GEN-2014-040
Impact Restudy for Generator Modification (Turbine Change)

May 2015
Generator Interconnection

Southwest Power Pool

Executive Summary

The GEN-2014-040 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 1.79MW wind turbine generators (195 machines total) to Vestas V110 2.0MW wind turbine generators (160 machines total).

In this restudy the project uses one hundred sixty (160) Vestas V110 2.0MW wind turbine generators for an aggregate power of 320MW. The point of interconnection (POI) for GEN-2014-040 is at the Southwestern Public Service (SPS) Castro 115 kV Substation. The Interconnection Customer has provided documentation that shows the Vestas V110 VCSS 2.0MW wind turbine generators have a reactive capability of 0.98 lagging (providing VARS) and 0.96 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-2014-002 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 V110 2.0MW 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. Since the Vestas V110 VCSS 2.0MW wind turbines have limited reactive capability, the generation facility will need external capacitor banks or other reactive equipment to meet the power factor requirement at the POI. Additionally, the project will be required to install approximately 15 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 2014-002 in place, GEN-2014-040 with the Vestas V110 2.0MW 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.

I. Introduction

GEN-2014-040 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 one-hundred-ninety-five (195) GE 1.79MW wind turbine generators to one-hundred-sixty (160) Vestas V110 2.0MW wind turbine generators.

Table I-1: Interconnection Request

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2014-040	320	Vestas V110 2.0MW [one-hundred-sixty (160) generators]	Castro 115kV

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
ASGI-2013-001	11.5	Siemens 2.3MW	Pantex South 115kV
GEN 2002-022	240	Siemens 2.3MW	Bushland 230kV
GEN-2008-051	322	Siemens 2.3MW	Potter County 345kV
GEN-2008-088	50.6	Siemens SWT 2.3MW	Vega 69kV

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 2015 summer peak, the 2015 winter 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-2014-040 generation interconnection request is shown in Figure II-1. The POI is the SPS Castro 115kV substation.

