GEN-2013-032 & GEN-2015-053 Impact Restudy for Generator Modification (Turbine Change)

March 2018
Generator Interconnection

SPP Southwest Power Pool

Revision History

Date	Author	Change Description
03/21/2018	SPP	First draft

Executive Summary

The Interconnection Customer for GEN-2013-032 and GEN-2015-053 has requested wind turbine generator modifications to its Generator Interconnection Agreement and has also requested that the two requests be combined into one. The requested change is from one-hundred twenty (120) GE 1.7MW wind turbine generators in GEN-2013-032 (aggregate power of 204MW) plus twenty-eight (28) GE 1.79MW wind turbine generators in GEN-2015-053 (aggregate power of 50.12MW) to one-hundred one (101) GE 2.5MW wind turbine generators (aggregate power of 252.5MW).

The point of interconnection (POI) remains unchanged at the Nebraska Public Power District (NPPD) Antelope 115kV substation. However, the two prior requests will now share a common substation and 115 kV transmission line to this POI.

The proposed new GE 2.5MW wind turbine generators are electrically equivalent to the GE 1.7MW and GE 1.79MW versions being replaced, and the dynamic characteristics are essentially the same. The topology of the project has changed in order to accommodate the reduction in quantity of wind turbine generators to be used in the project, combining the collector cables into a common substation, changing from a single main transformer to two transformers, and sharing a common transmission line to the POI. This study analyzed the change in system impedance between the original project and the modified project and found it to be a 7.77% increase, and, therefore, the modified project will have a steady state and dynamic performance similar to the original study. The results of the previous studies of GEN-2013-032[1] and GEN-2015-053[2], except for the results of the reactor analyses, are still valid.

Power factor requirements for GEN-2013-032 and GEN-2015-053 can be found in the previous system impact studies and are still valid for this change request. The combined facilities 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 for this modification request. GEN-2013-032 and GEN-2015-053 will be required to install approximately 22 Mvars of shunt reactors on its substation 34.5kV buses. This is necessary to offset the capacitive effect on the transmission network caused by the projects' transmission line and collector system during low-wind/no-wind

[1] See *Definitive Interconnection System Impact Restudy DISIS-2013-002* posted 1/31/2014, which may be accessed through the following link:
http://sppoasis.spp.org/documents/swpp/transmission/studies/files/2013_Generation_Studies/DISIS-2013-002_Final_1_31_2014.pdf

[2] See *Definitive Interconnection System Impact Study DISIS-2015-002-1* posted 8/5/2016, which may be accessed through the following link:
http://sppoasis.spp.org/documents/swpp/transmission/studies/files/2015_Generation_Studies/DISIS-2015-002-1_FINAL_08052016.pdf

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-2013-032 and GEN-2015-053 with the GE 2.5MW wind turbine generators should be able to reliably interconnect to the SPP transmission grid.

The results of this study show that the requested generator turbine modification does not constitute a Material Modification.

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-2013-032 and GEN-2015-053 has requested a change in wind turbine generators and has also requested that the two requests be combined into one. Table 1-1 shows both interconnection requests as previously studied. Table 1-2 shows the requested wind turbine modification and combination of the projects.

Table 1-1: Interconnection Request (Previous Studies)

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2013-032	204	120 x GE 1.7MW	Antelope 115kV substation
GEN-2015-053	50.12	28 x GE 1.79MW	Antelope 115kV substation
Total	**254.12**		

Table 1-2: Interconnection Request (Modification)

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2013-032 and GEN-2015-053	252.5	101 x GE 2.5MW	Antelope 115kV substation

The proposed new GE 2.5MW wind turbine generators are electrically equivalent to the GE 1.7MW and GE 1.79MW versions being replaced, and the dynamic characteristics are essentially the same. The total number of wind turbines is reduced which required a change in topology. Collector cables now connect to a common substation and that common station now contains two transformers. The combined request now also shares a common transmission line to the POI.

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 approximately 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.

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 both GEN-2013-032 and GEN-2015-053 is the Antelope 115kV substation. The interconnection requests as previously studied are both shown in Figure 2-1.

