GEN-2014-056 & GEN-2015-057

Impact Restudy for
Generator Modification
(Turbine Change)

Published October 2018

By SPP Generator Interconnections Dept.

REVISION HISTORY

DATE OR VERSION NUMBER	AUTHOR	CHANGE DESCRIPTION
10/18/2018	SPP	Initial report issued.

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SUMMARY

The GEN-2014-056 and GEN-2015-057 Interconnection Customer has requested a modification to its Interconnection Request. This system impact restudy was performed to determine the effects of changing wind turbine generators from the previously studied ninety-nine (99) GE 2.3 MW and twelve (12) GE 1.79MW wind turbine generators at GEN-2014-056 and thirty-seven (37) GE 2.3 MW, three (3) GE 2.0 MW and five (5) GE 1.79 MW wind turbine generators at GEN-2015-057 to fifty-six (56) GE 1.715 MW, ten (10) GE 1.79 MW, fifty-four (54) GE 2.5 MW wind turbine generators at GEN-2014-056 and five (5) GE 1.79 MW , twenty-nine (29) GE 2.3 MW and ten (10) GE 2.5 MW wind turbine generators at GEN-2015-057. The total nameplate changes from 100.05 MW at GEN-2014-056 and 249.18 MW at GEN-2015-057 to 100.65 MW at GEN-2014-056 and 248.94 MW at GEN-2015-057. The point of interconnection (POI) is at the Oklahoma Gas & Electric (OKGE) Minco 345 kV Substation.

Because the turbine changes were all from GE turbines to GE turbines and the total change in collector system impedance was less than 10%, no stability analysis was performed

A power factor analysis was previously performed and remains valid. The facility will be required to maintain a 95% lagging (providing VARs) and 95% leading (absorbing VARs) power factor at the POI. A low-wind/no-wind condition analysis was performed identifying a need for 37.6 MVAr of reactive compensation at GEN-2014-056 and 10.5 MVAr of reactive compensation at GEN-2015-057. 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. Reactive compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability.

With the assumptions outlined in this report and with all the required network upgrades from the DISIS 2016-001-1 in place, fifty-six (56) GE 1.715 MW, ten (10) GE 1.79 MW, fifty-four (54) GE 2.5 MW wind turbine generators at GEN-2014-056 and five (5) GE 1.79 MW , twenty-nine (29) GE 2.3 MW and ten (10) GE 2.5 MW wind turbine generators at GEN-2015-057 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. 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.

A: CONSULTANT'S MATERIAL MODIFICATION STUDY REPORT

See next page for the Consultant's Material Modification Study report.

Aneden Consulting

Submitted to

Southwest Power Pool

SPP Southwest Power Pool

Report On

GEN-2014-056_2015-057
Modification Request Impact Study

Revision R1

anedenconsulting.com

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Executive Summary

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2014-056 and GEN-2015-057, an active generation interconnection requests with the same point of interconnection (POI) at the Minco 345 kV Substation.

The GEN-2014-056 and GEN-2015-057 projects are proposed to interconnect in the Oklahoma Gas and Electric (OKGE) control area with a combined capacity of 349.23 MW. GEN-2014-056 current configuration includes ninety-nine (99) GE 2.3 MW wind turbine generators and twelve (12) GE 1.79MW wind turbine generators (aggregate power of 249.18 MW) while GEN-2015-057 currently comprises of thirty-seven (37) GE 2.3 MW wind turbine generators, three (3) GE 2.0 MW wind turbine generators, and five (5) GE 1.79 MW wind turbine generators (aggregate power of 100.05MW). This Study has been requested to evaluate the modification of GEN-2014-056 and GEN-2015-057 to change turbine configurations with a combined capacity of 349.59 MW:

- GEN-2014-056: 56 x GE 1.715 MW+ 10 x GE 1.79 MW + 54 x GE 2.5 MW wind turbines
- GEN-2015-057: 5 x GE 1.79 MW + 29 x GE 2.3 MW + 10 x GE 2.5 MW wind turbines

In addition, the modification request included changes to the generation interconnection lines, and the collection system. The modification request changes are shown in Table ES-1 below.

