GEN-2013-029
Impact Restudy for Generator Modification (Turbine Change)

January 2016
Generator Interconnection

Southwest Power Pool

Revision History

Date	Author	Change Description
9/2/2015	SPP	GEN-2013-029 Impact Restudy for Generator Modification (Turbine Change) issued.
1/21/2016	SPP	Revised document to read Siemens SWT 2.3MW instead of Siemens 2.0MW VS

Executive Summary

The GEN-2013-029 Interconnection Customer has requested a modification to its Generator Interconnection Request to change from a combination of sixty-six (66) GE 1.7MW wind turbine generators (aggregate power of 148.0MW) and seventy-four (74) Vestas V100 2.0MW wind turbine generators (aggregate power of 151.8MW for a total generation facility power of 299.8MW) to one hundred thirty (130) Siemens SWT 2.3MW wind turbine generators (aggregate power of 299.0MW). The point of interconnection (POI) is the Oklahoma Gas and Electric (OKGE) Renfrow 345kV substation.

The study models used were the 2015 summer, the 2015 winter, and the 2025 summer cases and included Interconnection Requests through DISIS-2015-001. The restudy showed that no stability problems were found with the contingencies studied during the summer and the winter peak conditions as a result of changing to the Siemens SWT 2.3MW wind turbine generators. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.

A power factor analysis was performed and GEN-2013-029 will be required to meet the 0.95 power factor lagging (providing vars) to 0.95 power factor leading (absorbing vars) at the POI. A short circuit analysis was performed and has been included in this report.

A low-wind/no-wind condition analysis was performed for this modification request. The project will be required to install approximately 17 Mvars of shunt reactors on its substation 34.5kV bus(es). 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.

With the assumptions outlined in this report and with all required network upgrades in place, GEN-2013-029 with the Siemens SWT 2.3MW wind turbine generators should be able to reliably interconnect 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. 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 GEN-2013-029 Interconnection Customer has requested a modification to its Generator Interconnection Request to change from a combination of sixty-six (66) GE 1.7MW wind turbine generators (aggregate power of 148.0MW) and seventy-four (74) Vestas V100 2.0MW wind turbine generators (aggregate power of 151.8MW for a total generation facility power of 299.8MW) to one hundred thirty (130) Siemens SWT 2.3MW wind turbine generators (aggregate power of 299.0MW). The point of interconnection (POI) is the Oklahoma Gas and Electric (OKGE) Renfrow 345kV substation. Table 1-1 shows the interconnection request.

Table 1-1: Interconnection Request

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2013-029	299.0	Siemens SWT 2.3MW	OKGE Renfrow 345kV Substation

The prior-queued, equally-queued and lower queued requests shown in Table 1-2 were included in this study and the wind farms were dispatched to 100% of rated capacity.

Table 1-2: Prior and Later Queued Interconnection Requests

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2002-004	199.5	GE.1.5MW	Latham 345kV (532800)
GEN-2005-013	199.8	Vestas V90 1.8MW	Caney River 345kV (532780)
GEN-2007-025	299.2	GE 1.6MW	Viola 345kV (532798)
GEN-2008-013	299.04	GE 1.68MW	Hunter 345kV (515476)
GEN-2008-021	1283	GENROU	Wolf Creek 345kV (532797)
GEN-2008-098	100.0	Gamesa G114 2.0MW	Tap on the Wolf Creek – LaCygne 345kV line (Waverly 345kV, 532799)
GEN-2009-025	59.8	Siemens 2.3MW	Tap on the Deerck – Sincblk 69KV line (515528)
GEN-2010-003	100.0	Gamesa G114 2.0MW	Tap on the Wolf Creek – LaCygne 345kV line (Waverly 345kV, 532799)
GEN-2010-005	299.2	GE 1.6MW	Viola 345kV (532798)
ASGI-2010-006	150	GE1.5MW	Remington 138kV (301369)
GEN-2010-055	4.8	GENROU	Wekiwa 138kV (509757)
GEN-2011-057	150.0	Vestas V110 2.0MW	Creswell 138kV (532981)
GEN-2012-027	150.7	GE 1.62MW	Shidler 138kV (510403)
GEN-2012-032	299	Siemens 2.3MW	Tap Rose Hill-Sooner 345kV (562318)
GEN-2012-033	98.8	GE 1.62MW	Tap Bunch Creek-South 4th 138kV(562303)
GEN-2012-040	76.5	GE 1.7MW	Chilocco 138kV (521198)

Table 1-2: Prior and Later Queued Interconnection Requests

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2012-041	85 Summer 121.5 Winter	GENROU	Tap Rose Hill-Sooner 345kV (562318)
GEN-2013-012	4 x 168.0MW Summer 4 x 215MW Winter	GENROU (514910) (514911) (514912) (514942)	Redbud 345kV (514909)
GEN-2013-028	516.4 Summer 559.5 Winter	GENROU (583743, 583746)	Tap on Tulsa N to GRDA1 345kV (562423)
GEN-2013-029	300	Vestas V100 VCSS 2MW (583753, 583756)	Renfrow 345kV(515543)
GEN-2014-001	200.6	GE 1.7MW 100m (583853,583856)	Tap Wichita to Emporia Energy Center 345kV (562476)
GEN-2014-028	35 (Uprate) (Pgen=259W /256S)	GENROU	Riverton 161kV (547469)
GEN-2014-064	248.4	GE 2.3MW	Otter 138kV (514708)
ASGI-2014-014	56.4W/54.3S	GENROU	Ferguson 69kV (512664)
GEN-2015-015	154.6	Siemens 2.3MW with Power Boost (115kW => 2.415MW)	Tap Medford Tap – Coyote 138kV
GEN-2015-016	200.0	Vestas V110 2.0MW	Tap Centerville – Marmaton 161kV
GEN-2015-024	220.0	GE 2.0MW	Tap on Thistle to Wichita 345kV, ckt1&2 (560033)
GEN-2015-025	220.0	GE 2.0MW	Tap on Thistle to Wichita 345kV, ckt1&2 (560033)
GEN-2015-028	3.0 uprate to GEN-2009-025 for total 62.8MW	Siemens 2.3MW with Power Boost (115kW => 2.415MW)	Nardins 69kV
GEN-2015-030	200.1	GE 2.3MW	Sooner 345kV
ASGI-2015-004	54.300 Summer 56.364 Winter	GENSAL	Coffeyville Municipal Light & Power Northern Industrial Park Substation 69kV (512735)

The study included a stability analysis of the interconnection request. Contingencies that resulted in a prior-queued project tripping off-line, if any, were re-run with the prior-queued project's voltage and frequency tripping relays disabled. Also a low-wind/no-wind analysis was performed on this project since it is a wind farm. The analyses were performed on three seasonal models, the modified versions of the 2015 summer peak, the 2015 winter peak, and the 2025 summer peak cases. The models included Interconnection Requests through DISIS-2015-001.

The stability analysis determines the impacts of the new interconnecting project on the stability and voltage recovery of the nearby systems and the ability of the interconnecting project to meet FERC Order 661A. If problems with stability or voltage recovery are identified, the need for reactive compensation or system upgrades is investigated. The three-phase faults and the single line-to-ground faults listed in Table 3-1 were used in the stability analysis. A power factor analysis at the POI was performed and a short circuit analysis was performed on busses up to five levels away from 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 the GEN-2013-029 interconnection request is the Oklahoma Gas and Gas and Electric (OKGE) Renfrow 230kV substation.