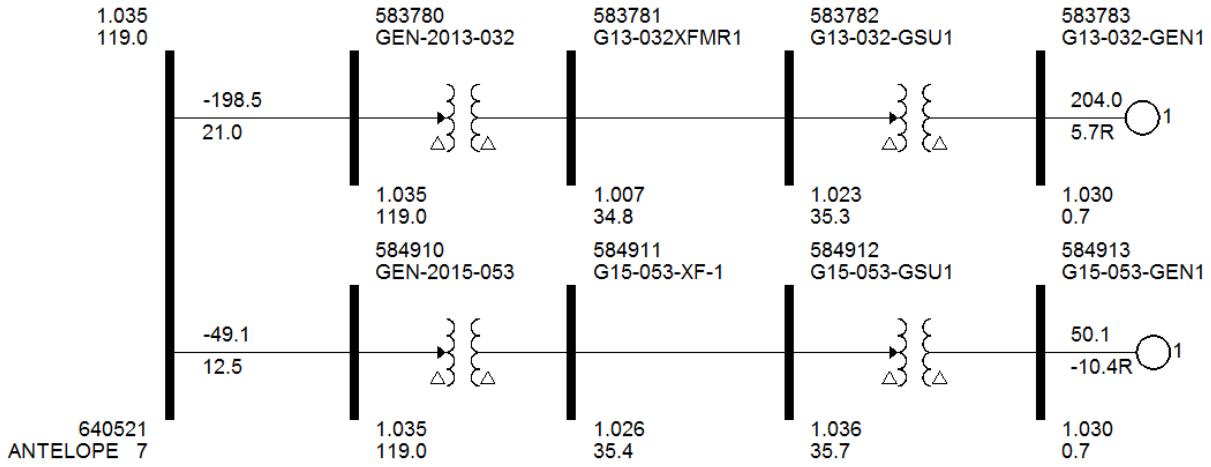

Figure 2-1: Power Flow Model and POI for GEN-2013-032 and GEN-2015-053 as previously studied

An updated equivalent power flow model was developed from the data provided by the interconnection customer and is shown in Figure 2-2.

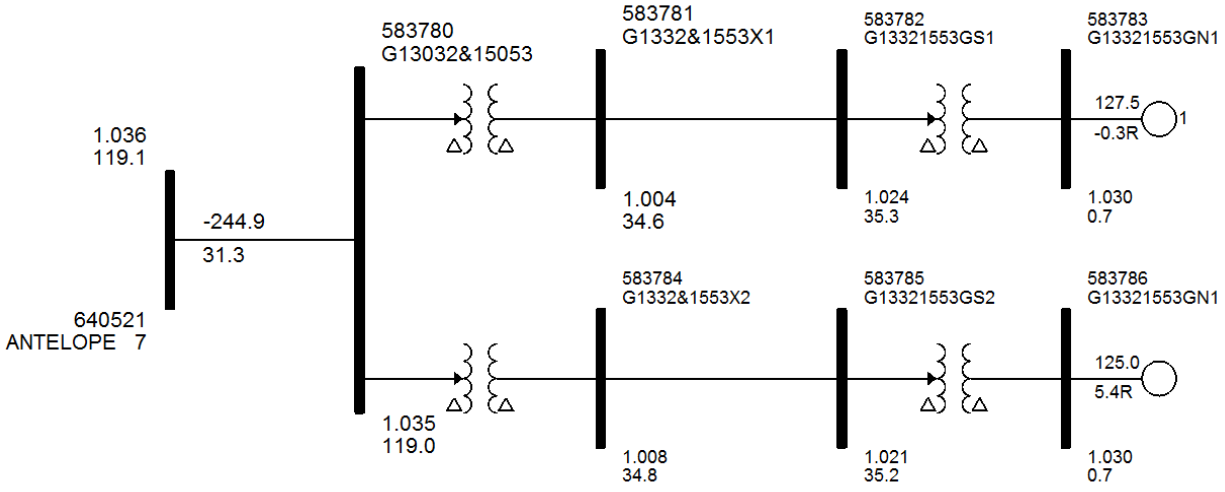

Figure 2-2: Power Flow Model and POI for the Modified and combined GEN-2013-032 and GEN-2015-053

3. Modification Evaluation

The electrical characteristics and the dynamic response of the GE 2.5MW, GE 1.7MW and the GE 1.79MW wind turbine generators are nearly identical. The change in topology due to the reduced number of wind turbines, and shared substation and transmission line was analyzed to determine how much the system impedance changed from the previous topology to the modified topology. This was done by using the ASCC (Automatic Sequence Fault Calculation) feature of PSSE to determine the Thevenin equivalent impedances for the previous and the modified topologies.