Table ES-1: GEN-2014-056/GEN-2015-057 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Minco 345 kV Substation (532874)	Minco 345 kV Substation (532874)
Configuration/Capacity	99 x GE 2.3 MW, 12 x GE 1.79 MW = 249.18 MW 37 x GE 2.3 MW, 3 x GE 2.0 MW, 5 x 1.79 MW = 100.05 MW	56 x GE 1.715 MW+ 10 x GE 1.79 MW + 54 x GE 2.5 MW = 248.94 MW 5 x GE 1.79 MW GE+ 29 x GE 2.3 MW GE + 10 x GE 2.5 MW = 100.65 MW
POI to MINCO-WTG3 Junction Generation Interconnection Line	Length = 10.4 miles R = 0.000560 pu X = 0.005090 pu B = 0.090600 pu	Length = 10.4 miles R = 0.000560 pu X = 0.005090 pu B = 0.090600 pu
MINCO-WTG3 to GEN-2015-057 Generation Interconnection Line	Length = 15 miles R = 0.000600 pu X = 0.006060 pu B = 0.102060 pu	Length = 12.15 miles R = 0.000660 pu X = 0.005700 pu B = 0.109080 pu
GEN-2015-057 to GEN-2014-056 Generation Interconnection Line	Length = 12.5 miles R = 0.000740 pu X = 0.007490 pu B = 0.126000 pu	Length = 15.6 miles R = 0.000850 pu X = 0.007370 pu B = 0.140060 pu
Main Substation Transformers	GEN-2014-056: Z = 9%, Rating 280 MVA GEN-2015-057: Z = 8%, Rating 125 MVA	GEN-2014-056: Z = 9%, Rating 280 MVA GEN-2015-057: Z = 8%, Rating 125 MVA
GEN-2014-056 Equivalent Collector Line	R = 0.002720 pu X = 0.005650 pu B = 0.201320 pu	R = 0.007510 pu X = 0.013860 pu B = 0.183000 pu

GEN-2015-057 Equivalent Collector Line	R = 0.001370 pu X = 0.001990 pu B = 0.047760 pu	R = 0.008570 pu X = 0.014410 pu B = 0.047080 pu

The modification request retains the same GE wind turbine technology and as such, the combined impedances from the POI up to and including the step-up transformers for both GEN-2014-056 and GEN-2015-057 were calculated before and after the modification requests. The results showed that the change in the combined impedances were 7.2% and 7.5% for GEN-2014-056 and GEN-2015-057. As a result, the scope of this modification request study was limited to the reactive power analysis (low wind) analysis.

Aneden performed reactive power analysis using the modification request data based on the DISIS-2016-001 ReStudy #1 Group 1 study models:

1. 2016 Winter Peak (2016WP),
2. 2017 Summer Peak (2017SP) and
3. 2025 Summer Peak (2025SP).

A power factor analysis was not performed since there was no modification to the current point of interconnection.

The results of the reactive power analysis, also known as the low-wind/no-wind condition analysis, performed using all three models showed that the GEN-2014-056 and GEN-2015-057 project may require 37.6 MVAr and 10.5 MVAr shunt reactors at their respective 345 kV collector substations. The shunt reactors are needed to reduce the reactive power transfer at the POI to approximately zero during low/no wind conditions while the generation interconnection project remains connected to the grid.

The results of this Study show that the GEN-2014-056/GEN-2015-057 Modification Request does not constitute a material modification.

1.0 Introduction

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2014-056/GEN-2015-057, an active generation interconnection request with point of interconnection (POI) at the Minco 345 kV Substation.

The GEN-2014-056 and GEN-2015-057 projects are proposed to interconnect in the Oklahoma Gas and Electric (OKGE) control area with a combined capacity of 349.23 MW. GEN-2014-056 current configuration includes ninety-nine (99) GE 2.3 MW wind turbine generators and twelve (12) GE 1.79MW wind turbine generators (aggregate power of 249.18 MW) while GEN-2015-057 currently comprises of thirty-seven (37) GE 2.3 MW wind turbine generators, three (3) GE 2.0 MW wind turbine generators, and five (5) GE 1.79 MW wind turbine generators (aggregate power of 100.05MW) as shown in **Table 0-2** below. Details of the modification request as provided in Section 2.0 below.

Table 0-2: Existing GEN-2014-056/GEN-2015-057 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2014-056	249.18	99 x GE 2.3 MW, 12 x GE 1.79 MW	Minco 345 kV Substation (532874)
GEN-2015-057	100.05	37 x GE 2.3 MW, 3 x GE 2.0 MW, 5 x 1.79 MW	Minco 345 kV Substation (532874)
Total	**349.23**		

Scope

The Study included equivalent impedance comparison and reactive power analysis. The methodology, assumptions and results of the analyses are presented in the following four main sections:

1. Project and Modification Request
2. Equivalent Impedance Comparison
3. Reactive Power Analysis
4. Conclusions

Aneden performed a reactive power analysis, short circuit analysis and dynamic stability analysis using a set of modified study models developed using the modification request data and the three DISIS-2016-001 ReStudy #1 study models:

1. 2016 Winter Peak (2016WP),
2. 2017 Summer Peak (2017SP), and
3. 2025 Summer Peak (2025SP).

