

**GEN-2007-062 Phase II  
Impact Restudy for  
Generator Modification  
(Turbine Change)**

**December 2017  
Generator Interconnection**



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## Revision History

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Date	Author	Change Description
12/15/2017	SPP	GEN-2007-062 Phase II Impact Restudy for Generator Modification (Turbine Change) issued.

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## Executive Summary

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The Interconnection Customer for GEN-2007-062 Phase II has requested wind turbine generator modifications to its Generator Interconnection Agreement. The requested change is from eighty-three (83) GE 2.4MW wind turbine generators (aggregate power of 199.2MW) to seventy-three (73) GE 2.5MW wind turbine generators and seven (7) GE 2.3MW wind turbine generators (aggregate power of 198.6MW).

The point of interconnection (POI) remains unchanged and is the Oklahoma Gas and Electric (OKGE) Woodward EHV 345kV Substation.

The proposed new wind turbine generators, GE 2.3MW and GE 2.5MW, are electrically equivalent to the GE 2.4MW 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. This study analyzed the change in system impedance between the original project and the modified project and found it to be a 2.75% increase, and, therefore, the modified project will have a steady state and dynamic performance similar to the original study. The results of the previous generator modification study of GEN-2007-062<sup>1</sup>, except for the results of the reactor analysis, are still valid for GEN-2007-062 Phase II.

A low-wind/no-wind condition analysis was performed for this modification request. GEN-2007-062 Phase II will be required to install approximately 13 Mvars of shunt reactors on its substation 34.5kV bus. 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.

With the assumptions outlined in this report and with all required network upgrades in place, GEN-2007-062 Phase II with the GE 2.3MW and the GE 2.5 MW 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.

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<sup>1</sup> See *GEN-2007-062, GEN-2011-019, GEN-2011-020 Impact Restudy for Generator Modification (Turbine Change)* posted September 29, 2016, which may be accessed through the following link: [http://sppoasis.spp.org/documents/swpp/transmission/studies/files/2007\\_Generation\\_Studies/GE\\_N-2007-062\\_Modification\\_Study\\_9-29-2016.pdf](http://sppoasis.spp.org/documents/swpp/transmission/studies/files/2007_Generation_Studies/GE_N-2007-062_Modification_Study_9-29-2016.pdf)

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# 1. Introduction

The Interconnection Customer for GEN-2007-062 Phase II has requested a change in wind turbine generators. Table 1-1 shows the interconnection request as studied in the previous generator modification request. Table 1-2 shows the requested wind turbine modification for the project.

**Table 1-1: Interconnection Request (Previous Study)**

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2007-062 Phase II	199.2	83 x GE 2.4MW	Woodward EHV 345kV Substation

**Table 1-2: Interconnection Request (Modification)**

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2007-062 Phase II	198.6	73 x GE 2.5 MW and 7 x GE 2.3MW	Woodward EHV 345kV Substation

The proposed new wind turbine generators, GE 2.3MW and GE 2.5MW, are electrically equivalent to the GE 2.4MW being replaced, and the dynamic characteristics are essentially the same. The total number of wind turbines is reduced which required a change in topology. Also, the number of substation transformers was reduced from two to one.

