Interconnection Facilities Study
For
Generator Interconnection
Request
GEN-2014-041
(IFS-2014-002-15)

SPP Generator
Interconnection Studies

(#GEN-2014-041)
(#IFS-2014-002-15)

October 2015

Revision History

Date	Author	Change Description
9/01/2015	SPP	Draft Interconnection Facilities Study Report Revision 0 Issued
10/2/2015	SPP	Final Interconnection Facilities Study Report Revision 0 Issued

Summary

Sunflower Electric Power Corporation (SUNC) performed a detailed Interconnection Facilities Study at the request of Southwest Power Pool (SPP) for Generation Interconnection Request (GIR) GEN-2014-041/IFS-2014-002-15 (123.165 MW/Wind) located in Ness County, Kansas. The Interconnection Customer's originally proposed in-service date for GEN-2014-041/IFS-2014-002-15 is March 31, 2016. SPP has proposed that the full interconnection service in-service date will be after the assigned Interconnection Facilities and Non-Shared Network upgrades are completed. Full Interconnection Service will require the Network Upgrades listed in the "Other Network Upgrades" section. The request for interconnection was placed with SPP in accordance with SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Phases of Interconnection Service

It is not expected that interconnection service will require phases however, interconnection service will not be available until all interconnection facilities and network upgrades can be placed in service.

Interconnection Customer Interconnection Facilities

The Interconnection Customer's generation facility consists of fifty-one (51) Siemens 2.3 MW wind turbines with the Weak Grid Module[1]. The wind turbine "Power Boost" feature brings each wind turbine nameplate rating to 2.415 MW for a total generation nameplate rating of 123.165 MW. The 34.5kV collector system for this wind facility is planned to connect to one (1) 115/34.5kV Interconnection Customer owned and maintained transformer(s) at the Interconnection Customer owned substation. An approximate five (5) mile overhead 115kV transmission circuit will connect GEN-2014-041/IFS-2014-002-15 to the Point of Interconnection (POI) at the existing SUNC owned 115kV bus at the Arnold Station. The Interconnection Customer will be responsible for all of the transmission facilities connecting the Interconnection Customer owned substation to the Point of Change of Ownership (PCO).

The Interconnection Customer will be responsible for any equipment located at the Customer substation necessary to maintain a power factor of 0.95 lagging and 0.95 leading at the POI, including approximately 5.2 Mvar[2] of reactors to compensate for injection of reactive power into the transmission system under reduced generating conditions. Also, the Interconnection Customer will need to coordinate with the Transmission Owner for relay, protection, control, and communication system configurations.

Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades

To facilitate the interconnection the Transmission Owner will extend the existing 115kV radial bus, replace control panels, construct three breaker and breaker positions, re-route

[1] The requirement for the Siemens Weak Grid Module was determined in the addendum to this report for DISIS-2014-002 Group 4 Stability and Reduced Wind Analysis Addendum

[2] This is an approximate minimum reactor amount needed for the configuration of the wind farm studied in DISIS-2014-002 Group 04 Stability and Reduced Wind Analysis Addendum. This approximate amount of reactors is subject to change based on results of modification study discussed above.

Grove 115kV and Ransom lines into the new breaker positions, and associated terminal equipment for acceptance of the Interconnection Customer's Interconnection Facilities. Because the substation is a single breaker-single bus substation, one of the circuit breakers is classified as an Interconnection Facility. Currently, SUNC estimates an Engineering and Construction (E&C) lead time of approximately twenty-four (24) months after a fully executed Generator Interconnection Agreement (GIA) for the completion of Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades. **Table 1** displays the estimated costs for Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades.