All analyses were performed using the PTI PSS/E version 32 software. The results of each analysis are presented in the following sections.

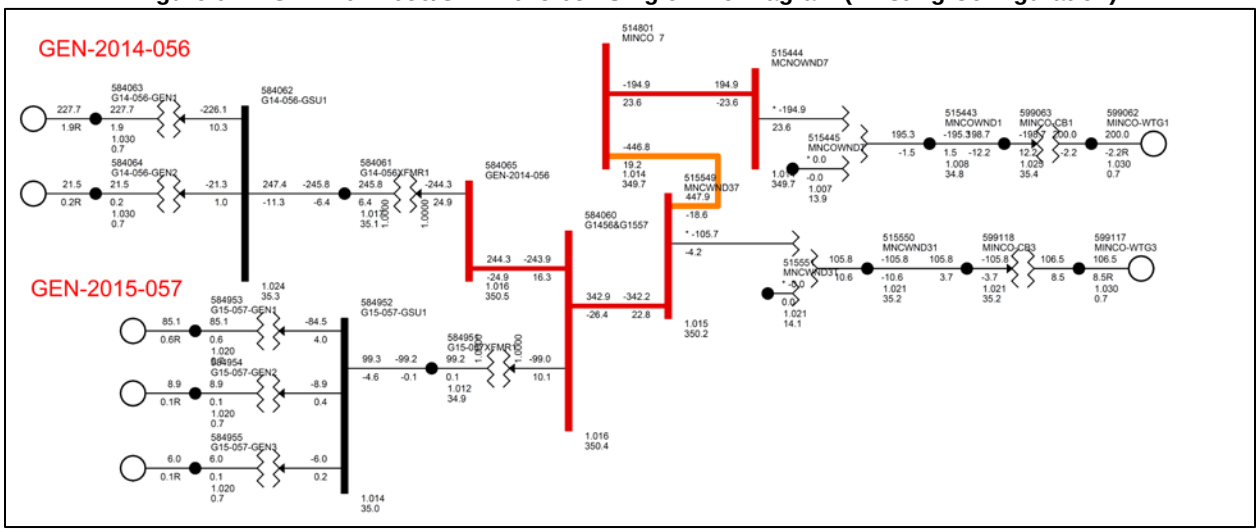
Study Limitations

The assessments and conclusions provided in this report are based on assumptions and information provided to Aneden by others. While the assumptions and information provided may be appropriate for the purposes of this report, Aneden does not guarantee that those conditions assumed will occur. In addition, Aneden did not independently verify the accuracy or completeness of the information provided. As such, the conclusions and results presented in this report may vary depending on the extent to which actual future conditions differ from the assumptions made or information used herein.

2.0 Project and Modification Request

Figure 0-1 shows the power flow model single line diagram for the existing GEN-2014-056 and GEN-2015-057 configuration.

Figure 0-1: GEN-2014-056/GEN-2015-057 Single Line Diagram (Existing Configuration)



The GEN-2014-056/GEN-2015-057 Modification Request included a change to turbine configurations with a combined capacity of 349.59 MW:

- GEN-2014-056: 56 x GE 1.715 MW+ 10 x GE 1.79 MW + 54 x GE 2.5 MW wind turbines
- GEN-2015-057: 5 x GE 1.79 MW + 29 x GE 2.3 MW + 10 x GE 2.5 MW wind turbines

In addition, the modification request also included changes to the collection system, the main substation transformer and the generation interconnection line. The major modification request changes are shown in Figure 0-2 and Table 0-3 below.