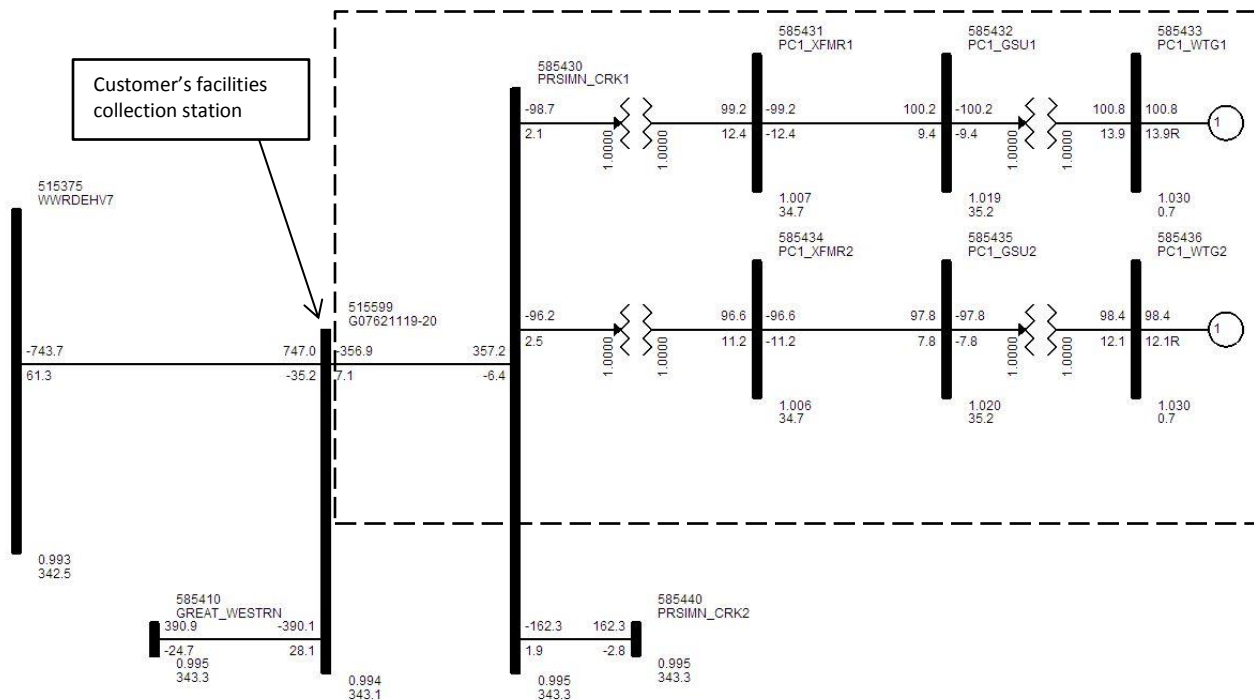
The low-wind/no-wind analysis determines the capacitive effect at the POI caused by the project’s collector system and transmission line capacitance. A shunt reactor size was determined to offset the capacitive effect and to maintain approximately zero Mvar flow at the POI when the plant generators and 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

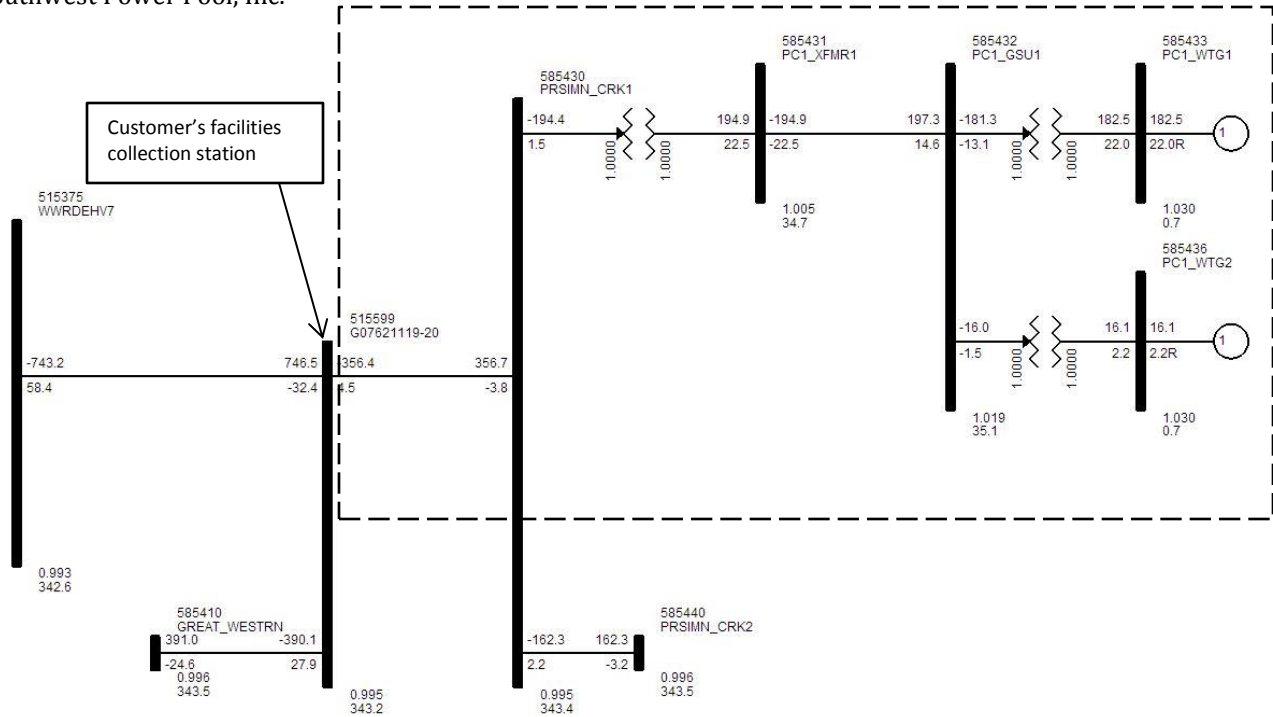
### Generating Facility

The point of interconnection (POI) for the GEN-2007-062 Phase II is the OKGE Woodward EHV 345kV substation. The interconnection request as previously studied is shown in Figure 2-1. Note that the Interconnection Customer has several other generation facilities nearby and all are connected to a common collection station from which a single 345kV transmission line goes to the POI.