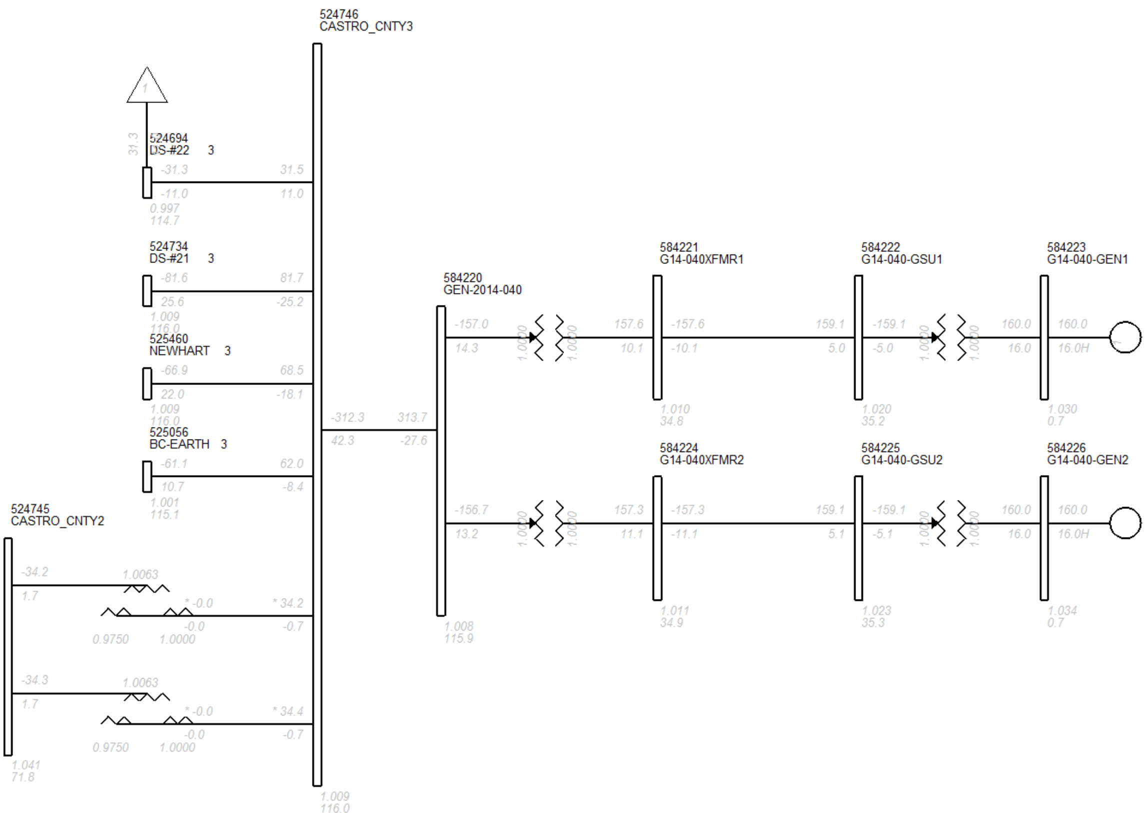

Figure II-1: GEN-2014-040 One-line Diagram

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 2014 series of Model Development Working Group (MDWG) dynamic study models including the 2015 summer peak, the 2015 winter 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

Nineteen (19) 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

Cont. No.	Contingency Name	Description
1	FLT_01_Castro_DS21_115kV_3PH	3 phase fault on the Castro County (524746) to Deaf Smith #21 (524734) 115kV line circuit 1, near Castro County. a. Apply fault at the Castro County 115kV bus. b. Clear fault after 5 cycles and trip 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_Castro_BCEarth_115kV_3PH	3 phase fault on the Castro County (524746) to BC-Earth (525056) 115kV line circuit 1, near Castro County. a. Apply fault at the Castro County 115kV bus. b. Clear fault after 5 cycles and trip 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_Castro_Newhart_115kV_3PH	3 phase fault on the Castro County (524746) to Newhart (525460) 115kV line circuit 1, near Castro County. a. Apply fault at the Castro County 115kV bus. b. Clear fault after 5 cycles and trip 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_DS21_DeafSmith_115kV_3PH	3 phase fault on the DS #21 (524734) to Deaf Smith (524622) 115kV line circuit 1, near DS #21. a. Apply fault at the DS #21 115kV bus. b. Clear fault after 5 cycles and trip 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_DeafSmith_NEHereford_115kV_3PH	3 phase fault on the Deaf Smith (524622) to NE_Hereford (524567) 115kV line circuit 1, near Deaf Smith. a. Apply fault at the Deaf Smith 115kV bus. b. Clear fault after 5 cycles and trip 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_DeafSmith_Panda_115kV_3PH	3 phase fault on the Deaf Smith (524622) to Panda (524597) 115kV line circuit 1, near Deaf Smith. a. Apply fault at the Deaf Smith 115kV bus. b. Clear fault after 5 cycles and trip 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

Cont. No.	Contingency Name	Description
7	FLT_07_DeafSmith_Hereford_115kV_3PH	3 phase fault on the Deaf Smith (524622) to Hereford (524606) 115kV line circuit 1, near Deaf Smith. a. Apply fault at the Deaf Smith 115kV bus. b. Clear fault after 5 cycles and trip 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_BCEarth_PlantX_115kV_3PH	3 phase fault on the Castro County 115/69kV autotransformer near Castro County 115kV (524746). a. Apply fault at the Castro County 115kV bus. b. Clear fault after 5 cycles and trip the faulted line.
9	FLT_09_PlantX_EMU&VLTTP_115kV_3PH	3 phase fault on the BC-Earth (525056) to Plant X (525480) 115kV line circuit 1, near BC-Earth. a. Apply fault at the BC-Earth 115kV bus. b. Clear fault after 5 cycles and trip 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_PlantX_HLCSOLTON_115kV_3PH	3 phase fault on the Plant X (525480) to EMU&VLY_TP (525019) 115kV line circuit 1, near Plant X. a. Apply fault at the Plant X 115kV bus. b. Clear fault after 5 cycles and trip 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_PlantX_HaleCo_115kV_3PH	3 phase fault on the Plant X (525480) to LC-S_Olton (525440) 115kV line circuit 1, near Plant X. a. Apply fault at the Plant X 115kV bus. b. Clear fault after 5 cycles and trip 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_PlantX_WLITLFLD_115kV_3PH	3 phase fault on the Plant X (525480) to Hale County (525454) 115kV line circuit 1, near Plant X. a. Apply fault at the Plant X 115kV bus. b. Clear fault after 5 cycles and trip 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	FLT_13_Newhart_HartIndustrial_115kV_3PH	3 phase fault on the Plant X (525480) to W_LITLFLD (525641) 115kV line circuit 1, near Plant X. a. Apply fault at the Plant X 115kV bus. b. Clear fault after 5 cycles and trip 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