The Customer's facilities collection station (shown as bus number 640521 in Figures 2-1 and 2-2) was used as the "home" bus for the PSSE ASCC function. The Thevenin impedance was obtained before and after the modification. The generator Zsource was subtracted from the Thevenin impedance since it is the same as for all three of the GE wind turbines. The resultant Thevenin impedance is due to:

- The short transmission line from the shared GEN-2013-032 and GEN-2015-053 substation to the Interconnection Customer's facilities collection station,
- The substation transformer(s),
- The equivalent collector system,
- The generator step up units.

Note that all other elements not related to GEN-2013-032 and GEN-2015-053 were disconnected to remove their effects in determining the equivalent impedances.

The equivalent impedances are as follows:

Z_{TH}(previous) = 54.098 ∠ 88.296° Ohms
Z_{TH} (modified) = 58.300 ∠ 88.212° Ohms

The percent change is as follows (only the magnitudes of the impedances were used in the following calculation):

D = [Z_{TH} (modified) – Z_{TH} (previous)] / Z_{TH} (previous) * 100 %
D = [58.3 – 54.098] / 54.098 * 100
D = 7.77% increase

The change in impedance is a 7.77 % increase, and the modification will have minimal impact on the results in the previous restudy.

4. Stability Analysis

A stability analysis for this modification request was not performed. The results from the previous study are still valid

5. Power Factor Analysis

A power factor analysis for this modification request was not performed. Power factor requirements for GEN-2013-032 and GEN-2015-053 can be found in the previous system impact studies and are still valid for this change request. The combined facilities will be required to maintain a 95% lagging (providing VARs) and 95% leading (absorbing VARs) power factor at the POI.

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 and the generation facility still connected to the grid.

Results

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

Table 6-1: Summary of Shunt Reactor Requirements

Capacity	POI	Approximate Shunt Reactor Required
252.5	Antelope 115kV substation	22 Mvar

Figure 6-1 shows the capacitive effect that the combined GEN-2013-032 and GEN-2015-053 has on the POI when the generators are offline and the rest of the facility remains online. The capacitive effect is primarily due to the charging of the collector system and the charging on the transmission lead to the Interconnection Customer's facilities collection station.

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 wind farm project. For the combined GEN-2013-032 and GEN-2015-053, the reactor required is approximately 22 Mvar as shown in Figure 6-2.