**Figure 2-1: Power Flow Model and POI for GEN-2007-062 Phase II 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 GEN-2007-062 Phase II**

### 3. Modification Evaluation

The electrical characteristics and the dynamic response of the GE 2.3MW, the GE 2.4MW, and the GE 2.5MW wind turbine generators are nearly identical. The change in topology due to the reduced number of wind turbines and the change in project substation transformer were 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 PSS/E to determine the Thevenin equivalent impedances for the previous and the modified topologies.

The Customer’s facilities collection station (shown as bus number 515599 in Figures 2-1 and 2-2) was used as the “home” bus for the PSS/E ASCC function. The Thevenin impedance was obtained before and after the modification. The generator Z<sub>source</sub> 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 3 mile transmission line from GEN-2007-062 Phase II substation to the Interconnection Customer’s facilities collection station,
- The substation transformer(s),
- The equivalent collector system,
- The generator step up units.

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Note that all other elements not related to GEN-2007-062 Phase II were disconnected to remove their effects in determining the equivalent impedances.

The equivalent impedances are as follows:

$$Z_{th}(\text{previous}) = 0.011424 + j 0.466522 \text{ PU}$$

$$Z_{th}(\text{modified}) = 0.011273 + 0.479364 \text{ PU}$$

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

$$D = [Z_{th}(\text{modified}) - Z_{th}(\text{previous})] / Z_{th}(\text{previous}) * 100 \%$$

$$D = [0.479497 - 0.466662] / 0.466662 * 100$$

$$D = 2.75 \% \text{ increase}$$

The change in impedance is a 2.75 % increase, and the modification will have minimal impact on the results in the previous restudy.

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## 4. Stability Analysis

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

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## 5. Power Factor Analysis

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

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## 6. Reduced Generation Analysis

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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.