Figure 0-2: GEN-2014-056/GEN-2015-057 Single Line Diagram (New Configuration)

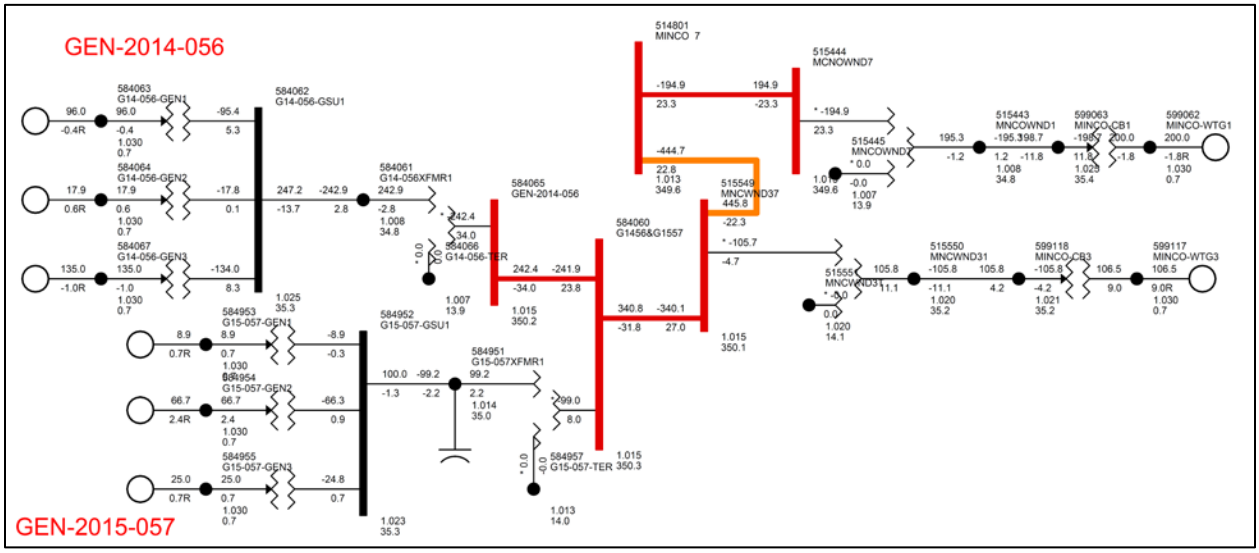


Table 0-3: GEN-2014-056/GEN-2015-057 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Minco 345 kV Substation (532874)	Minco 345 kV Substation (532874)
Configuration/Capacity	99 x GE 2.3 MW, 12 x GE 1.79 MW = 227.7 MW 37 x GE 2.3 MW, 3 x GE 2.0 MW, 5 x 1.79 MW = 85.1 MW	5 x GE 1.79 MW GE+ 29 x GE 2.3 MW GE + 10 x GE 2.5 MW = 100.65 MW 56 x GE 1.715 MW+ 10 x GE 1.79 MW + 54 x GE 2.5 MW = 248.94 MW
POI to MINCO-WTG3 Junction Generation Interconnection Line	Length = 10.4 miles R = 0.000560 pu X = 0.005090 pu B = 0.090600 pu	Length = 10.4 miles R = 0.000560 pu X = 0.005090 pu B = 0.090600 pu
MINCO-WTG3 to GEN-2015-057 Generation Interconnection Line	Length = 15 miles R = 0.000600 pu X = 0.006060 pu B = 0.102060 pu	Length = 12.15 miles R = 0.000660 pu X = 0.005700 pu B = 0.109080 pu
GEN-2015-057 to GEN-2014-056 Generation Interconnection Line	Length = 12.5 miles R = 0.000740 pu X = 0.007490 pu B = 0.126000 pu	Length = 15.6 miles R = 0.000850 pu X = 0.007370 pu B = 0.140060 pu
Main Substation Transformers	GEN-2014-056: Z = 9%, Rating 280 MVA GEN-2015-057: Z = 8%, Rating 125 MVA	GEN-2014-056: Z = 9%, Rating 280 MVA GEN-2015-057: Z = 8%, Rating 125 MVA
GEN-2014-056 Equivalent Collector Line	R = 0.002720 pu X = 0.005650 pu B = 0.201320 pu	R = 0.007510 pu X = 0.013860 pu B = 0.183000 pu
GEN-2015-057 Equivalent Collector Line	R = 0.001370 pu X = 0.001990 pu B = 0.047760 pu	R = 0.008570 pu X = 0.014410 pu B = 0.047080 pu

3.0 Equivalent Impedance Comparison

The power factor analysis was performed using the modified study models created using the DISIS-2016-001 ReStudy #1 2016WP, 2017SP and 2025SP models. The methodology and results of the power flow analysis are described below. The analysis was completed using PSS/E version 32 software. The detail results are provided in Appendix A.

Methodology and Criteria

The impedances from all the components of the transmission lines, substation and step-up transformers and equivalent collector line impedances were added in series for GEN-2014-056 and GEN-2015-057 before and after the modification request. The percentage increase in the impedances before and after the modification request were then compared. If the percentage increase was greater than 10%, additional dynamic stability analysis would be performed to assess the impact of the modification request.