Table 1: GEN-2014-041/IFS-2014-002-15 TOIF and Non-Shared Network Upgrades

Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades Description	Allocated Cost ($)	Allocated Percent (%)	Total Cost ($)
Arnold Substation - Transmission Owner Interconnection Facilities 115kV Substation work for a new line terminal position, one (1)115kV circuit breaker, disconnect switches, line switch, dead end structure, communications, revenue metering, and line arrestors	$1,200,000	100%	$1,200,000
Arnold Substation - Network Upgrades 115kV Substation work for extending the existing 115kV bus, control panel replacements, install two (2) new terminal positions with two (2) 3000A breakers , associated 1200A switches, and associated structure.	$3,443,230	100%	$3,443,230
Total	$4,643,230	100%	$4,643,230

The Interconnection Customer was studied within the DISIS-2014-002 Impact Study and the DISIS-2014-002-1 Impact Restudy as Energy Resource Interconnection Service (ERIS) with updated cost allocations in DISIS-2014-002-2 Impact Restudy. During the impact study, Arnold – Ransom 115kV transmission circuit was identified as a thermal constraint. To mitigate the thermal constraint, SUNC will be required to replace relays and a control panel at the Ransom Substation. In addition, the Transmission Owner has identified switch upgrade replacements at Ness City 115kV Substation for the addition of GEN-2014-041/IFS-2014-002-15. At this time, the Interconnection Customer is allocated $468,321 for Non-Shared Network Upgrades identified in the latest impact restudy. Current cost estimate and upgrade descriptions are listed in **Table 2**.

Table 2: GEN-2014-041/IFS-2014-002-15 DISIS-2014-002-2 Non-Shared Network Upgrades

Non-Shared Network Upgrades Description	Allocated Cost ($)	Allocated Percent (%)	Total Cost ($)
Ness City Substation Network Upgrades 115kV Substation work for replacing existing 600A switches to 1200A switches	$200,000	100%	$200,000
Ransom 115kV Substation: Upgrade relays and control panel	$268,321	100%	$268,321
Total	$468,321	100%	$468,321

At this time, GEN-2014-041/IFS-2014-002-15 is responsible for $5,111,551 of Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades.

Shared Network Upgrades

The Interconnection Customer was studied within the DISIS-2014-002 Impact Study and the DISIS-2014-002-1 Impact Restudy as Energy Resource Interconnection Service (ERIS) with updated cost allocations in DISIS-2014-002-2 Impact Restudy. At this time, the Interconnection Customer is allocated $0 for Shared Network Upgrades. If higher queued interconnection customers withdraw from the queue, suspend or terminate their GIA, restudies will have to be conducted to determine the Interconnection Customers' allocation of Shared Network Upgrades. All studies have been conducted on the basis of higher queued interconnection requests and the upgrades associated with those higher queued interconnection requests being placed in service. At this time, the Interconnection Customer is allocated the following cost for Shared Network Upgrade:

Table 3: GEN-2014-041/IFS-2014-002-15 Shared Network Upgrades

Shared Network Upgrades Description	Allocated Cost ($)	Allocated Percent (%)	Total Cost ($)
Currently, GEN-2014-041 is not allocated any Shared Network Upgrades	$0	n/a	$0
Total	$0	n/a	$0

Other Network Upgrades

Certain Other Network Upgrades are currently not the cost responsibility of the Customer but will be required for full Interconnection Service. Currently, the following Other Network Upgrades are required:

- Buckner – Spearville 345kV circuit #1 terminal equipment upgrade assigned DISIS-2010-002 Interconnection Customer.

Depending upon the status of higher or equally queued customers, the Interconnection Customer's in-service date is at risk of being delayed or their Interconnection Service is at risk of being reduced until the in-service date of these Other Network Upgrades.

Conclusion

Interconnection Service for GEN-2014-041/IFS-2014-002-15 will be delayed until the Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades are constructed. The Interconnection Customer is responsible for $5,111,551 of Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades. At this time, the Interconnection Customer is allocated $0 for Shared Network Upgrades. After all Interconnection Facilities and Non-Shared Network Upgrades have been placed into service, Interconnection Service for 123.165 MW, as requested by GEN-2014-041/IFS-2014-002-15, can be allowed.

At this time the total allocation of costs assigned to GEN-2014-041/IFS-2014-002-15 for interconnection Service are estimated at $5,111,551.

1. Introduction

<OMITTED TEXT> (Interconnection Customer) has requested an Interconnection Facilities Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnecting a 123.165 MW wind generation facility in Ness County, Kansas to the transmission system of Sunflower Electric Power Corporation (SUNC). The generator facility, GEN-2014-041, is comprised of fifty-one (51) Siemens 2.415 MW wind turbines with "Power Boost" feature for a total nameplate of 123.165 MW.

