GEN-2014-056
GEN-2015-057
Impact Restudy for Generator Modification (Turbine Change)

April 2017
Generator Interconnection

SPP Southwest Power Pool

Revision History

Date	Author	Change Description
4/28/2017	SPP	GEN-2014-056 and GEN-2015-057 Impact Restudy for Generator Modification (Turbine Change) issued.

Executive Summary

The Interconnection Customer for GEN-2014-056 and GEN-2015-057 has requested wind turbine generator modifications to its Generator Interconnection Requests. Additionally, the modification requests include the exchanging of physical locations between GEN-2014-056 and GEN-2015-057. The purpose of this study is to determine if there is Material Modifications as a result of the change in wind turbine generators and the exchange in physical locations of the two interconnection requests.

GEN-2014-056 was previously studied in DISIS-2014-002 Group 1[1] with one hundred twenty-five (125) GE 2.0MW wind turbine generators (aggregate power of 250.0MW). GEN-2015-057 was previously studied in DISIS-2015-002 Group 1[2] with fifty (50) GE 2.0MW wind turbine generators (aggregate power of 100.0MW). In this modification study the interconnection customer has requested that GEN-2014-056 be studied with ninety-nine (99) GE 2.3MW wind turbine generators and twelve (12) GE 1.79MW wind turbine generators (aggregate power of 249.18mw). GEN-2015-057 is to be studied with thirty-seven (37) GE 2.3MW wind turbine generators, three (3) GE 2.0MW wind turbine generators, and five (5) GE 1.79MW wind turbine generators (aggregate power of 100.05MW). The Interconnection Customer provided a PSSE raw data file that incorporated the modifications for GEN-2014-056 and GEN-2015-057. The point of interconnection (POI) remains unchanged and is the Oklahoma Gas and Electric Company (OKGE) Minco 345kV substation.

The proposed new wind turbine generators, the GE 2.3MW and the GE 1.79MW, are electrically equivalent to the GE 2.0MW being replaced, and the dynamic characteristics are essentially the same. The topology of each Interconnection Request has changed due to change in the number of wind turbines needed to maintain the original (or near original) nameplate power output. This study analyzed the changes in system impedances between the original projects and the modified projects and found them to be insignificant. Therefore, the modified projects will have dynamic performances similar to their original studies. The requested changes do not constitute a Material Modification for either project. Except for the results of the reactor analysis (low wind/no wind conditions), the results of their respective original impact studies are still valid for GEN-2014-056 and GEN-2015-057 with the wind turbine modifications and with the swapping of their physical locations requested by the interconnection customer.

[1] See "DISIS-2014-002 (Group 1) Definitive Impact Study" final report produced by S&C Electric Company, dated January 22, 2015. The report is found in "Appendix J: Group 1 Dynamic Stability Analysis Report" in the SPP DISIS-2014-002 study posted in January 2015.
[2] See "DISIS-2015-002 (Group 1) Definitive Impact Study" final report produced by S&C Electric Company, dated March 11, 2016. The report is found in "Appendix J: Group 1 Dynamic Stability Analysis Report" in the SPP DISIS-2015-002 study posted in April 2016.

Since GEN-2014-056 is 250.0 MW in size and GEN-2015-057 is 100.0MW in size, GEN-2014-056 may require additional site control since it will be occupying the area whose site control was originally established for GEN-2015-057. The site control can be demonstrated in the final site layout.

A low-wind/no-wind condition analysis was performed for this modification request. GEN-2014-056 will be required to provide approximately 37.8 Mvars of reactive capability at its substation 34.5kV bus. GEN-2015-057 will be required to provide approximately 9.9 Mvars of reactive capability at its substation 34.5kV bus. 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. The Interconnection Customer may utilize the G.E. "WindFREE" option to meet this requirement.

With the assumptions outlined in this report and with all required network upgrades in place, GEN-2014-056 with ninety-nine (99) GE 2.3MW wind turbine generators and twelve (12) GE 1.79MW wind turbine generators (aggregate power of 249.18mw) and GEN-2015-057 with thirty-seven (37) GE 2.3MW wind turbine generators, three (3) GE 2.0MW wind turbine generators, and five (5) GE 1.79MW wind turbine generators (aggregate power of 100.05MW) 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.