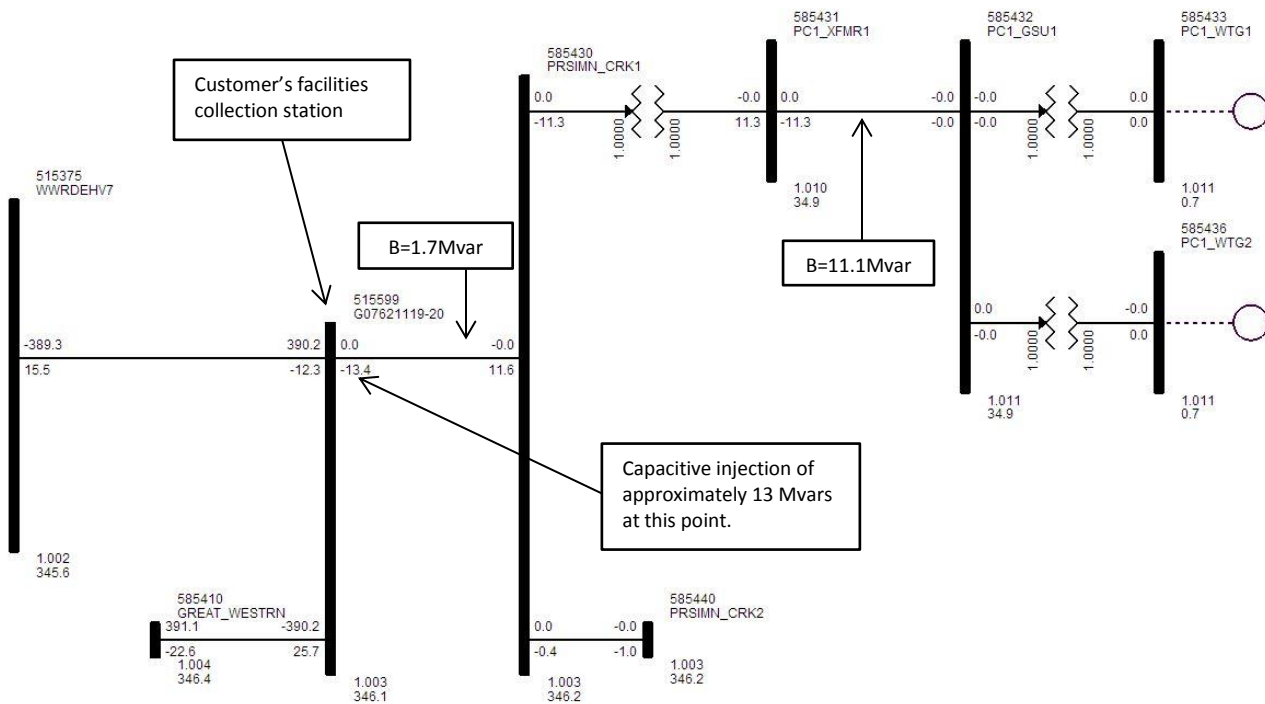


**Table 6-1: Summary of Shunt Reactor Requirements**

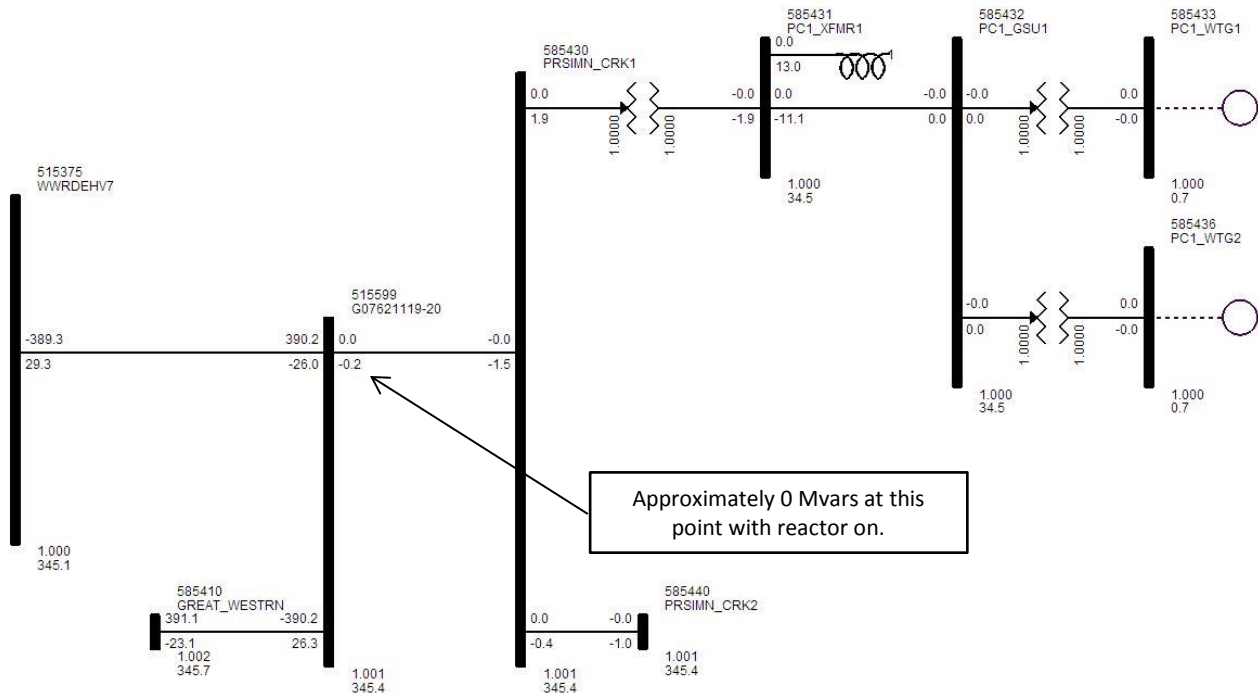
Request	Capacity	POI	Approximate Shunt Reactor Required
GEN-2007-062 Phase II	199.2	Woodward EHV 345kV Substation	13Mvar

Figure 6-1 shows the capacitive effect that GEN-2007-062 Phase II 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 GEN-2007-062 Phase II the reactor required is approximately 13Mvar as shown in Figure 6-2.



**Figure 6-1: GEN-2007-062 Phase II with generators off and no shunt reactors**  
 (Reactive contributions (line charging denoted as B) are shown for the collector system equivalent and for the transmission lead from the project substation to the interconnection customer’s generation collection station shown as bus 515599.)



**Figure 6-2: GEN-2007-062 Phase II 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 GEN-2007-062 Phase II has requested a modification to its Generator Interconnection Agreement to change wind turbine generators from GE 2.4MW to GE 2.3MW and GE 2.5MW wind turbine generators as shown in Table 1-2.

With the exception of the reactor requirement the results of the previous study for generator modification are still valid for GEN-2007-062 Phase II as modified with GE 2.3MW and GE 2.5MW wind turbine generators.

A low-wind/no-wind condition analysis was performed for this wind turbine modification request. GEN-2007-062 Phase II will be required to install approximately 13 Mvars of shunt reactors on its substation 34.5kV bus. This is necessary to offset the capacitive effect on the transmission network

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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.