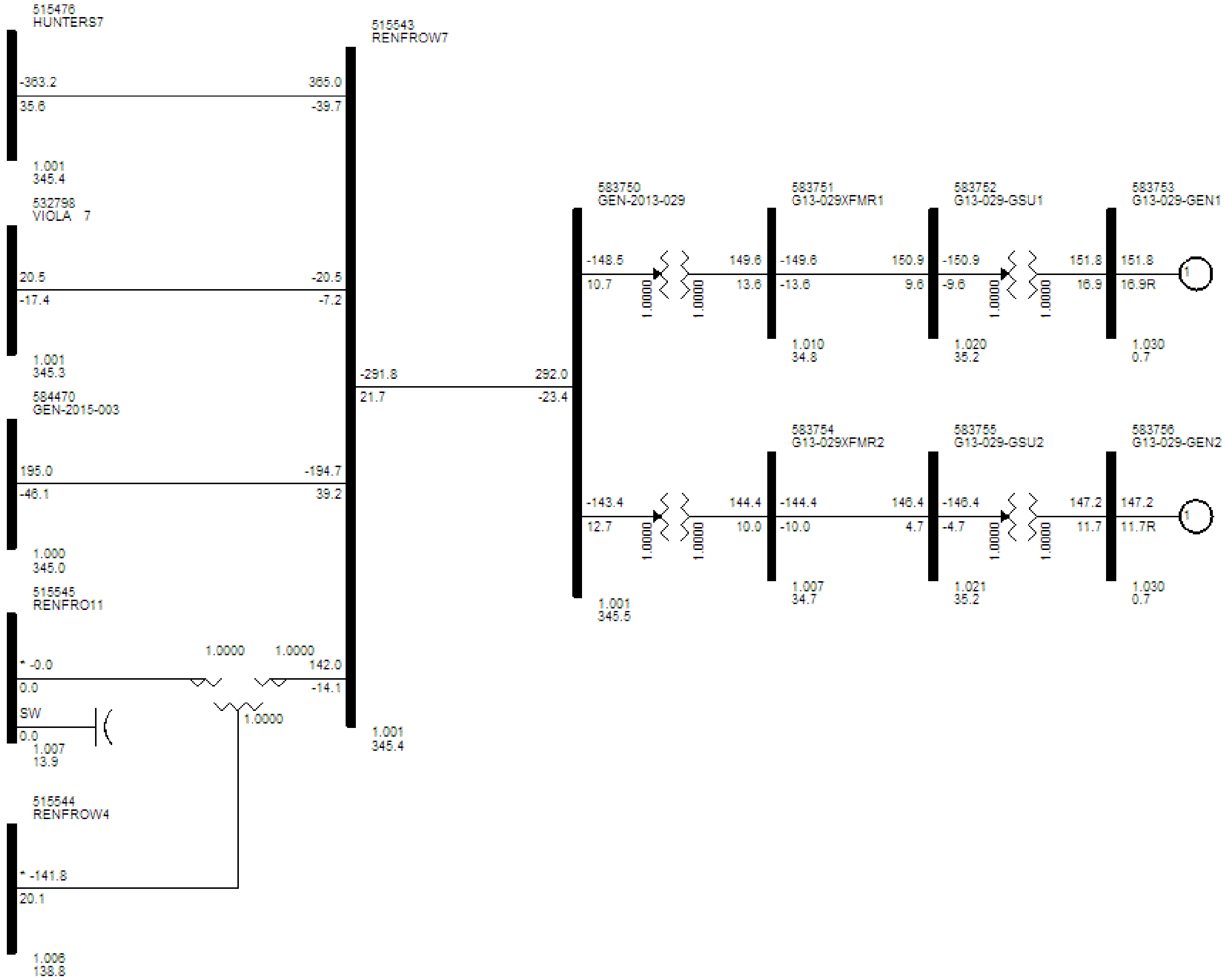

Figure 2-1 depicts the one-line diagram of the POI and the power flow model representing the request.