Table of Contents

1. Introduction

The Interconnection Customer for GEN-2014-056 and GEN-2015-057 has requested a change in wind turbine generators. Table 1-1 shows the interconnection requests as originally studied in DISIS-2014-002 Group 1 (GEN-2014-056) and DISIS-2015-002 Group 1 (GEN-2015-057). Table 1-2 shows the requested wind turbine modification. The Point of Interconnection (POI) is the Oklahoma Gas and Electric Company (OKGE) Minco 345kV substation.

Table 1-1: Interconnection Request (Original Studies)

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2014-056	250.0	125 x GE 2.0MW	OKGE Minco 345kV Substation
GEN-2015-057	100.0	50 x GE 2.0MW	OKGE Minco 345kV Substation

Table 1-2: Interconnection Request (Modification Request)

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2014-056	249.8	99 x GE 2.3MW and 12 x GE 1.79MW	OKGE Minco 345kV Substation
GEN-2015-057	100.05	37 x GE 2.3MW, 3 x GE 2.0MW, and 5 x GE 1.79MW	OKGE Minco 345kV Substation

The proposed new wind turbine generators, GE 2.3MW and GE 1.79, are electrically equivalent to the GE 2.0MW being replaced, and the dynamic characteristics are essentially the same. The topologies of the projects must change in order to accommodate change in the number of wind turbine generators necessary to maintain the original (or near original) power output of each project. Additionally, the interconnection customer has requested an exchange in the physical locations of GEN-2014-056 and GEN-2015-057. The resulting changes in topology were analyzed.

The low-wind/no-wind analysis determines the capacitive effect at the POI caused by the projects' collector system and transmission line. Shunt reactor sizes were determined to offset the capacitive effect at the POI when the plant generators and capacitors are off-line such as might be seen in low-wind or no-wind conditions.

Nothing in this study constitutes a request for transmission service or grants the Interconnection Customer any rights to transmission service.

2. Facilities

Generating Facility

The point of interconnection (POI) for the GEN-2014-056 and GEN-2015-057 interconnection requests is OKGE Minco 345kV substation. The interconnection requests as originally studied are shown in Figure 2-1 and Figure 2-2.

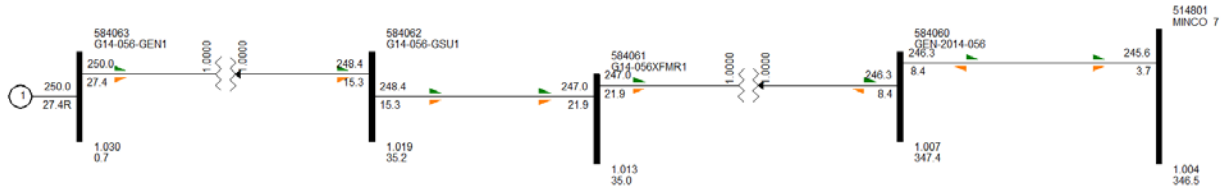

Figure 2-1: Power Flow Model and POI for GEN-2014-056 as originally studied in DISIS-2014-002[3]