Cont. No.	Contingency Name	Description
14	FLT_14_Newhart_Kress_115kV_3PH	3 phase fault on the New Hart (525460) to Hart Industrial (525124) 115kV line circuit 1, near New Hart. a. Apply fault at the New Hart 115kV bus. b. Clear fault after 5 cycles and trip 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_Castro_Castro_115_69kV_3PH	3 phase fault on the Newhart (525460) to Kress (525460) 115kV line circuit 1, near Hitchland. a. Apply fault at the Newhart 115kV bus. b. Clear fault after 5 cycles and trip 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_DeafSmith_DeafSmith_115_230kV_3PH	3 phase fault on the Deaf Smith (524623) 230/(524622) 115/(524620) 13.2kV Transformer circuit 1, near the 230kV bus. a. Apply fault at the Deaf Smith 230kV bus. b. Clear fault after 5 cycles and trip the faulted line.
17	FLT_17_Stuck_Breaker_Castro_BCEarth_115kV_1PH	**Castro stuck breaker** a. Apply single phase fault at Castro County on the Castro (524746) – BC Earth 115kV line b. After 20 cycles, trip the Castro 115kV (524746)/69kV (524745)/ 13.2kV (524743) transformer c. Remove the fault and trip the Castro (524746) – BC Earth (525056) 115kV line
18	FLT_18_Stuck_Breaker_Castro_Newhart_115kV_1PH	**Castro stuck breaker** a. Apply single phase fault at Castro County on the Castro (524746) – Newhart (525460) 115kV line b. After 20 cycles, trip the Castro 115kV (524746)/69kV (524745)/ 13.2kV (524744) transformer c. Remove the fault and trip the Castro - Newhart 115kV line
19	FLT_19_Castro_BCEarth_115kV_3PH_PO_Castro_Newhart	**Prior outage on the Castro – Newhart 115kV line** 3 phase fault on the Castro County (524746) to BC-Earth (525056) 115kV line circuit 1, near Castro County. a. Apply fault at the Castro County 115kV bus. b. Clear fault after 5 cycles and trip 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.

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-2014-040 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_Castro_DS21_115kV_3PH	Stable	Stable	Stable
2	FLT_02_Castro_BCEarth_115kV_3PH	Stable	Stable	Stable
3	FLT_03_Castro_Newhart_115kV_3PH	Stable	Stable	Stable
4	FLT_04_DS21_DeafSmith_115kV_3PH	Stable	Stable	Stable
5	FLT_05_DeafSmith_NEHereford_115kV_3PH	Stable	Stable	Stable
6	FLT_06_DeafSmith_Panda_115kV_3PH	Stable	Stable	Stable
7	FLT_07_DeafSmith_Hereford_115kV_3PH	Stable	Stable	Stable
8	FLT_08_BCEarth_PlantX_115kV_3PH	Stable	Stable	Stable
9	FLT_09_PlantX_EMU&VLTTP_115kV_3PH	[redacted]	Stable	Stable
10	FLT_10_PlantX_HLCSOLTON_115kV_3PH	Stable	Stable	Stable
11	FLT_11_PlantX_HaleCo_115kV_3PH	Stable	Stable	Stable
12	FLT_12_PlantX_WLITLFLD_115kV_3PH	[redacted]		Stable
13	FLT_13_Newhart_HartIndustrial_115kV_3PH	Stable	Stable	Stable
14	FLT_14_Newhart_Kress_115kV_3PH	Stable	Stable	Stable
15	FLT_15_Castro_Castro_115_69kV_3PH	Stable	Stable	Stable
16	FLT_16_DeafSmith_DeafSmith_115_230kV_3PH	Stable	Stable	Stable
17	FLT_17_Stuck_Breaker_Castro_BCEarth_115kV_1PH	Stable	Stable	Stable
18	FLT_18_Stuck_Breaker_Castro_Newhart_115kV_1PH	Stable	Stable	Stable
19	FLT_19_Castro_BCEarth_115kV_3PH_PO_Castro_Newhart	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 1 and 2 in Table III-2 simulated the LVRT contingencies. GEN-2014-040 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 V110 VCSS 2.0MW wind turbines have limited reactive capability (0.98 lagging and 0.96 leading), the generation facility will require external capacitor banks or other reactive equipment to meet the power factor requirement at the POI.