Results

Table 0-4 shows the impedance differences before and after the modification request. **Table 0-5** shows the increases in impedances from the original impedances to the modification request impedances. The results showed that the impedance increase was below 10%.

Table 0-4: GEN-2014-056/GEN-2015-057 Impedance Comparisons

System Component	Modification Request Impedances (p.u.)			Original Model Impedances (p.u.)		
	R	***X***	***B***	***R***	***X***	***B***
Gen Tie Line from MINCO 7 to MNCWND Junction	0.00056	0.00509	0.09060	0.00056	0.00509	0.09060
Gen Tie Line from MNCWND Junction to GEN-2015-057 Substation	0.00066	0.00570	0.10908	0.00060	0.00606	0.10206
Gen Tie Line from GEN-2015-057 to GEN-2014-056	0.00085	0.00737	0.14006	0.00074	0.00749	0.12600
GEN-2014-056 Collector System Equivalent	0.00751	0.01386	0.18300	0.00272	0.00565	0.20132
GEN-2015-057 Collector System Equivalent	0.00857	0.01441	0.04708	0.00137	0.00199	0.04776
	R	***X***	***MVA Base***	***R***	***X***	***MVA Base***
GEN-2014-056 Main Transformer @ 100 MVA	0.00088	0.05357	100	0.00252	0.05351	100
GEN-2015-057 Main Transformer @ 100 MVA	0.00200	0.10677	100	0.00193	0.10665	100
GEN-2014-056 Unit 1 Equivalent GSU @ 100 MVA	0.00293	0.02202	100	0.003049	0.022864	100
GEN-2014-057 Unit 2 Equivalent GSU @ 100 MVA	0.00695	0.05700	100	0.007525	0.056436	100
	R	***X***	***Z***	***R***	***X***	***Z***
GEN-2014-056 Total Impedance from POI to Generator	0.013386	0.107609	0.108439	0.010192	0.100666	0.101181
GEN-2015-057 Total Impedance from POI to Generator	0.018744	0.188963	0.189890	0.011988	0.176229	0.176636

Table 0-5: GEN-2014-056/GEN-2015-057 Combined Impedance Comparisons

Interconnection Request	Impedance Z (p.u.)
GEN-2014-056 Impedance Increase	7.17%
GEN-2015-057 Impedance Increase	7.50%

4.0 Reactive Power Analysis

The reactive power analysis, also known as the low-wind/no-wind condition analysis, was performed for GEN-2014-056/GEN-2015-057 to determine the reactive power contribution from the project's interconnection line and collector transformer and cables during low/no wind conditions while the project is still connected to the grid and to size shunt reactors that would reduce the project reactive power contribution to the POI to approximately zero.

Methodology and Criteria

For the GEN-2014-056/GEN-2015-057 project, the generator was switched out of service while other collector system elements remained in-service. A shunt reactor was tested at the study project substation high side bus to bring the MVAr flow into the POI down to approximately zero.