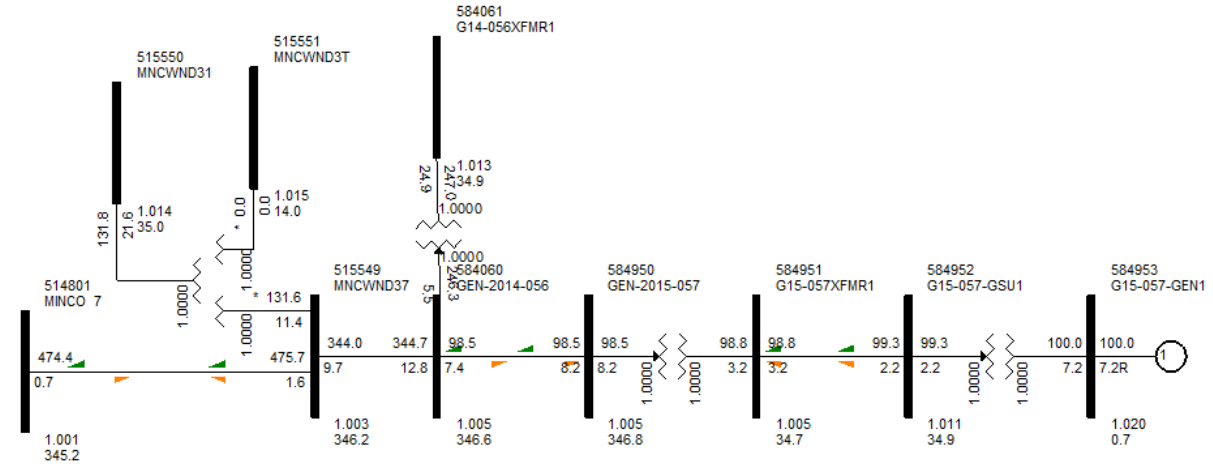

Figure 2-2: Power Flow Model and POI for GEN-2015-057 as originally studied in DISIS-2015-002[4]

The Interconnection Customer provided a PSSE raw data file that contained the modified requests. An equivalent power flow model was developed from the PSSE raw data and is shown in Figure 2-3.

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3 This figure is from "DISIS-2014-002 (Group 1) Definitive Impact Study" final report produced by S&C Electric Company, dated January 22, 2015. The report is found in "Appendix J: Group 1 Dynamic Stability Analysis Report" in the SPP DISIS-2014-002 study posted in January 2015.

4 This figure is from "DISIS-2015-002 (Group 1) Definitive Impact Study" final report produced by S&C Electric Company, dated March 11, 2016. The report is found in "Appendix J: Group 1 Dynamic Stability Analysis Report" in the SPP DISIS-2015-002 study posted in April 2016.

Note that GEN-2014-056 and GEN-2015-057 share a transmission line to the POI with GEN-2011-010 which is in commercial operation.

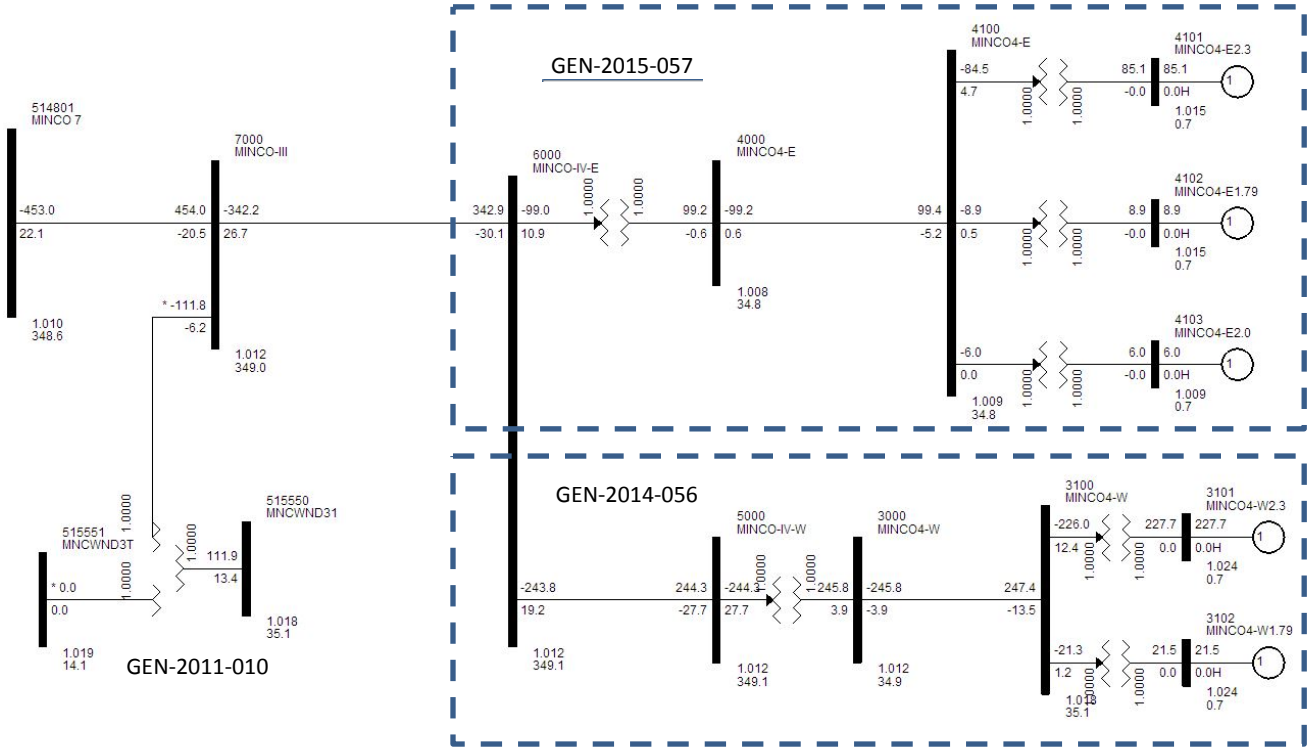

Figure 2-3: Power Flow Model and POI for the Modified GEN-2014-056 and GEN-2015-057 request