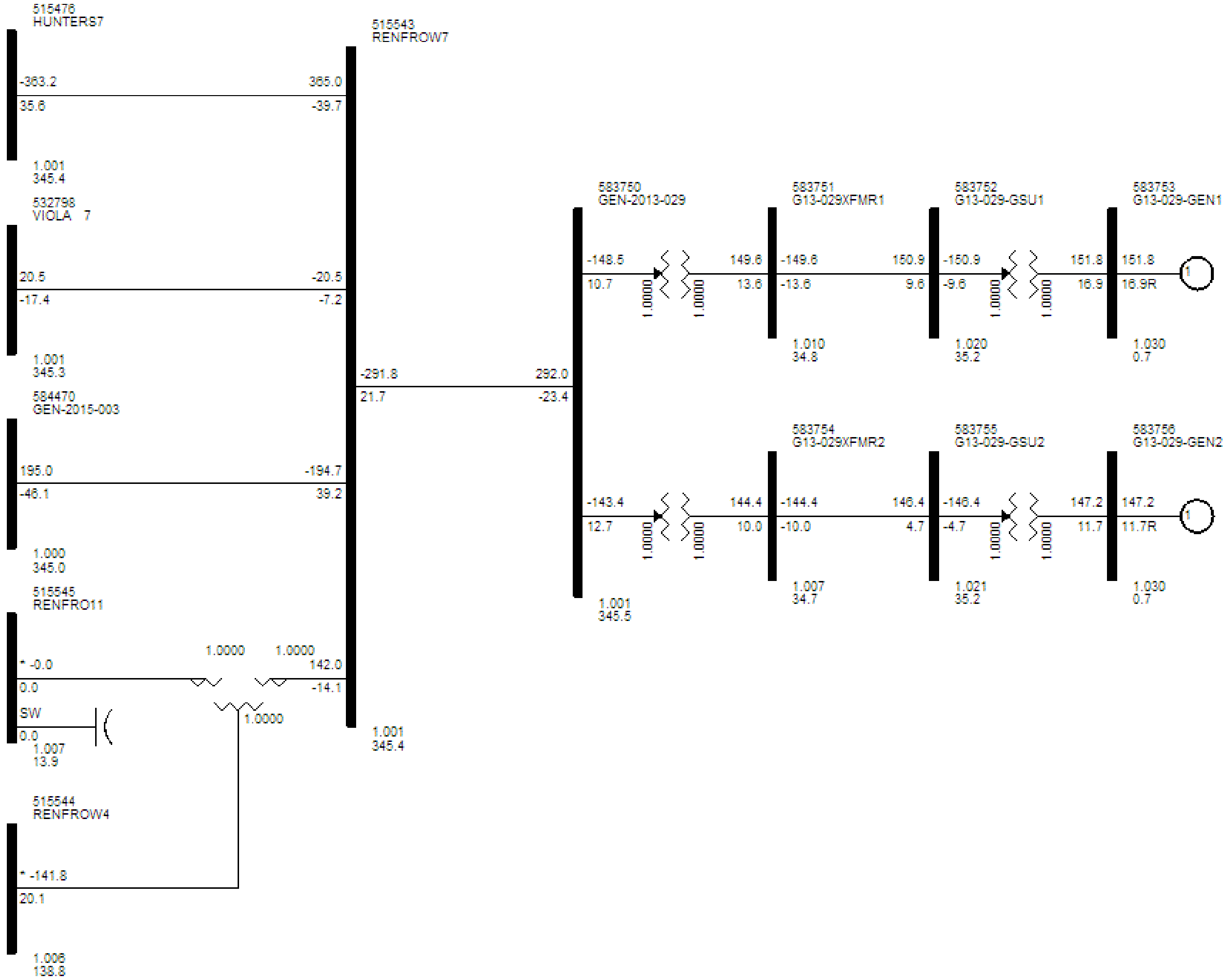

Figure 2-1: Proposed POI and Power Flow Model for GEN-2013-029

3. Stability Analysis

Transient stability analysis is used to determine if the transmission system can maintain angular stability and ensure bus voltages stay within planning criteria bandwidth during and after a disturbance while considering the addition of a generator interconnection request.

Model Preparation

Transient stability analysis was performed using modified versions of the 2014 series of Model Development Working Group (MDWG) dynamic study models including the 2015 summer peak, the 2015 winter peak, and the 2025 summer peak seasonal models. The cases are then loaded with prior queued interconnection requests and network upgrades assigned to those interconnection requests. Finally the prior queued and study generation are dispatched into the SPP footprint. Initial simulations are then carried out for a no-disturbance run of twenty (20) seconds to verify the numerical stability of the model.

Disturbances

Twenty-one (21) contingencies were identified for use in this study and are listed in Table 3-1. These contingencies included three-phase faults and single-phase line faults at locations defined by SPP. Single-phase line faults were simulated by applying fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice.

Except for transformer faults, the typical sequence of events for a three-phase and a single-phase fault is as follows:

1. apply fault at particular location
2. continue fault for five (5) cycles, clear the fault by tripping the faulted facility
3. after an additional twenty (20) cycles, re-close the previous facility back into the fault
4. continue fault for five (5) additional cycles
5. trip the faulted facility and remove the fault

Transformer faults are typically modeled as three-phase faults, unless otherwise noted. The sequence of events for a transformer fault is as follows:

1. apply fault for five (5) cycles
2. clear the fault by tripping the affected transformer facility (unless otherwise noted there will be no re-closing into a transformer fault)

Table 3-1: Contingencies Evaluated

Cont. No.	Contingency Name	Description
1	FLT01-3PH	3 phase fault on the Renfrow (515543) to Hunter (515476) 345kV line, near Renfrow. a. Apply fault at the Renfrow 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
2	FLT02-3PH	3 phase fault on the Renfrow (515543) to Viola (532798) 345kV line, near Renfro. a. Apply fault at the Renfro 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
3	FLT03-3PH	3 phase fault on the Viola (532798) to Wichita (532796) 345kV line, near Viola. a. Apply fault at the Viola 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
4	FLT04-3PH	3 phase fault on the Wichita (532796) to Benton (532791) 345kV line, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
5	FLT05-3PH	3 phase fault on the Wichita (532796) to G14-001 Tap (562476) 345kV line, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
6	FLT06-3PH	3 phase fault on the Emporia EC (562476) to G14-001 Tap (562476) 345kV line, near G14-001. a. Apply fault at the G14-001 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
7	FLT07-3PH	3 phase fault on the Wichita (532796) to G1524&G1525T (560033) 345kV line circuit 1, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line.
8	FLT08-3PH (2025SP Only)	3 phase fault on the Viola (532798) 345/(533075) 138/(532832) 13.8kV transformer, near Viola 345. a. Apply fault at the Viola 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line.
9	FLT09-3PH	3 phase fault on the Renfrow (515543) 345/(515544) 138/(515545) 13.8kV transformer, near Renfrow 345. a. Apply fault at the Renfrow 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line.

Table 3-1: Contingencies Evaluated

Cont. No.	Contingency Name	Description
10	FLT10-3PH	3 phase fault on the Reno (532771) to Wichita (532796) 345kV circuit 1 line, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
11	FLT11PO-3PH	**Prior outage on the Caney River (532780) – Neosho (532780) 345kV line** 3 phase fault on the Wichita (532796) to Benton (532791) 345kV line, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
12	FLT12PO-3PH	**Prior outage on the Renfrow (515543) 345/ (515544) 138/ (515545) 13.8kV transformer** 3 phase fault on the Renfrow (515543) to Viola (532798) 345kV line, near Renfrow. a. Apply fault at the Renfrow 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
13	FLT13PO-3PH	**Prior outage on the Renfrow (515543) 345/ (515544) 138/ (515545) 13.8kV transformer** 3 phase fault on the Renfrow (515543) to Hunter (515476) 345kV line, near Renfrow. a. Apply fault at the Renfrow 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
14	FLT14PO-3PH	**Prior outage on the Renfrow (515543) 345/ (515544) 138/ (515545) 13.8kV transformer** 3 phase fault on the Viola (532798) to Wichita (532798) 345kV line, near Viola. a. Apply fault at the Viola 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
15	FLT15PO-3PH	**Prior outage on the Wichita (532796) – Benton (532791) 345kV line** 3 phase fault on the Hunter (515476) to Woodring (514715) 345kV line, near Hunter. a. Apply fault at the Hunter 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table 3-1: Contingencies Evaluated

Cont. No.	Contingency Name	Description
16	FLT16PO-3PH	**Prior outage on the Wichita (532796) – Benton (532791) 345kV line** 3 phase fault on the G14-01 Tap (562476) to Emporia EC (532768) 345kV line, near G14-01. a. Apply fault at the G14-01 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
17	FLT17PO-3PH	**Prior outage on the Wichita (532796) – Benton (532791) 345kV line** 3 phase fault on the Wichita (532796) to Viola (532798) 345kV line, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
18	FLT18PO-3PH	**Prior outage on the Wichita (532796) –** G1524&G1525T (560033) **345kV circuit 1 line** 3 phase fault on the Wichita (532796) to G1524&G1525T (560033) 345kV circuit 2 line, near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line.
19	FLT19PO-3PH	**Prior outage on the Viola (532798) – Renfrow (515543) 345kV line** 3 phase fault on the Rosehill (532794) to Open Sky (515621) 345kV line, near Rosehill. a. Apply fault at the Rosehill 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
20	FLT20SB-1PH	**Stuck Breaker on Renfrow – Viola 345kV circuit 1 line** a. Apply single-phase fault at Renfrow (515543) on the 345kV bus. b. After 20 cycles, trip the Renfrow 345/ (515544) 138/(515545) 13.8kV transformer c. Trip the Renfrow – Viola (532798) 345 kV circuit 1 line, and remove the fault
21	FLT21SB-1PH	**Stuck Breaker on Renfrow – Hunter 345kV circuit 1 line** a. Apply single-phase fault at Renfrow (515543) on the 345kV bus. b. After 20 cycles, trip the Renfrow 345/ (515544) 138/(515545) 13.8kV transformer c. Trip the Renfrow – Hunter (515476) 345 kV circuit 1 line, and remove the fault

Results

The stability analysis was performed and the results are summarized in Table 3-2. Based on the stability results and with all network upgrades in service, GEN-2013-029 did not cause any stability problems and remained stable for all faults studied. No generators tripped or went unstable, and voltages recovered to acceptable levels.