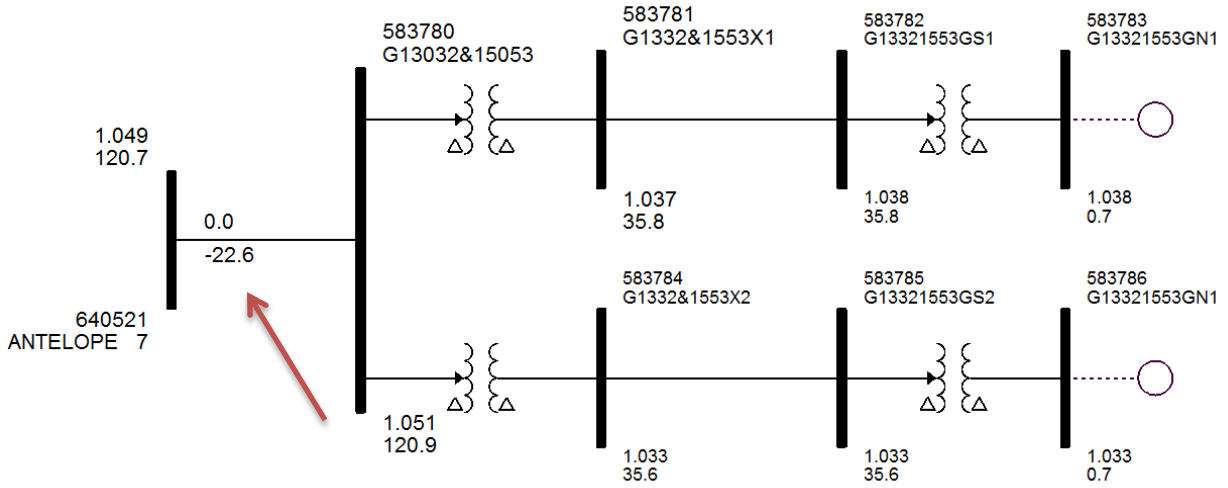

Figure 6-1: **GEN-2013-032 and GEN-2015-053** ***with generators off and no shunt reactors***

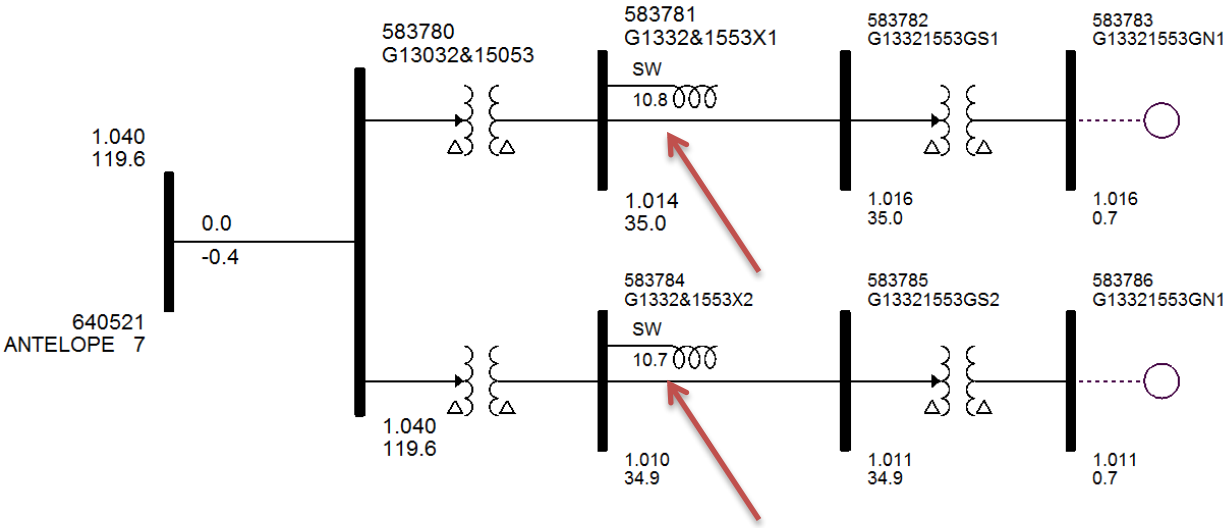

Figure 6-2: **GEN-2013-032 and GEN-2015-053** ***with generators off and with shunt reactor***

7. Short Circuit Analysis

A short circuit analysis for this modification request was not performed. The results from the previous study are still valid.

8. Conclusion

The Interconnection Customer for both GEN-2013-032 and GEN-2015-053 has requested a modification to its Generator Interconnection Agreement to change wind turbine generators from GE 1.7MW and GE 1.79MW to GE 2.5MW as shown in Table 1-2. They have also requested that the two requests be combined into one.

With the exception of the reactor requirement, the results of the previous studies are still valid for both GEN-2013-032 and GEN-2015-053 as modified with GE 2.5MW wind turbine generators.

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 for this wind turbine modification request. GEN-2013-032 will be required to install approximately 22 Mvars of shunt reactors on its substation 34.5kV buses. This is necessary to offset the capacitive effect on the transmission network caused by the projects' 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.

The results of this study show that the requested generator turbine modification does not constitute a Material Modification.

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.