3. Modification Evaluation

The change in topology was analyzed to determine how much the system impedance changed from the original topology to the modified topology. This was done by using the ASCC feature of PSSE to determine the Thevenin equivalent impedances for the original and the modified topologies. If the change was less than 10%, then the impact was considered minimal.

The equivalent Thevenin impedance was determined for the original and modified topologies under the following two conditions:

1. The project under study to the POI which includes
   - The generator step units,
   - The equivalent collector system,
   - The substation transformer, and
   - The transmission line from the POI to project under study.

2. The project under study to the high side of its substation transformer which includes
   - The generator step units,
   - The equivalent collector system, and
   - The substation transformer.

The equivalent impedances are shown in the following tables. The greatest impedance change was much less than 10% and should have minimal effect on the original stability results. Therefore, the change in topologies is not considered a Material Modification.

Since GEN-2014-056 is 250.0 MW in size and GEN-2015-057 is 100.0MW in size, GEN-2014-056 may require additional site control since it will be occupying the area whose site control was originally established for GEN-2015-057. The site control can be demonstrated in the final site layout.

Table 3-1: GEN-2014-056 to POI			
	Rz (Ohm)	Xz (Ohm)	|Z| (Ohm)
MODIFICATION	12.071	463.351	463.508
ORIGINAL	8.765	461.774	461.857
		%change	%change
		0.342	0.357

Table 3-2: GEN-2015-057 to POI			
	Rz (Ohm)	Xz (Ohm)	|Z| (Ohm)
MODIFICATION	13.574	1052.897	1052.984
ORIGINAL	20.444	1126.042	1126.228
		%change	%change
		-6.496	-6.503

Table 3-3: GEN-2014-056 to high side substation xfmr			
	Rz (Ohm)	Xz (Ohm)	|Z| (Ohm)
MODIFICATION	9.876	440.988	441.099
ORIGINAL	7.408	448.586	448.647
		%change	%change
		-1.694	-1.683

Table 3-4: GEN-2015-057 to high side substation xfmr			
	Rz (Ohm)	Xz (Ohm)	|Z| (Ohm)
MODIFICATION	12.254	1039.443	1039.515
ORIGINAL	18.444	1112.283	1112.436
		%change	%change
		-6.549	-6.555

4. Stability Analysis

The greatest impedance change was much less than 10% and will have minimal effect on the original stability results. The results of the original stability analyses for GEN-2014-056 (DISIS-2014-002 Group 01) and GEN-2015-057 (DISIS-2015-002 Group 01) are still valid.

5. Power Factor Analysis

The power factor analysis for GEN-2014-056 that was reported in DISIS-2014-002 Group01 is still valid. The power factor analysis for GEN-2015-057 was reported in DISIS-2015-002 Group01 is still valid.

6. Reduced Generation 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.

Results

Shunt reactor requirements for the interconnection requests are shown below in Table 6-1.

Table 6-1: Summary of Shunt Reactor Requirements

Request	Capacity	Approximate Shunt Reactor Required
GEN-2014-056	249.18MW	37.8Mvar
GEN-2015-057	100.05MW	9.9Mvar

Figure 6-1 shows the capacitive effect that GEN-2014-056 and GEN-2015-057 (and also GEN-2011-010) have on the POI when the generators are offline and the rest of the facilities remain online. The capacitive effect is due to the charging of the collector system and the charging on the transmission leads. GEN-2014-056 and GEN-2015-057 will be responsible for their capacitive effects up to the point where they share the transmission lead to the POI with GEN-2010-010 (this is bus 7000 shown in Figure 6-1). Figure 6-2 shows how the addition of shunt reactors in GEN-

2014-056 and GEN-2015-057 will offset the reactive injection at the POI. The 5.9Mvar reactive injection at the POI is due to GEN-2011-010.