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-2014-040	320	Vestas V110 VCSS 2.0MW	Castro 115kV (524746)	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 Analysis**.

Table V-1: Summary of Shunt Reactor Requirements

Request	Capacity	POI	Approximate Shunt Reactor Required
GEN-2014-040	320MW	Castro 115kV (524746)	15Mvar

The results shown are for the 2025 summer case. The other two cases (2015 summer and 2015 winter) were almost identical since the generation plant design is the same in all cases.

VI. Conclusion

The SPP GEN-2014-040 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-2014-040	320	Vestas V110 2.0MW [one-hundred-sixty (160) generators]	Castro 115kV (524746)

With all Base Case Network Upgrades in service, previously assigned Network Upgrades in service, and required capacitor banks in service, the GEN-2014-040 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 15Mvar 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 14-040 restudy Group 05 POI - CASTRO_CNTY3115.00 115.0 (524746)		2015 Summer Voltage = 1.0 pu				2015 Winter Voltage = 1.01919782162 pu				2025 Summer Voltage = 1.0 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	320	-59.9303	0.9829109	LEAD	320	-59.7352	0.98302	LEAD	320	-30.25349	0.995561	LEAD
1	FLT_01_Castro_DS#21_115kV	320	-41.6202	0.9916476	LEAD	320	-37.6216	0.99316	LEAD	320	-14.34512	0.998997	LEAD
2	FLT_02_Castro_BCEarth_115kV	320	-52.7904	0.986664	LEAD	320	-50.8723	0.9876	LEAD	320	-42.15717	0.991433	LEAD
3	FLT_03_Castro_Newhart_115kV	320	-45.539	0.9900253	LEAD	320	-49.8915	0.98806	LEAD	320	-8.31951	0.999662	LEAD
4	FLT_04_DS#21_DeafSmith_115kV	320	-34.362	0.994284	LEAD	320	-36.838	0.99344	LEAD	320	-2.988881	0.999956	LEAD
5	FLT_05_DeafSmith_NEHereford_115kV	320	-59.7322	0.9830209	LEAD	320	-59.6073	0.98309	LEAD	320	-29.90045	0.995663	LEAD
6	FLT_06_DeafSmith_Panda_115kV	320	-64.4931	0.9802891	LEAD	320	-64.515	0.98028	LEAD	320	-34.16747	0.994348	LEAD
7	FLT_07_DeafSmith_Hereford_115kV	320	-59.816	0.9829744	LEAD	320	-59.578	0.98311	LEAD	320	-30.05173	0.995619	LEAD
8	FLT_08_BCEarth_PlantX_115kV	320	-23.6059	0.9972902	LEAD	320	-48.3473	0.98878	LEAD	320	-3.434906	0.999942	LEAD
9	FLT_09_PlantX_EMU&VLTTP_115kV	[redacted]				320	-60.0032	0.98287	LEAD	320	-29.10574	0.995889	LEAD
10	FLT_10_PlantX_HLCSOLTON_115kV	320	-55.5596	0.9852598	LEAD	320	-59.5319	0.98313	LEAD	320	-26.3463	0.996628	LEAD
11	FLT_11_PlantX_HaleCo_115kV	320	-58.6271	0.9836281	LEAD	320	-58.9246	0.98347	LEAD	320	-29.21321	0.995859	LEAD
12	FLT_12_PlantX_WLITLFLD_115kV	[redacted]								320	-29.89886	0.995663	LEAD
13	FLT_13_Newhart_HartIndustrial_115kV	320	-61.7755	0.9818713	LEAD	320	-58.614	0.98364	LEAD	320	-36.23877	0.993649	LEAD
14	FLT_14_Newhart_Kress_115kV	320	-57.3384	0.9843233	LEAD	320	-57.0588	0.98447	LEAD	320	-31.41954	0.995214	LEAD
15	FLT_15_Castro_Castro_115_69kV	320	-59.9303	0.982911	LEAD	320	-59.7352	0.98302	LEAD	320	-30.25348	0.995561	LEAD
16	FLT_16_DeafSmith_DeafSmith_115_230kV	320	-52.5903	0.9867629	LEAD	320	-55.6306	0.98522	LEAD	320	-21.02866	0.997848	LEAD