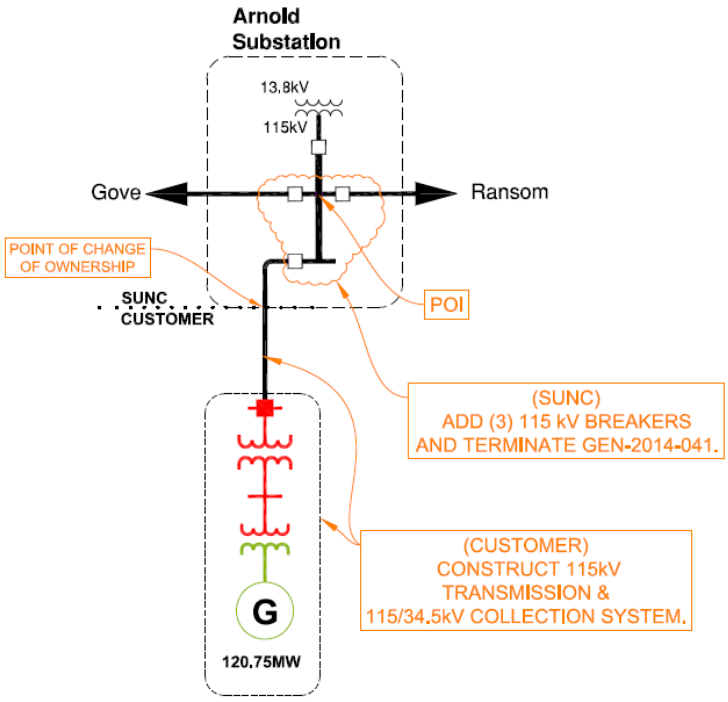
2. Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades

The cost for the Transmission Owner Interconnection Facilities and Non-Shared Network Upgrades is listed below in Table 1. GEN-2014-041/IFS-2014-002-15 is planned to interconnect at the SUNC owned 115kV bus located at Arnold 115kV Station. The estimated lead time for Transmission Owner Interconnection Facilities and Network Upgrades is twenty-four (24) months after a fully executed Generator Interconnection Agreement (GIA). The one-line diagram is shown in Figure 1.

Table 1: Required Transmission Owner Interconnection Facilities and Non Shared Network Upgrades

Description	Estimated Cost
Arnold Substation - Transmission Owner Interconnection Facilities 115kV Substation work for a new line terminal position, one (1) 115kV circuit breaker, disconnect switches, line switch, dead end structure, communications, revenue metering, and line arrestors	$1,200,000
Arnold Substation - Network Upgrades 115kV Substation work for extending the existing 115kV bus, control panel replacements, add two (2) new terminal positions with two (2) 3000A breakers , associated 1200A switches, and associated structure	$3,443,230
Ness City Substation Network Upgrades 115kV Substation work for replacing existing 600A switches to 1200A switches	$200,000
Ransom 115kV Substation: Upgrade relays and control panel	$268,321
Total:	**$5,111,551**

Figure 1: Interconnection Configuration for GEN-2014-041



2.1. **<u>Interconnection Customer Facilities</u>** – The Interconnection Customer will be responsible for its Generating Facility and its one (1) 115/34.5 kV transformer that connect to the wind generators to the Point of Interconnection. In addition, the Interconnection Customer will be required to install the following equipment in its facilities.

2.1.1. **<u>Reactive Power Equipment</u>** – The Customer will be responsible for reactive power compensation equipment to maintain 95% lagging (providing vars) and 95% leading (absorbing vars) power factor at the point of interconnection, which may be provided in part by the reactive power capability of the generators. Any capacitor banks installed by the Interconnection Customer shall not cause voltage distortion in accordance with Article 9.7.4 of the standard SPP Generator Interconnection Agreement. In addition, for no-wind/low wind conditions, 5.2Mvars of reactor banks (or other equivalent means of providing reactive power under no wind conditions) are required.