Complete sets of plots for the stability analysis are available on request.

Table 3-2: Stability Analysis Results

Contingency Number and Name		2015SP	2015WP	2025SP
1	FLT01-3PH	Stable	Stable	Stable
2	FLT02-3PH	Stable	Stable	Stable
3	FLT03-3PH	Stable	Stable	Stable
4	FLT04-3PH	Stable	Stable	Stable
5	FLT05-3PH	Stable	Stable	Stable
6	FLT06-3PH	Stable	Stable	Stable
7	FLT07-3PH	Stable	Stable	Stable
8	FLT08-3PH	NA	NA	Stable
9	FLT09-3PH	Stable	Stable	Stable
10	FLT10-3PH	Stable	Stable	Stable
11	FLT11PO-3PH	Stable	Stable	Stable
12	FLT12PO-3PH	Stable	Stable	Stable
13	FLT13PO-3PH	Stable	Stable	Stable
14	FLT14PO-3PH	Stable	Stable	Stable
15	FLT15PO-3PH	Stable	Stable	Stable
16	FLT16PO-3PH	Stable	Stable	Stable
17	FLT17PO-3PH	Stable	Stable	Stable
18	FLT18PO-3PH	Stable	Stable	Stable
19	FLT19PO-3PH	Stable	Stable	Stable
20	FLT20SB-1PH	Stable	Stable	Stable
21	FLT21SB-1PH	Stable	Stable	Stable

NOTE: “ NA“ means the contingency is not applicable

FERC LVRT Compliance

FERC Order #661A places specific requirements on wind farms through its Low Voltage Ride Through (LVRT) provisions. For Interconnection Agreements signed after December 31, 2006, wind farms shall stay on line for faults at the POI that draw the voltage down at the POI to 0.0 pu.

Contingencies 1 and 2 in Table 3-2 simulated the LVRT contingencies. GEN-2013-029 met the LVRT requirements by staying on line and the transmission system remaining stable.

4. Power Factor Analysis

A power factor analysis was performed for this change request. The results are listed in the tables shown in **Appendix B: Power Factor Analysis**. The final power factor requirement for GEN-2013-029 will be the pro-forma 95% lagging to 95% leading at the POI.

5. Reduced Generation Analysis

Interconnection requests for wind generation projects that interconnect to a 345kV or 230kV bus on the SPP system are analyzed for the capacitive charging effects during reduced generation conditions (due to unsuitable wind speeds, curtailment, etc.) at the generation site

Model Preparation

The project generators and capacitors (if any), and all other wind projects that share the same POI, were turned off in the base case. The resulting reactive power injection into the transmission network comes from the capacitance of the project's transmission lines and collector cables. This reactive power injection is measured at the POI. Shunt reactors were added at the study project substation low voltage bus to bring the Mvar flow into the POI down to approximately zero.

Results

A final shunt reactor requirement for each of the studied interconnection requests is shown in **Table 5-1**. One line drawings used in the analysis are shown in Error! Reference source not found..

Table 5-1: Summary of Shunt Reactor Requirements

Request	Capacity	POI	Approximate Shunt Reactor Required
GEN-2013-029	299.0MW	OKGE Renfrow 345kV Substation	17 Mvar

The results shown are for the 2025 summer case. The other two cases (2015 summer and 2015 winter) were almost identical since the generation plant design is the same in all cases.

6. Short Circuit Analysis

The short circuit analysis was performed on the 2025 Summer Peak power flow case using the PSS/E ASCC program. Since the power flow model does not contain negative and zero sequence data, only three-phase symmetrical fault current levels were calculated at the point of interconnection up to and including five levels away. **Appendix D: Short Circuit Analysis** contains as listing of the short circuit currents.

7. Conclusion

The SPP GEN-2013-029 Impact Restudy evaluated the impact of interconnecting the project shown below in Table 7-1.

Table 7-1: Interconnection Request

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2013-029	299.0	Siemens SWT 2.3MW	OKGE Renfrow 345kV Substation

With all Base Case Network Upgrades in service, previously assigned Network Upgrades in service, and required capacitor banks in service, the GEN-2013-029 project was found to remain on line, and the transmission system was found to remain stable for all conditions studied.

A low-wind/no-wind condition analysis was performed for this modification request. The project will be required to install a total of approximately 17Mvar of reactor shunts on its substation 34.5kV buses. This is necessary to offset the capacitive effect on the transmission network cause by the project's transmission line and collector system during low-wind or no-wind conditions.

A power factor analysis was performed for this study. GEN-2013-029 will be required to meet 0.95 power factor lagging (providing vars) to 0.95 power factor leading (absorbing vars) at the POI.

Low Voltage Ride Through (LVRT) analysis showed the study generators did not trip offline due to low voltage when all Network Upgrades are in service.

All generators in the monitored areas remained stable for all of the modeled disturbances.

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 System Impact Study constitutes a request for transmission service or confers upon the Interconnection Customer any right to receive transmission service.

APPENDIX A: PLOTS

Available on request

APPENDIX B: POWER FACTOR ANALYSIS

A Power Factor Analysis was performed and the results are shown in Tables B-1 through B-3. Only three phase N-1 and single phase stuck breaker contingencies were evaluated. GEN-2013-029 will be required to meet 0.95 power factor lagging (providing vars) to 0.95 power factor leading (absorbing vars) at the POI.

GEN-2013-029 Turbine Restudy POI - RENFROW7 345.00 347.900665283 (515543)		**2015 Summer Voltage = 1.00840771198 pu**			
Cont. No.	**Contingency Name**	**Power at POI**	**VARS at POI**	**Power Factor**	
0	FLT_00_NoFault	499	-8.97376	0.999838	LEAD
1	FLT_01_Renfrow_Hunter_345kV	499	19.71913	0.99922	LAG
2	FLT_02_Renfrow_Viola_345kV	499	-23.7018	0.998874	LEAD
3	FLT_03_Viola_Wichita_345kV	499	146.7896	0.959353	LAG
4	FLT_04_Wichita_Benton_345kV	499	12.37986	0.999692	LAG
5	FLT_05_Wichita_G14001Tap_345kV	499	-1.61779	0.999995	LEAD
6	FLT_06_EmporiaEC_G14001Tap_345kV	499	0.474253	1	LAG
7	FLT_07_Wichita_G1524&G1525T_345kV	499	-5.66225	0.999936	LEAD
8	FLT_08_Viola_Viola_345_138kV	499	-8.97376	0.999838	LEAD
9	FLT_09_Renfrow_Renfrow_345_138kV	499	3.08956	0.999981	LAG
10	FLT_10_Reno_Wichita_345kV	499	-0.86868	0.999998	LEAD
20	FLT_20SB_Renfrow_Renfrow_345_138kV	499	3.08956	0.999981	LAG
21	FLT_21SB_Renfrow_Renfrow_345_138kV	499	3.08956	0.999981	LAG