The detailed shunt reactor calculations are shown in Table 6-2 and in Table 6-3. See Figure 6-1 or Figure 6-2 for the bus numbers referenced in the two tables. The charging values in the two tables were taken from the raw file provided by the interconnection customer.

Description	From Bus	To Bus	Charging (Mvar)
Collector system	3100	3000	20.132
Transmission line	5000	6000	12.600
One Half of Transmission line	6000	7000	5.103
		Total	**37.835**

Table 6-2: GEN-2014-056 Detailed Shunt Reactor Calculation

Description	From Bus	To Bus	Charging (Mvar)
Collector system	4100	4000	4.776
One Half of Transmission line	6000	7000	5.103
		Total	**9.879**

Table 6-3: GEN-2015-057 Detailed Shunt Reactor Calculation

To offset the reactive injection at the POI during reduced generation conditions reactors (or other reactive means such as the “WindFree” option available on GE wind turbine generators) will be needed at the generation facility.

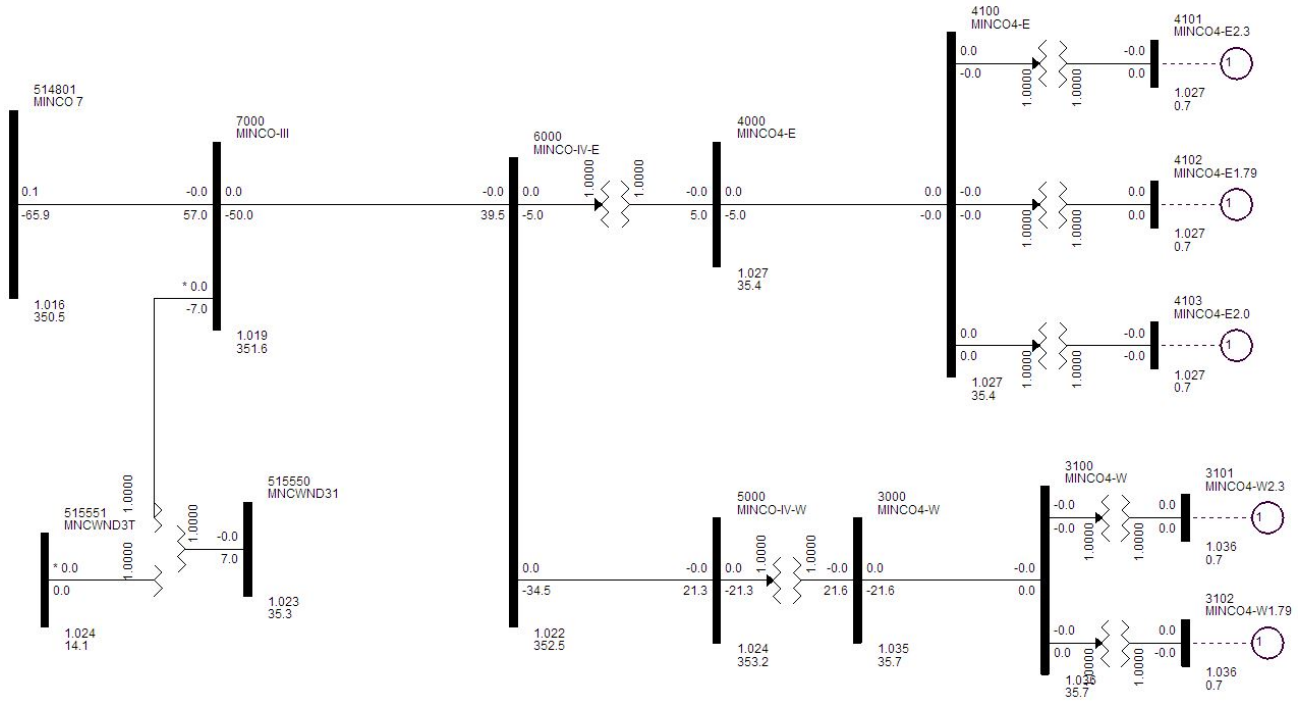

Figure 6-1: GEN-2014-056 and GEN-2015-057 with generators off and no shunt reactors