3. <u>Conclusion</u>

The Interconnection Customer's Interconnection Facilities and Non-Shared Network Upgrades are estimated at $5,111,551.

Interconnection Facilities Study Addendum

Additional Stability and Reduced Generation Analysis

GEN-2014-041/IFS-2014-002-15

August 2015

Generator Interconnection Studies

SPP Southwest Power Pool

Additional Stability Analysis

SPP has performed an additional stability analysis to determine the effects of manufacturer dynamic model revisions for the generator used by the GEN-2014-041 Interconnection Request. The GEN-2014-041 Interconnection Request was studied in DISIS-2014-002 which was posted in January 2015. The request uses Siemens 2.3-108 VS wind turbine generators with the Power Boost option (2.415MW/turbine) for a total of 123.165MW (51 machines total). The project has one 115/34.5kV substation transformer that will connect the Customer's 115kV project substation to the Point of Interconnection (POI), Arnold 115kV Station, by approximately five (5) miles of overhead 115kV transmission circuit. The interconnection customer has provided documentation that shows the wind turbine generators have a reactive capability of 0.90 lagging (providing VARS) and 0.90 leading (absorbing VARS) power factor at nominal power.

During the analysis, generator response issues were observed with the revised model when simulating FLT45-3PH from DISIS-2014-002 Group 4 Stability Analysis; a fault at Arnold 115kV that is cleared by tripping the circuit from Arnold to Ransom 115kV. The generator response to FLT45-3PH from DISIS-2014-002 Group 4 Stability Analysis for the 2015 Winter Peak model is shown below in **Figure 1**. The dynamic model revision changes that may impact the generator response include: Power Boost Slightly Changed, WGO Control Mode made Available, and Enhanced Transient Performance when Fault is cleared.

A short circuit analysis was done at the POI for system intact (no line outages) and for line outages at the POI. The results of the short circuit analysis are shown in **Table 1** where it can be seen that the short circuit ratio (SCR) for the Arnold to Ransom 115kV line outage is very small, 1.79. Most wind turbines will not operate effectively with this low SCR without some additional reactive support, network upgrades, or a controlled generator response.

With the Weak Grid Option (WGO), the GEN-2014-041 project will have adequate reactive support for the outage of the Arnold to Ransom 115kV line. The generator response to FLT45-3PH from DISIS-2014-002 Group 4 Stability Analysis with the WGO is shown below in **Figure *2***. It was determined that the GEN-2014-041 Interconnection request will need to utilize the WGO to resolve the generator response issues.

Table 1: Short Circuit Ratio (SCR) Analysis for GEN-2014-041 request for 123.165MW

Outage	Season	Transmission System Short Circuit Availability (MVA)	Short Circuit Ratio (SCR)
System Intact (no outages)	2015 Summer Peak	532.24	4.32
	2015 Winter Peak	528.05	4.29
	2025 Summer Peak	533.23	4.33
Arnold to Gove 115kV	2015 Summer Peak	319.23	2.59
	2015 Winter Peak	316.19	2.57
	2025 Summer Peak	319.57	2.59
Arnold to Ransom 115kV	2015 Summer Peak	220.55	1.79
	2015 Winter Peak	220.35	1.79
	2025 Summer Peak	220.79	1.79