Table B-1: Power Factor Analysis – 2015 Summer

GEN-2013-029 Turbine Restudy POI - RENFROW7 345.00 345.0 (515543)		**2015 Winter Voltage = 1.0 pu**			
Cont. No.	**Contingency Name**	**Power at POI**	**VARS at POI**	**Power Factor**	
0	FLT_00_NoFault	499	64.46638	0.991758	LAG
1	FLT_01_Renfrow_Hunter_345kV	499	118.8634	0.972783	LAG
2	FLT_02_Renfrow_Viola_345kV	499	-55.1761	0.993942	LEAD
3	FLT_03_Viola_Wichita_345kV	499	245.4126	0.897348	LAG
4	FLT_04_Wichita_Benton_345kV	499	67.99586	0.990843	LAG
5	FLT_05_Wichita_G14001Tap_345kV	499	73.7998	0.98924	LAG
6	FLT_06_EmporiaEC_G14001Tap_345kV	499	76.65858	0.988405	LAG
7	FLT_07_Wichita_G1524&G1525T_345kV	499	69.09211	0.99055	LAG
8	FLT_08_Viola_Viola_345_138kV	499	64.46638	0.991758	LAG
9	FLT_09_Renfrow_Renfrow_345_138kV	499	83.21606	0.986378	LAG
10	FLT_10_Reno_Wichita_345kV	499	78.30004	0.987912	LAG
20	FLT_20SB_Renfrow_Renfrow_345_138kV	499	83.21606	0.986378	LAG
21	FLT_21SB_Renfrow_Renfrow_345_138kV	499	83.21606	0.986378	LAG

Table B-2: Power Factor Analysis – 2015 Winter

GEN-2013-029 Turbine Restudy POI - RENFROW7 345.00 348.098022461 (515543)		**2025 Summer Voltage = 1.00897979736 pu**			
Cont. No.	**Contingency Name**	**Power at POI**	**VARS at POI**	**Power Factor**	
0	FLT_00_NoFault	499	-17.5709	0.999381	LEAD
1	FLT_01_Renfrow_Hunter_345kV	499	13.05111	0.999658	LAG
2	FLT_02_Renfrow_Viola_345kV	499	-16.1671	0.999476	LEAD
3	FLT_03_Viola_Wichita_345kV	499	47.08953	0.995577	LAG
4	FLT_04_Wichita_Benton_345kV	499	-11.4202	0.999738	LEAD
5	FLT_05_Wichita_G14001Tap_345kV	499	-11.7141	0.999725	LEAD
6	FLT_06_EmporiaEC_G14001Tap_345kV	499	-10.6629	0.999772	LEAD
7	FLT_07_Wichita_G1524&G1525T_345kV	499	-14.7253	0.999565	LEAD
8	FLT_08_Viola_Viola_345_138kV	499	-14.0109	0.999606	LEAD
9	FLT_09_Renfrow_Renfrow_345_138kV	499	-24.1604	0.99883	LEAD
10	FLT_10_Reno_Wichita_345kV	499	-2.13005	0.999991	LEAD
20	FLT_20SB_Renfrow_Renfrow_345_138kV	499	-24.1604	0.99883	LEAD
21	FLT_21SB_Renfrow_Renfrow_345_138kV	499	-24.1604	0.99883	LEAD