APPENDIX C

PROJECT MODELS

GEN-2014-040 (Vestas V110 2.0MW)

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@! ----------- Bus Data -----------
BAT_SPLT,524746,584220,'GEN-2014-040', 115.00,;
BAT_BUS_DATA_2,584220,1,,,, 115.00,,,'GEN-2014-040',;
BAT_BUS_DATA_2,584221,1,,,,  34.50,,,'G14-040XFMR1',;
BAT_BUS_DATA_2,584222,1,,,,  34.50,,,'G14-040-GSU1',;
BAT_BUS_DATA_2,584223,2,,,,   0.69,,,'G14-040-GEN1',;
BAT_BUS_DATA_2,584224,1,,,,  34.50,,,'G14-040XFMR2',;
BAT_BUS_DATA_2,584225,1,,,,  34.50,,,'G14-040-GSU2',;
BAT_BUS_DATA_2,584226,2,,,,   0.69,,,'G14-040-GEN2',;
@!
@! ----------- Generator Data -----------
BAT_PLANT_DATA,584223,     0, 1.000,,;
BAT_PLANT_DATA,584226,     0, 1.000,,;
@! 100%
  BAT_MACHINE_DATA_2,584223,'1',1,,,,,0, 160.0, 0.0, 0.0000,  0.0000, 160.00, 0.0, 160.000, 0.0050, 0.1991,,,,,,,, 1.00,;
  BAT_MACHINE_DATA_2,584226,'1',1,,,,,0, 160.0, 0.0, 0.0000,  0.0000, 160.00, 0.0, 160.000, 0.0050, 0.1991,,,,,,,, 1.00,;
@!  20%
@!BAT_MACHINE_DATA_2,584223,'1',1,,,,,0,  32.0, 0.0, 0.0000,  0.0000, 160.00, 0.0, 160.000, 0.0050, 0.1991,,,,,,,, 1.00,;
@!BAT_MACHINE_DATA_2,584226,'1',1,,,,,0,  32.0, 0.0, 0.0000,  0.0000, 160.00, 0.0, 160.000, 0.0050, 0.1991,,,,,,,, 1.00,;
@!
@! ----------- Transformer Data -----------
BAT_TWO_WINDING_DATA_3,584220,584221,'1',1,,,,,,33,,,,1,0,1,2,1, 0.00219, 0.08997,  90.00,,,,,, 150.00, 150.00, 150.00,,,,,,,,,,,,,,,;
BAT_TWO_WINDING_DATA_3,584220,584224,'1',1,,,,,,33,,,,1,0,1,2,1, 0.00219, 0.08997,  90.00,,,,,, 150.00, 150.00, 150.00,,,,,,,,,,,,,,,;
BAT_TWO_WINDING_DATA_3,584222,584223,'1',1,,,,,, 5,,,,1,0,1,2,1, 0.00630, 0.07580, 168.00,,,,,, 160.00, 160.00, 160.00,,,,,,,,,,,,,,,;
BAT_TWO_WINDING_DATA_3,584225,584226,'1',1,,,,,, 5,,,,1,0,1,2,1, 0.00630, 0.07580, 168.00,,,,,, 160.00, 160.00, 160.00,,,,,,,,,,,,,,,;
@!
@! ----------- Add New Collector Cables -----------
BAT_BRANCH_DATA,584221,584222,'1',1,,,,,, 0.00595, 0.00652, 0.06519,,,,,,,,      ,,,,,;
BAT_BRANCH_DATA,584224,584225,'1',1,,,,,, 0.00756, 0.00938, 0.07991,,,,,,,,      ,,,,,;
@!
@! ----------- Transmission Line from Substation to POI -----------
BAT_BRANCH_DATA,524746,584220,'1',1,,,,,, 0.00149, 0.01538, 0.00284,,,,,,,,  4.0,,,,,;
@!