Figure 1: GEN-2014-041 Response to FLT45-3PH

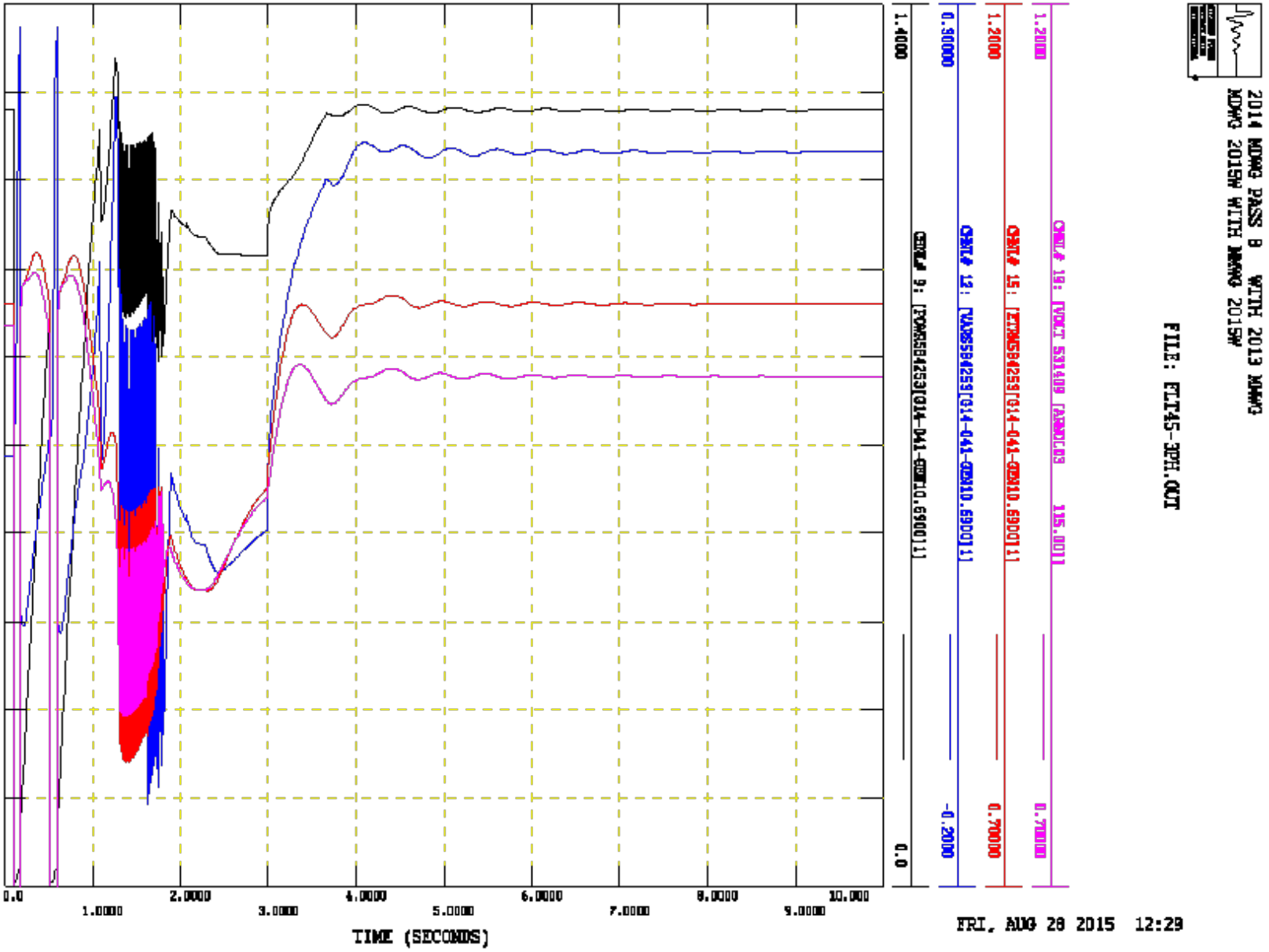
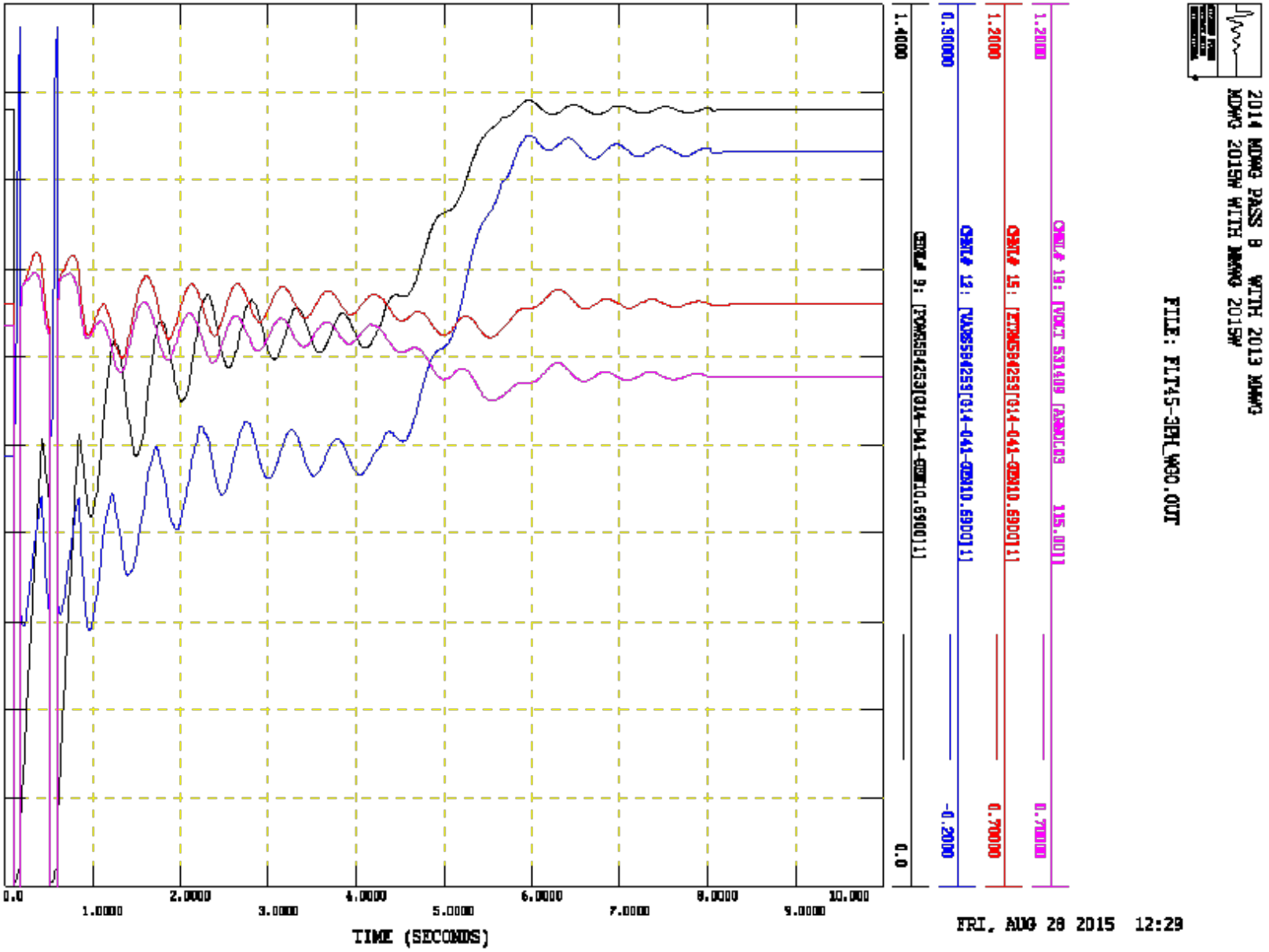