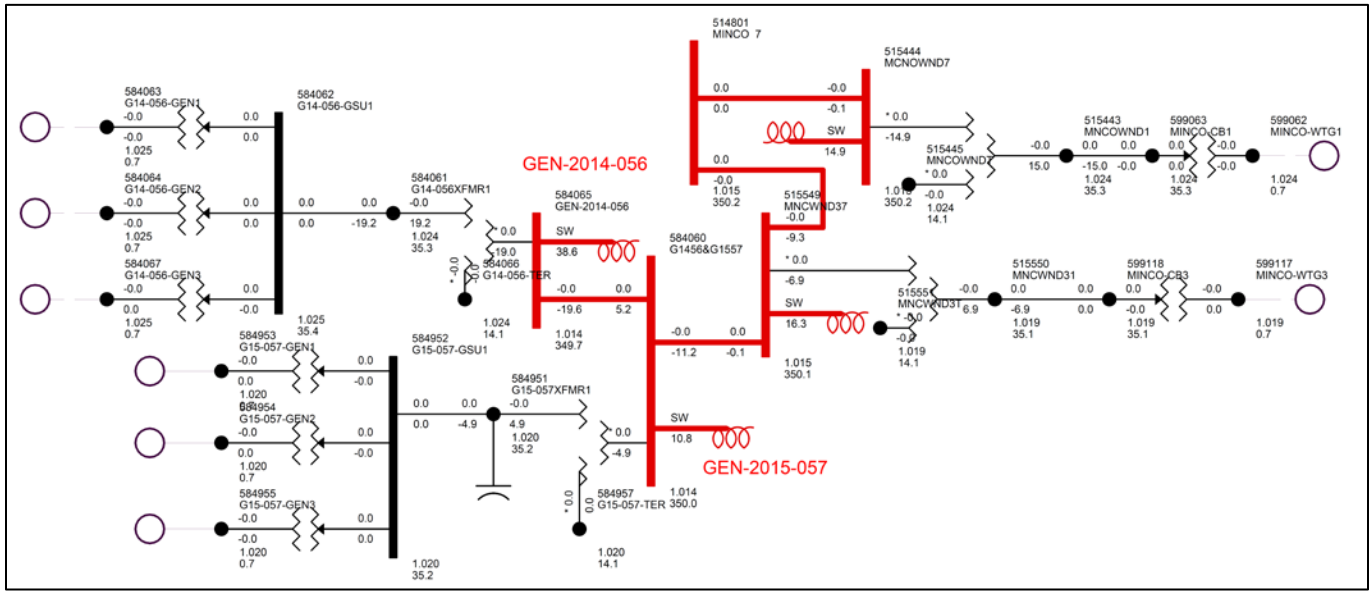
Results

The results from the reactive power analysis showed that the GEN-2014-056 and GEN-2015-057 project required approximately 37.6 MVAr and 10.5 shunt reactors respective at the project substations, to reduce the POI MVAr to zero. **Figure 0-3** illustrates the shunt reactor size required to reduce the POI voltage to approximately zero. Reactive compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability. Note that the GEN-2015-057 capacitor bank was not contributing reactive power to the collection system.

Table 0-6: Shunt Reactor Size for Low Wind Study

Machine	POI Bus Number	POI Bus Name	Reactor Size (MVAr)		
			16WP	17SP	25SP
GEN-2014-056	514801	MINCO 7	37.6	37.6	37.6
GEN-2015-057	514801	MINCO 7	10.5	10.5	10.5

Figure 0-3: GEN-2014-056/GEN-2015-057 Single Line Diagram (Shunt Reactor)


GEN-2014-056
GEN-2015-057
584063 G14-056-GEN1
584064 G14-056-GEN2
584067 G14-056-GEN3
584062 G14-056-GSU1
584061 G14-056XFMR1
584065 GEN-2014-056
584066 G14-056-TER
584953 G15-057-GEN1
584954 G15-057-GEN2
584955 G15-057-GEN3
584952 G15-057-GSU1
584951 G15-057XFMR1
584957 G15-057-TER
584060 G1456&G1557
514801 MINCO 7
515444 MCNOWND7
515445 MCNOWND2
515549 MCNWND37
515550 MCNWND31
515443 MNCOWND1
599063 MINCO-CB1
599062 MINCO-WTG1
599118 MINCO-CB3
599117 MINCO-WTG3

5.0 Conclusions

The Interconnection Customer for GEN-2014-056 and GEN-2015-057 requested a Modification Request Impact Study to assess the impact of the turbine and facility changes presented in **Table 0-7** below.

Table 0-7: Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Minco 345 kV Substation (532874)	Minco 345 kV Substation (532874)
Configuration/Capacity	99 x GE 2.3 MW, 12 x GE 1.79 MW = 227.7 MW 37 x GE 2.3 MW, 3 x GE 2.0 MW, 5 x 1.79 MW = 85.1 MW	5 x GE 1.79 MW GE+ 29 x GE 2.3 MW GE + 10 x GE 2.5 MW = 100.65 MW 56 x GE 1.715 MW+ 10 x GE 1.79 MW + 54 x GE 2.5 MW = 248.94 MW
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GEN-2015-057 Equivalent Collector Line	R = 0.001370 pu X = 0.001990 pu B = 0.047760 pu	R = 0.008570 pu X = 0.014410 pu B = 0.047080 pu

The results of the reactive power analysis, also known as the low-wind/no-wind condition analysis, performed using all three models showed that the GEN-2014-056 and GEN-2015-057 project required approximately 37.6 MVAr and 10.5 shunt reactors on the 345 kV bus of the project substations. The shunt reactor is needed to reduce the reactive power transfer at the POI to approximately zero during low/no wind conditions while the generation interconnection project remains connected to the grid.

In conclusion, the results of this Study showed that the Modification Request shown in Table 0-7 do not constitute a material modification.