/
/ V110 VCSS 2.0 MW 60 Hz Mk10 (VestasWT_7_6_0_PSSE32.lib)
/ V110 VCSS 2.0 MW
584223 'USRMDL' '1'  'VWCOR6' 1 1 2 45 23 104 1 0
 2000.0000 690.0000 903.3041 700.0000 2.6200 0.9676 0.0232
 1.9807 8.3333 1.9807 8.3333 30.0000 0.2000 1.2000
 0.1000 0.0012 0.9925 0.0474 1.6118 0.0000 351.8584
 161.5343 0.0300 0.0000 0.0300 0.3000 0.0000 1.0000
 0.3183 4.9736 2812227.1900 43.2960 90.0120 600000.0000 3.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000/
0 'USRMDL' 0 'VWVAR6' 8 0 2 0 0 30 584223 '1'  /
0 'USRMDL' 0 'VWLVR6' 8 0 3 65 10 35 584223 '1' 1
 0.9000 0.0010 0.1500 18.6316 74.5430 74.5430 74.5430
 0.5000 1.0000 2.6200 0.9676 1.2000 0.5000 690.0000
 903.3041 0.3500 0.0500 0.2500 0.0200 3.0000 4.0000
 9999.0000 0.0232 0.9000 0.9000 0.0500 0.0000 0.0100
 0.0000 2.0000 0.0000 1.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 /
0 'USRMDL' 0 'VWPWR6' 8 0 3 30 7 10 584223 '1' 1
```