Table B-3: Power Factor Analysis – 2025 Summer

APPENDIX C: REDUCED GENERATION ANALYSIS

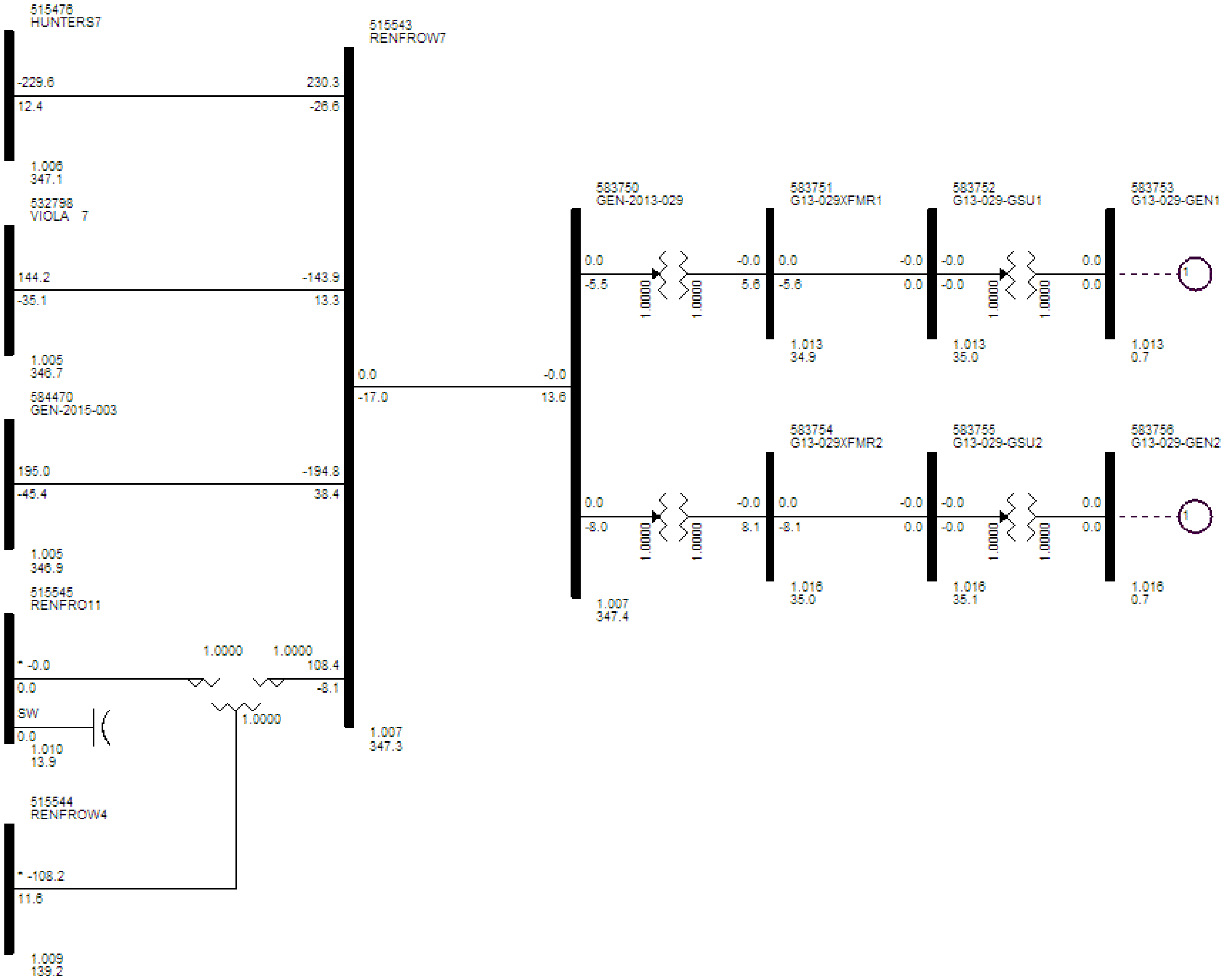

Figure C-4: GEN-2013-029 with generators off and no shunt reactors

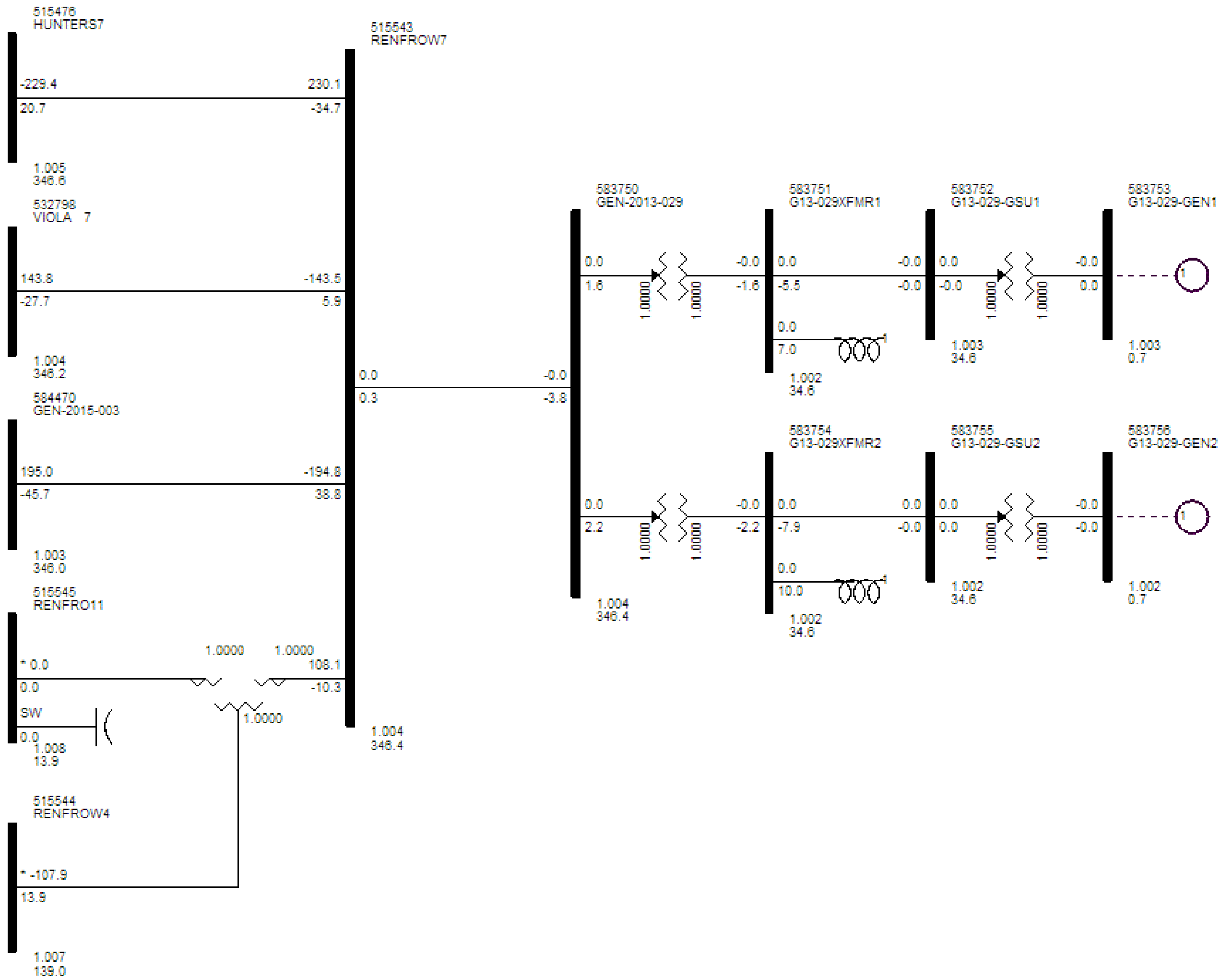

Figure C-5: GEN-2013-029 with generators turned off and shunt reactors added to the low side of the substation 345/34.5kV transformer

APPENDIX D: SHORT CIRCUIT ANALYSIS

Table D-1: Short Circuit Currents at GEN-2014-001 POI (Tap on Wichita to Emporia Energy Center) and five levels away

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                             PSS(R)E-32.2.2 ASCC SHORT CIRCUIT CURRENTS
MON, AUG 31 2015  18:19
2014 MDWG PASS 8   WITH 2013 MMWG
MDWG 2025S WITH MMWG 2024S

OPTIONS USED:
    - FLAT CONDITIONS
         - BUS VOLTAGES SET TO 1 PU AT 0 PHASE ANGLE
         - GENERATOR P=0, Q=0
         - TRANSFOMRER TAP RATIOS=1.0 PU and PHASE ANGLES=0.0
         - LINE CHARGING=0.0 IN +/-/0 SEQUENCE
         - LOAD=0.0 IN +/- SEQUENCE, CONSIDERED IN ZERO SEQUENCE
         - LINE/FIXED/SWITCHED SHUNTS=0.0 AND MAGNETIZING ADMITTANCE=0.0 IN +/-
/0 SEQUENCE
         - DC LINES AND FACTS DEVICES BLOCKED
         - TRANSFORMER ZERO SEQUENCE IMPEDANCE CORRECTIONS IGNORED

