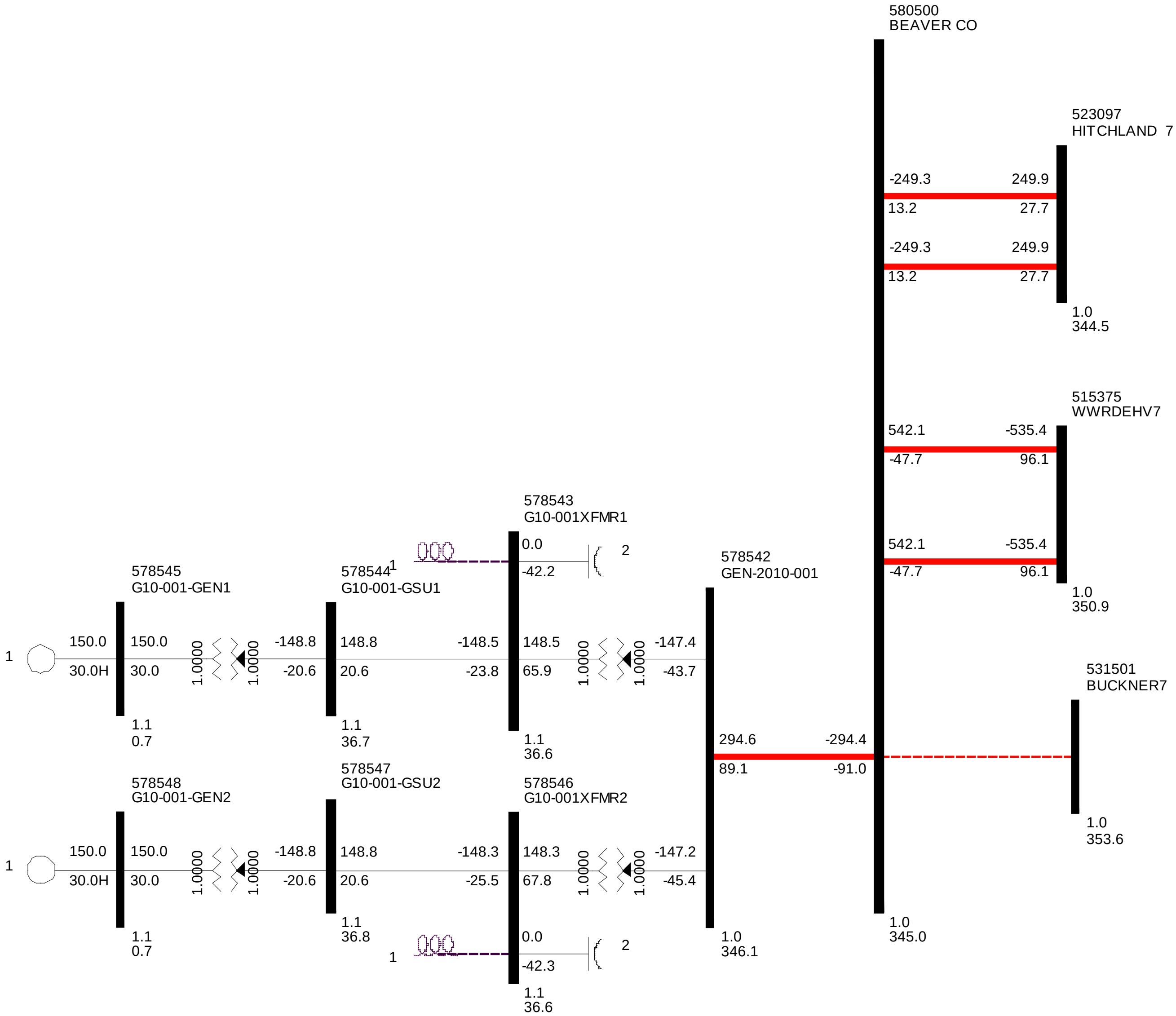


Figure 3 Reactive Compensation to Meet 95% Lag at POI