```
 1.0000 0.5000 -0.5000 0.6988 0.8844 0.9800 0.9600
 0.2000 0.2000 1.0000 1.0000 0.0000 0.0000 0.1000
 0.1000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 /
0 'USRMDL' 0 'VWMEC6' 8 0 2 10 8 0 584223 '1'
 2000.0000 422.2301 4736.7543 420.7500 83.5000 6188.8071 39.3992
 0.0000 0.0000 0.0000 /
0 'USRMDL' 0 'VWMEA6' 8 0 2 10 8 5 584223 '1'
 0.1000 0.1000 0.1000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000/
0 'USRMDL' 0 'VWVPR6' 0 2 7 30 0 18 584223 '1'  1 1 0 0 0
 0.8500 11.0000 0.8500 11.0000 0.9000 60.0000 1.1000
 60.0000 1.1500 2.0000 1.2000 0.0800 1.2500 0.0050
 1.2500 0.0050 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.1500 0.8000 2.7000 0.8500 3.5000
 0.9000 5.0000 /
0 'USRMDL' 0 'VWFPR6' 0 2 3 12 0 7 584223 '1'  0
 56.4000 0.2000 56.4000 0.2000 56.4000 0.2000 63.6000
 0.2000 63.6000 0.2000 63.6000 0.2000 /
/ V110 VCSS 2.0 MW
584226 'USRMDL' '1'  'VWCOR6' 1 1 2 45 23 104 1 0
 2000.0000 690.0000 903.3041 700.0000 2.6200 0.9676 0.0232
 1.9807 8.3333 1.9807 8.3333 30.0000 0.2000 1.2000
 0.1000 0.0012 0.9925 0.0474 1.6118 0.0000 351.8584
 161.5343 0.0300 0.0000 0.0300 0.3000 0.0000 1.0000
 0.3183 4.9736 2812227.1900 43.2960 90.0120 600000.0000 3.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000/
0 'USRMDL' 0 'VWVAR6' 8 0 2 0 0 30 584226 '1'  /
0 'USRMDL' 0 'VWLVR6' 8 0 3 65 10 35 584226 '1' 1
 0.9000 0.0010 0.1500 18.6316 74.5430 74.5430 74.5430
 0.5000 1.0000 2.6200 0.9676 1.2000 0.5000 690.0000