                                  THREE PHASE FAULT
X---------- BUS ----------X          /I+/    AN(I+)
515543 [RENFROW7    345.00] AMP    12297.6   -84.86
515476 [HUNTERS7    345.00] AMP    12302.3   -84.75
515544 [RENFROW4    138.00] AMP    13826.7   -84.83
515545 [RENFRO11    13.800] AMP    48731.4   -87.25
532798 [VIOLA   7   345.00] AMP    13429.7   -85.47
583750 [GEN-2013-029345.00] AMP    10833.3   -84.78
584470 [GEN-2015-003345.00] AMP     9186.3   -84.65
514715 [WOODRNG7    345.00] AMP    16534.7   -84.81
515477 [CHSHLMV7    345.00] AMP    12285.7   -84.75
515546 [GRANTCO4    138.00] AMP     6746.7   -81.30
515569 [MDFRDTP4    138.00] AMP    11548.6   -83.53
520409 [SAND RDG_138138.00] AMP    10092.0   -83.03
532792 [FR2EAST7    345.00] AMP     6373.0   -85.81
532796 [WICHITA7    345.00] AMP    24477.8   -86.34
532832 [VIOLA1X1    13.800] AMP    56039.1   -85.77
533075 [VIOLA  4    138.00] AMP    20554.1   -85.86
583751 [G13-029XFMR134.500] AMP    16911.3   -87.56
583754 [G13-029XFMR234.500] AMP    16759.8   -87.48
584471 [G15-003XFMR134.500] AMP    27755.2   -86.39
514714 [WOODRNG4    138.00] AMP    17713.0   -83.21
514803 [SOONER 7    345.00] AMP    22732.0   -86.55
515479 [CHSHMVE1    34.500] AMP    17532.4   -88.60
515482 [CHSHMVET    13.200] AMP    37761.2   -88.83
515484 [CHSHMVW1    34.500] AMP    17755.9   -88.58
515485 [CHSHMVWT    13.200] AMP    37696.6   -88.83
515497 [MATHWSN7    345.00] AMP    28563.4   -86.09
515547 [GRANTCO2    69.000] AMP     7515.8   -80.50
515548 [GRANTC11    13.800] AMP     7913.2   -84.72
515770 [WOODRNG1    13.800] AMP    24173.4   -89.28
520205 [WAKITA_138  138.00] AMP     5513.8   -79.80
532771 [RENO   7    345.00] AMP    12195.7   -86.28
532791 [BENTON 7    345.00] AMP    18978.7   -85.77
532795 [FR2WEST7    345.00] AMP     5131.5   -85.84
532829 [WICH11 1    13.800] AMP    50360.2   -87.28
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532830 [WICH12 1    13.800] AMP    50540.2   -87.65
532984 [SUMNER 4    138.00] AMP     9886.9   -82.75
533036 [CLEARWT4    138.00] AMP    17042.2   -84.85
533040 [EVANS N4    138.00] AMP    41385.5   -87.22
533046 [GILL S 4    138.00] AMP    27099.9   -85.12
533127 [F2EAST11    13.800] AMP    58617.4   -85.48
533128 [F2EAST21    13.800] AMP    58626.5   -85.51
533131 [FR2ELV11    34.500] AMP    14238.9   -88.38
533132 [FR2ELV21    34.500] AMP    14187.9   -88.37
560031 [G15-015-TAP 138.00] AMP     8474.9   -81.12
560033 [G1524&G1525T345.00] AMP    19483.7   -86.44
562476 [G14-001-TAP 345.00] AMP    10523.5   -85.17
583752 [G13-029-GSU134.500] AMP    16184.3   -85.79
583755 [G13-029-GSU234.500] AMP    15485.1   -84.90
584472 [G15-003-GSU134.500] AMP    27345.7   -85.73
512694 [CLEVLND7    345.00] AMP    14505.1   -86.34
514708 [OTTER  4    138.00] AMP     9392.5   -82.44
514709 [FRMNTAP4    138.00] AMP    16396.7   -82.81
514711 [WAUKOTP4    138.00] AMP    14506.3   -81.46
514719 [CLYDE  2    69.000] AMP     4577.7   -73.45
514733 [MARSHL 4    138.00] AMP     7690.4   -80.56
514739 [MEDFORD2    69.000] AMP     5441.1   -76.50
514802 [SOONER 4    138.00] AMP    31274.8   -86.85
514806 [SOONER2G    20.000] AMP   200101.9   -88.66
514880 [NORTWST7    345.00] AMP    29408.3   -86.09
514881 [SPRNGCK7    345.00] AMP    21344.6   -85.57
514901 [CIMARON7    345.00] AMP    30018.6   -85.94
515407 [TATONGA7    345.00] AMP    16407.3   -86.61
515486 [CHSHMVE1-GSU34.500] AMP    15835.1   -85.63
515487 [CHSHMVW1-GSU34.500] AMP    16005.3   -85.56
515576 [RANCHRD7    345.00] AMP    12903.5   -86.70
515581 [COYOTE 4    138.00] AMP     8343.1   -80.59
515760 [SOONER 1    13.800] AMP    43074.9   -87.60
520204 [SANDY_CN_138138.00] AMP     5429.7   -79.79
520206 [WAKITA_13.8 13.800] AMP     9093.5   -86.63
521085 [WAKITA 2    69.000] AMP     5201.1   -80.81
532721 [EEC U1      16.000] AMP    78004.3   -88.56
532722 [EEC U2      24.000] AMP   113622.5   -88.66
532729 [EVAN SVC    8.0000] AMP   140300.3   -88.34
532739 [GILL SVC    8.0000] AMP    93830.1   -87.89
532768 [EMPEC 7     345.00] AMP    16789.3   -86.14
532773 [SUMMIT 7    345.00] AMP    10996.2   -86.09
532794 [ROSEHIL7    345.00] AMP    18273.0   -85.80
532797 [WOLFCRK7    345.00] AMP    15965.7   -86.82
532807 [RENO 1X1    14.400] AMP    45066.8   -87.92
532810 [RENO 2X1    14.400] AMP    44857.8   -87.96
532821 [BENTN1 1    13.800] AMP    23685.8   -88.68
532822 [BENTN2 1    13.800] AMP    45086.2   -87.32
532982 [OXFORD 4    138.00] AMP     9011.7   -82.84
532986 [BENTON 4    138.00] AMP    28090.6   -85.81
532992 [TIMBJCT4    138.00] AMP     5610.1   -83.23
533029 [59TH ST4    138.00] AMP    18582.7   -83.61
533041 [EVANS S4    138.00] AMP    41385.5   -87.22
533045 [GILL W 4    138.00] AMP    27099.9   -85.12
533063 [SC10BEL4    138.00] AMP     9561.3   -81.60
533065 [SG12COL4    138.00] AMP    22604.1   -85.63
533106 [GILL S 1    13.200] AMP    17370.8   -89.57
533107 [GILL S 2    13.200] AMP    17370.8   -89.57
533129 [F2WEST11    13.800] AMP    53755.9   -85.54
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533130	[F2WEST21	13.800]	AMP	53514.5	-85.56
533133	[FR2WLV11	34.500]	AMP	13764.8	-88.31
533134	[FR2WLV21	34.500]	AMP	13743.7	-88.29
533135	[ECLCT1 1	34.500]	AMP	12490.7	-87.16
533136	[ECLCT2 1	34.500]	AMP	12413.9	-87.06
533390	[MAIZEW 4	138.00]	AMP	27643.7	-85.43
533416	[RENO 3	115.00]	AMP	29745.4	-86.45
533795	[GILL E 2	69.000]	AMP	33294.6	-85.25
533796	[GILL W 2	69.000]	AMP	33294.6	-85.25
539675	[MILANTP4	138.00]	AMP	6543.9	-74.95
539801	[THISTLE7	345.00]	AMP	15955.2	-85.90
583850	[GEN-2014-001	345.00]	AMP	7022.2	-84.93
584570	[GEN-2015-015	138.00]	AMP	5860.3	-81.71
584660	[G1524&G1525	345.00]	AMP	5107.3	-85.51
584690	[GEN-2015-030	345.00]	AMP	17642.0	-86.00
300138	[4CLEVLND	138.00]	AMP	16442.1	-85.56
509852	[T.NO.--7	345.00]	AMP	23169.9	-86.29
512817	[CLEVLND1	13.800]	AMP	12906.7	-89.63
514703	[FAIRMNT4	138.00]	AMP	10521.3	-83.45
514704	[MILLERT4	138.00]	AMP	20229.8	-85.65
514707	[PERRY 4	138.00]	AMP	10860.7	-83.35
514710	[WAUKOMI4	138.00]	AMP	9331.5	-80.31
514713	[WRVALLY4	138.00]	AMP	8593.7	-82.20
514731	[SO4TH 4	138.00]	AMP	14081.6	-80.73
514736	[4CORNER2	69.000]	AMP	4074.1	-69.64
514740	[NUMAOGE2	69.000]	AMP	4574.9	-73.82
514757	[CHIKASI4	138.00]	AMP	9111.1	-79.28
514798	[SNRPMPT4	138.00]	AMP	20277.5	-85.63
514801	[MINCO 7	345.00]	AMP	15961.3	-85.15
514805	[SOONER1G	22.000]	AMP	174547.4	-88.34
514827	[CTNWOOD4	138.00]	AMP	16182.6	-80.57
514879	[NORTWST4	138.00]	AMP	41551.3	-85.97
514882	[SPGCK1&2	13.800]	AMP	111041.2	-89.52
514883	[SPGCK3&4	13.800]	AMP	75457.9	-89.31
514885	[NORTWS41	13.800]	AMP	49778.6	-88.35
514898	[CIMARON4	138.00]	AMP	40870.5	-85.08
514908	[ARCADIA7	345.00]	AMP	24976.0	-86.51
514934	[DRAPER 7	345.00]	AMP	20968.7	-85.31
515375	[WWRDEHV7	345.00]	AMP	20315.5	-86.09
515447	[MORISNT4	138.00]	AMP	13354.0	-83.12
515448	[CRSRDSW7	345.00]	AMP	11575.0	-85.66
515610	[FSHRTAP7	345.00]	AMP	15933.5	-85.16
515621	[OPENSKY7	345.00]	AMP	11583.8	-86.70
515714	[CIMARO11	13.800]	AMP	37456.9	-88.58
515715	[CIMARO21	13.800]	AMP	52150.9	-87.61
515742	[NORTWS21	13.800]	AMP	47926.1	-87.27
515743	[NORTWS31	13.800]	AMP	49778.6	-88.35
520203	[BYRON_138	138.00]	AMP	4171.3	-79.43
520938	[HAZLTNJ2	69.000]	AMP	2712.9	-56.40
521006	[MARSHAL4	138.00]	AMP	7655.0	-80.50
521008	[NASH 2	69.000]	AMP	2652.3	-74.83
532723	[EEC GT1	13.800]	AMP	50278.0	-89.24
532724	[EEC GT2	13.800]	AMP	50314.3	-89.24
532725	[EEC GT3	18.000]	AMP	67672.0	-89.37
532733	[GEC U3	14.400]	AMP	87875.2	-88.12
532734	[GEC U4	14.400]	AMP	70899.1	-88.77
532740	[EMPEC121	13.800]	AMP	60859.4	-89.87
532741	[EMPEC341	13.800]	AMP	60859.4	-89.87
532742	[EMPEC5 1	18.000]	AMP	85198.1	-89.65