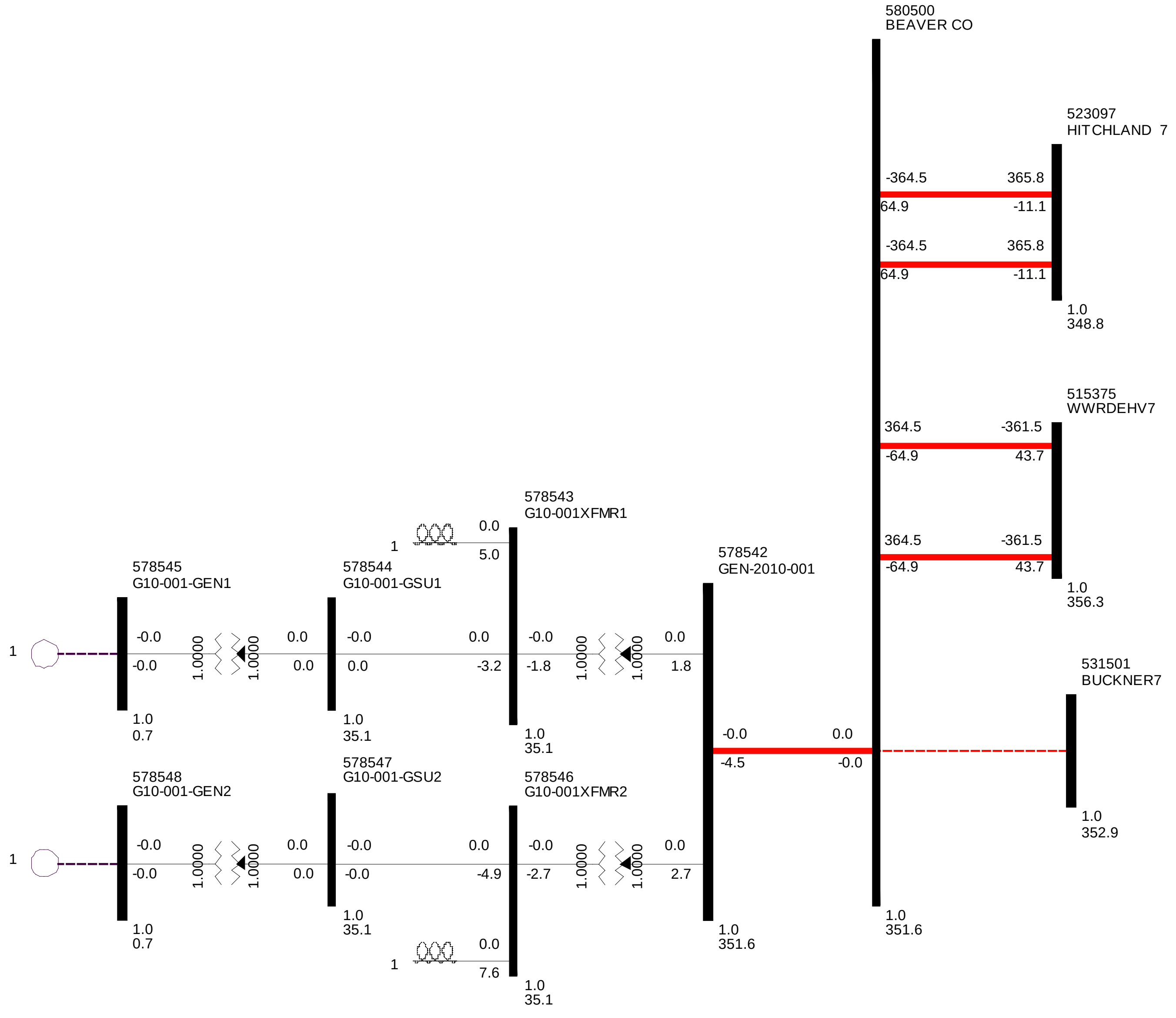


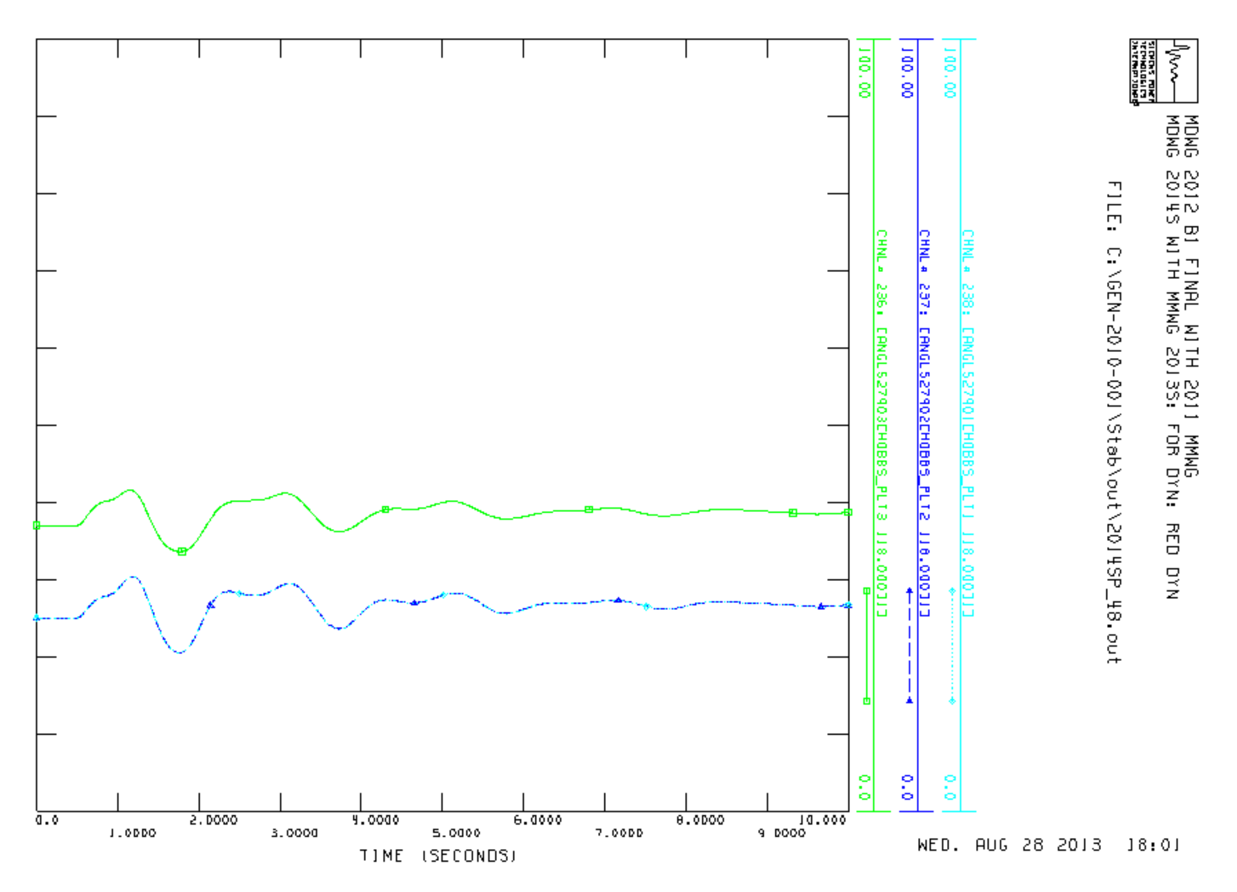
Figure 4 Required Off-line Reactive Compensation