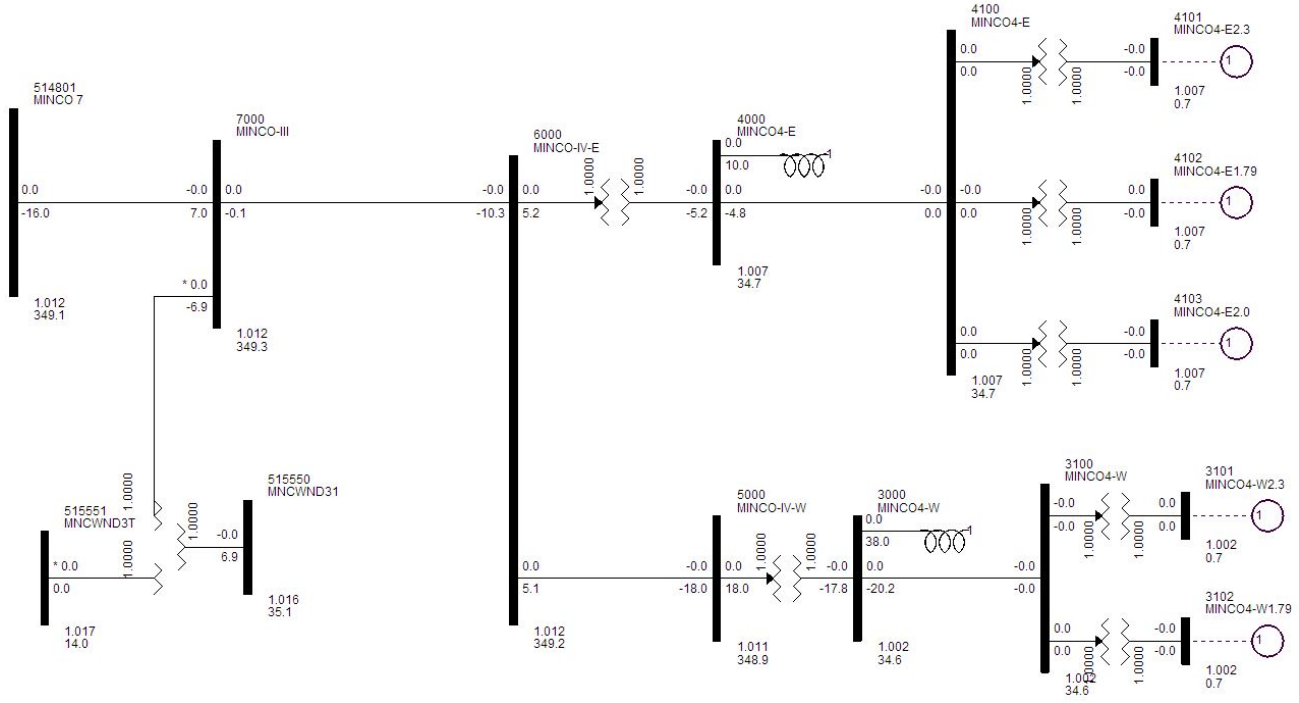

Figure 6-2: GEN-2014-056 and GEN-2015-057 with generators off and with shunt reactors on low side of 345/34.kV substation transformers

7. Short Circuit Analysis

Refer to Appendix J for the Group 01 Dynamic Stability Analysis Report in the original posting of DISIS-2015-002 for the short circuit analysis. The results are still valid for both GEN-2014-056 and GEN-2015-057.

8. Conclusion

The Interconnection Customer for GEN-2014-056 and GEN-2015-057 has requested a modification to their Interconnection Requests to use the wind turbine generators as shown in Table 1-2. Additionally, the modification request swaps the physical positions of GEN-2014-056 and GEN-2015-057

The analysis has shown that the requested wind turbine modifications to GEN-2014-056 and GEN-2015-057 swapping of physical locations do not constitute a material modification. With exception of the reactor requirements the results of the DISIS-2014-002 Group 01 and DISIS-2015-002 Group 01 studies are still valid for the requested wind turbine modifications.

A low-wind/no-wind condition analysis was performed for the wind turbine modification requests. GEN-2014-056 and GEN-2015-057 will be required to provide shunt reactive capability as shown in Table 6-1 on their substation 34.5kV bus(es). These are necessary to offset the capacitive effect on the transmission network caused by the projects' transmission lines and collector systems during low-wind/no-wind conditions. The Interconnection Customer may utilize the G.E. "WindFREE" option to meet these requirements.

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 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.