 903.3041 0.3500 0.0500 0.2500 0.0200 3.0000 4.0000
 9999.0000 0.0232 0.9000 0.9000 0.0500 0.0000 0.0100
 0.0000 2.0000 0.0000 1.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 /
0 'USRMDL' 0 'VWPWR6' 8 0 3 30 7 10 584226 '1' 1
 1.0000 0.5000 -0.5000 0.6988 0.8844 0.9800 0.9600
 0.2000 0.2000 1.0000 1.0000 0.0000 0.0000 0.1000
 0.1000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 /
0 'USRMDL' 0 'VWMEC6' 8 0 2 10 8 0 584226 '1'
 2000.0000 422.2301 4736.7543 420.7500 83.5000 6188.8071 39.3992
 0.0000 0.0000 0.0000 /
0 'USRMDL' 0 'VWMEA6' 8 0 2 10 8 5 584226 '1'
 0.1000 0.1000 0.1000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.0000/
0 'USRMDL' 0 'VWVPR6' 0 2 7 30 0 18 584226 '1'  1 1 0 0 0
 0.8500 11.0000 0.8500 11.0000 0.9000 60.0000 1.1000
 60.0000 1.1500 2.0000 1.2000 0.0800 1.2500 0.0050
 1.2500 0.0050 0.0000 0.0000 0.0000 0.0000 0.0000
 0.0000 0.0000 0.1500 0.8000 2.7000 0.8500 3.5000
 0.9000 5.0000 /
0 'USRMDL' 0 'VWFPR6' 0 2 3 12 0 7 584226 '1'  0
 56.4000 0.2000 56.4000 0.2000 56.4000 0.2000 63.6000
```

0.2000 63.6000 0.2000 63.6000 0.2000 /
/

APPENDIX D

LOW WIND COMPENSATION ANALYSIS

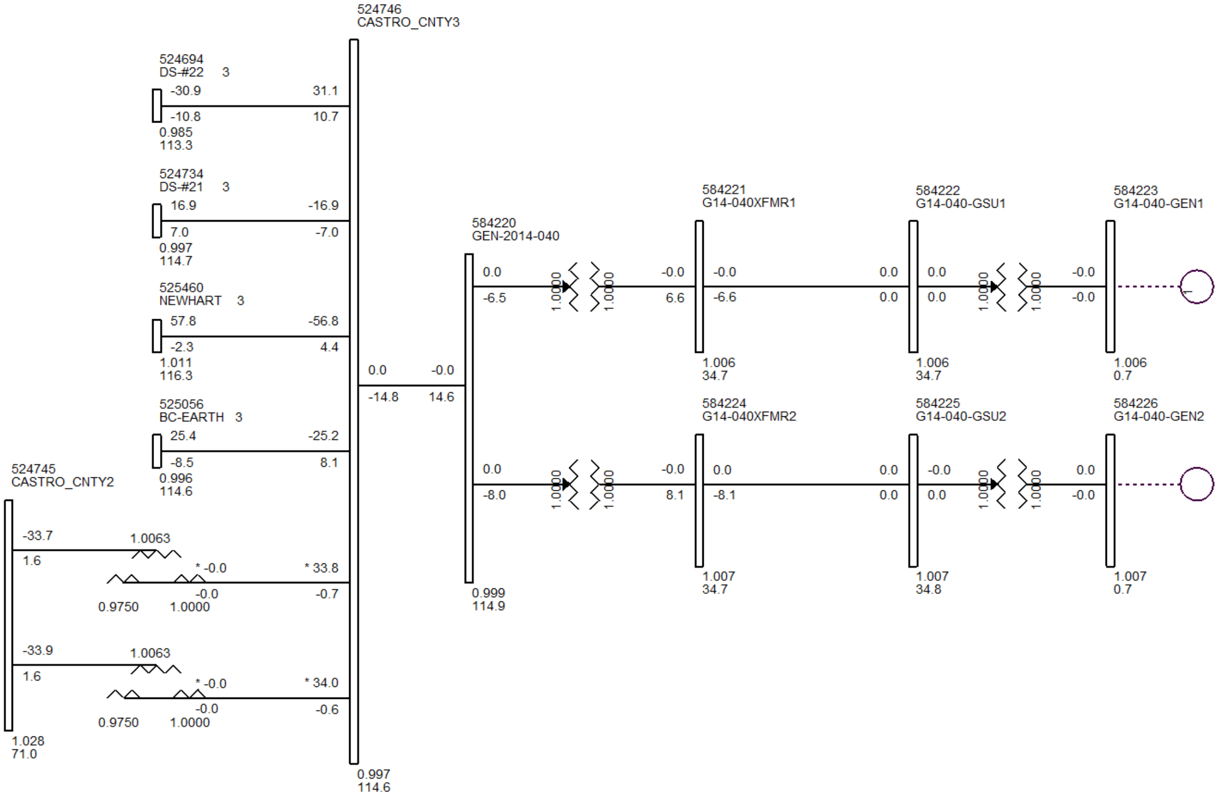

Figure E-1: GEN-2014-040 with generators off and no shunt reactors

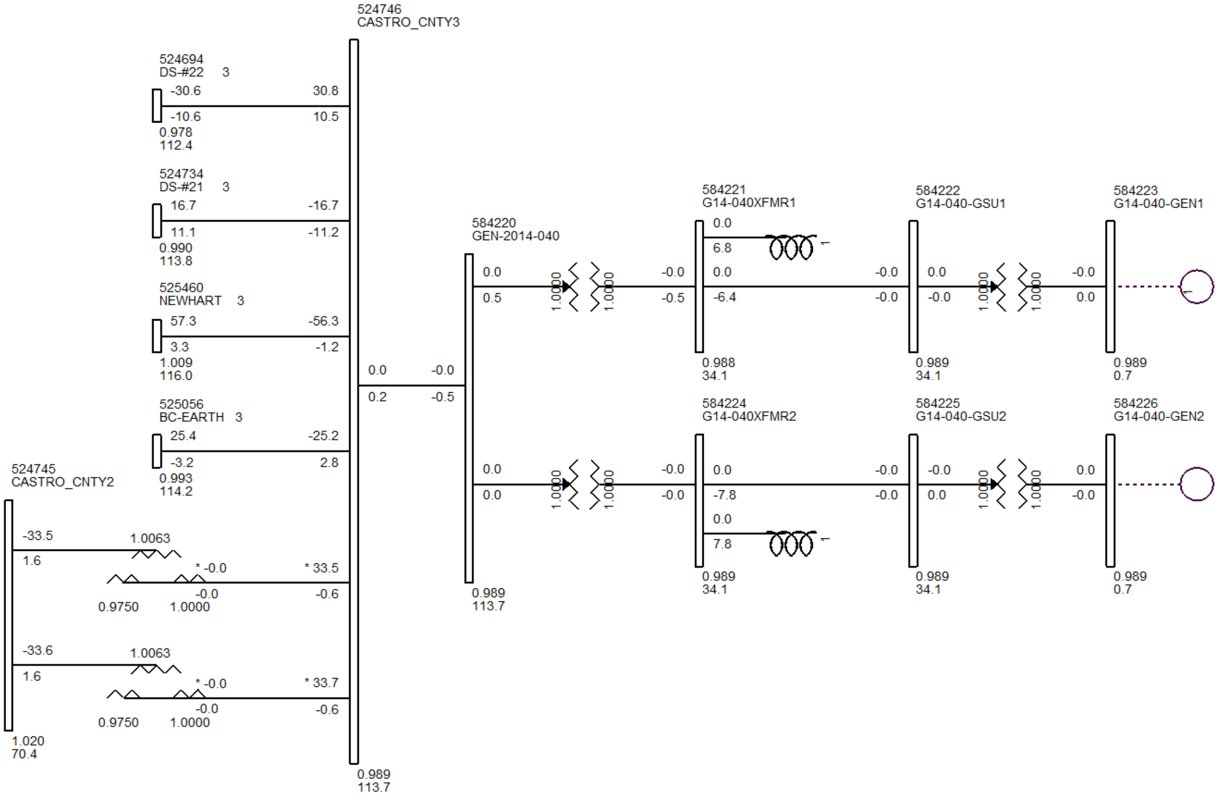

Figure E-2: GEN-2014-040 with generator turned off and shunt reactor added to the low side of the substation 345/34.5kV transformer