TRANSIENT STABILITY RESULTS

Dynamic simulations were performed for each fault noted in Section 2. All faults were cleared after five (5) cycles. Faulted transmission lines were reclosed into the fault 20 cycles after the initial clearing, then cleared and locked out after five (5) more cycles. Faulted transformers were not reclosed.

GEN-2010-001 was found to be stable for all conditions studied. For the faults studied, the three phase faults are relatively more severe than the corresponding single line to ground faults. No other generators pulled out of synchronism with the grid and no generators tripped.

Double circuit three-phase faults (FLT 46, FLT 47 & FLT 48) tend to be more severe than single circuit three phase faults. Below are the rotor angle plots of Hobbs units for FLT-48, a double circuit three phase fault on Woodward to Thistle 345kV lines, ckt1&2 at Woodward. The plots show stable response with oscillations damping out after a few seconds.



5. ROTOR ANGLE DAMPING AND VOLTAGE RECOVERY REQUIREMENT

Rotor angle damping and voltage recovery as determined via dynamic simulation were checked against all contingencies. If the voltage recovers post-fault to a steady-state level consistent with the steady-state simulation, the generator interconnection is considered stable from a voltage standpoint. POI voltage recovery plots for GEN-2010-001 are provided in Appendix B.

In these dynamic simulations, real loads are modeled as constant current and reactive loads are modeled as constant admittance; i.e. MW loads are proportional to voltage and MVAR loads are proportional to voltage squared. In contrast, loads are modeled as constant MW and constant MVAR in steady-state simulations. Therefore, due to differences in load modeling, minor differences in voltages are to be expected between dynamic and steady-state simulations.

Visual inspection of SPPR and SPPR5 showed compliance with Rotor angle damping requirement. The post fault voltage recovery was found to be within the criterion of 0.7 PU to 1.2 PU.

The wind farm GEN-2010-001 was found to meet FERC Order 661A (low voltage ride through and wind farm recovery to pre-fault voltage). It did not trip during any of the contingencies tested.

CONCLUSIONS

Based on the results of the GEN-2010-001 Impact Restudy analysis, the following findings had been observed:

- The power factor analysis identified the need for reactive power at the POI to be between 94.76% leading and 96.6% lagging under the contingency conditions modeled. For the network conditions studied, no single element contingencies tested will require the contribution of reactive power from GEN-2010-001 to exceed a net power factor of 95% lagging (supplying VARs to the network) to 95% leading (absorbing VARs from the network) at the POI. ,
- A double circuit outage of the Beaver CO to Hitchland 345kV lines would require a leading power factor of 94.76 to maintain 1.0 PU voltage at the POI.
- GEN-2010-001 will need to add approximately 75 MVAR of additional capacitive support to meet the 0.95% lagging power factor at the POI.
- A total of 12.2 MVAR of additional inductive support would be required to compensate for the charging of the collector system and lead line when GEN-2010-001 is off-line.
- GEN-2010-001 is capable of meeting LVRT requirements. GEN-2010-001 did not trip off line under any studied fault conditions.
- GEN-2010-001 has the capability of recovering to the pre-contingency voltage following all studied fault disturbances.
- All generators were found to be stable and met the rotor angle damping requirement for all conditions studied.