Figure 2: GEN-2014-041 with Weak Grid Option Response to FLT45-3PH



Reduced Generation Analysis

A reduced generation analysis has been performed for the GEN-2014-041 Interconnection Request. A reduced generation analysis was performed based on the large size of the GEN-2014-041 Interconnection Request (123.165 MW/ Wind) for the potential of excessive capacitive charging current caused by the addition of the GEN-2014-041 facilities. The Interconnection Customer 115kV facilities will connect to the, Point of Interconnection (POI), Arnold 115kV Station by approximately five (5) miles of overhead 115kV transmission circuit.

The project generator(s) and capacitors (if applicable) were turned off in the base case as show in **Figure 3**. The resulting reactive power injection into the transmission network comes from the capacitance of the project's transmission lines and collector cables.

Shunt reactors were added at the study project substation 34.5 kV bus to bring the Mvar flow into the Arnold 115kV substation down to approximately zero as show in ***Figure 4***. Final shunt reactor requirement for GEN-2014-041 is approximately 5.2 Mvars. The one-line diagram in ***Figure 3*** shows actual Mvar output at the specific voltages in the base case. The results shown are for the 2025SP case.

The other DISIS-2014-002 Group 04 stability seasonal cases are almost identical since the Interconnection Request facilities design is the same in all cases.

Figure 3: GEN-2014-041 with generator(s) off and no shunt reactor(s)

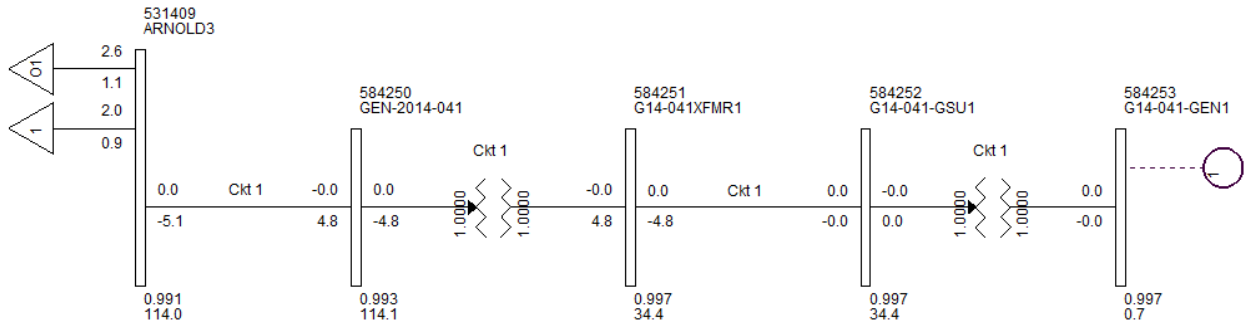


Figure 4: GEN-2014-041 with generator(s) turned off and shunt reactors added to the low side of the GEN-2014-041 substation 115/34.5kV transformer

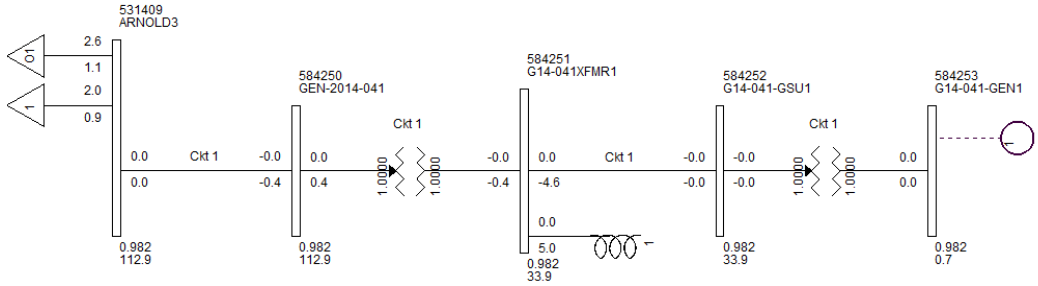


Table 2: Low Wind/No Wind Analysis

Request	Size (MW)	Point of Interconnection	Shunt Reactor Mvar Requirement
GEN-2014-041	123.165	Arnold 115kV	5.2

Conclusion

An additional stability analysis has been performed to determine the effects of manufacturer dynamic model revisions for the generator used by the GEN-2014-041 Interconnection Request. During the analysis, generator response issues were observed with the revised model when simulating FLT45-3PH from DISIS-2014-002 Group 4 Stability Analysis; a fault at Arnold 115kV that is cleared by tripping the circuit from Arnold to Ransom 115kV. The results of the short circuit analysis determined that the short circuit ratio (SCR) for the Arnold to Ransom 115kV line outage is very small, 1.79. It was determined that the GEN-2014-041 Interconnection request will need to utilize the Weak Grid Option (WGO) to resolve the generator response issues observed.

A reduced generation has been performed for the GEN-2014-041 Interconnection Request. A reduced generation analysis was performed based on the large size of the GEN-2014-041 Interconnection Request (123.165 MW/ Wind) for the potential of excessive capacitive charging current caused by the addition of the GEN-2014-041 facilities. The reduced generation analysis has determined the need for the GEN-2014-041 Interconnection Request to install approximately 5.2 Mvars of shunt reactor bank(s).