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532743 [EMPEC6 1    18.000] AMP    85198.1   -89.65
532744 [EMPEC7 1    18.000] AMP    85198.1   -89.65
532751 [WCGS U1     25.000] AMP   207657.6   -88.00
532767 [GEARY  7    345.00] AMP     9844.2   -86.34
532769 [LANG   7    345.00] AMP    16590.9   -86.13
532770 [MORRIS 7    345.00] AMP    12544.6   -85.50
532774 [SWISVAL7    345.00] AMP    16102.0   -85.33
532799 [WAVERLY7    345.00] AMP    14765.1   -86.54
532800 [LATHAMS7    345.00] AMP    10366.9   -85.57
532813 [SUMMIT 1    14.400] AMP    30622.8   -87.12
532826 [ROSEH1 1    13.800] AMP    39167.9   -88.54
532827 [ROSEH5 1    13.800] AMP    38930.1   -88.54
532831 [ROSEH3 1    13.800] AMP    39104.5   -88.54
532873 [SUMMIT 6    230.00] AMP    13611.9   -85.50
532981 [CRESWLN4    138.00] AMP     8031.4   -81.94
532985 [TCROCK 4    138.00] AMP     5251.3   -83.23
532988 [BELAIRE4    138.00] AMP    18633.7   -84.71
532990 [MIDIAN 4    138.00] AMP    10168.1   -80.54
533015 [BENTLEY4    138.00] AMP    12276.6   -84.35
533024 [29TH   4    138.00] AMP    19402.8   -85.03
533035 [CHISHLM4    138.00] AMP    22323.5   -84.73
533039 [ELPASO 4    138.00] AMP    25013.4   -84.13
533042 [FARBER 4    138.00] AMP    15981.2   -83.71
533044 [GILL E 4    138.00] AMP    27099.9   -85.12
533053 [LAKERDG4    138.00] AMP    19016.6   -85.54
533054 [MAIZE  4    138.00] AMP    23253.7   -85.10
533062 [ROSEHIL4    138.00] AMP    30981.0   -86.08
533072 [WACO   4    138.00] AMP    22780.8   -85.04
533074 [45TH ST4    138.00] AMP    28023.7   -85.60
533120 [TIMBJCT1    13.200] AMP    11729.6   -86.23
533137 [WCLCT1 1    34.500] AMP    12262.6   -87.28
533138 [WCLCT2 1    34.500] AMP    12240.5   -87.09
533413 [CIRCLE 3    115.00] AMP    29300.7   -86.57
533415 [DAVIS  3    115.00] AMP     9150.7   -82.79
533429 [MOUNDRG3    115.00] AMP     9751.9   -83.21
533438 [WMCPHER3    115.00] AMP    15912.8   -85.75
533558 [TIMBJCT2    69.000] AMP     8002.0   -83.96
533653 [WOLFCRK2    69.000] AMP     5909.2   -87.21
533798 [GILLJCT2    69.000] AMP    21783.4   -81.90
533804 [HAYSVLJ2    69.000] AMP    14204.8   -78.17
533812 [LIN    2    69.000] AMP     9690.2   -83.50
533813 [MACARTH2    69.000] AMP    22518.2   -80.86
533830 [PECK   2    69.000] AMP     6510.7   -83.84
533850 [BASICCH2    69.000] AMP    20318.2   -84.25
539668 [HARPER 4    138.00] AMP     5559.3   -78.95
539676 [MILAN 4     138.00] AMP     3505.7   -70.42
539800 [CLARKCOUNTY7345.00] AMP    12540.9   -85.60
539802 [THISTLE T1  13.800] AMP     8114.7   -88.41
539804 [THISTLE4    138.00] AMP    16476.0   -86.34
539805 [ELMCREEK7   345.00] AMP     5724.1   -85.76
562075 [G11-051-TAP 345.00] AMP    16704.5   -86.42
579253 [G07-21&14-02345.00] AMP    13579.9   -86.37
579268 [G07-44&14-03345.00] AMP     9129.7   -85.26
583490 [GEN-2012-041345.00] AMP    11414.7   -86.55
583851 [G14-001XFMR134.500] AMP    12913.5   -87.73
583854 [G14-001XFMR234.500] AMP    12853.8   -87.64
583990 [GEN-2014-049345.00] AMP     7874.9   -85.26
584170 [GEN-2014-064138.00] AMP     9322.5   -82.41
584450 [GEN-2015-001345.00] AMP    12903.5   -86.70
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584571 [G15-015XFMR134.500] AMP    13384.8   -85.99
584661 [G1524&1525X134.500] AMP    34351.5   -87.15
584691 [G15-030XFMR134.500] AMP    25942.6   -88.40
584700 [GEN-2015-029345.00] AMP     9771.0   -84.60
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