
**Submitted to**
**Southwest Power Pool**

SPP Southwest Power Pool

Report On

## GEN-2016-046
## Modification Request Impact Study

Revision R1

Date of Submittal
March 22, 2021

anedenconsulting.com

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# Revision History

| DATE OR VERSION NUMBER | AUTHOR | CHANGE DESCRIPTION |
|---|---|---|
| 03/22/2021 | Aneden Consulting | Initial Report Issued. |
| | | |
| | | |

# Executive Summary

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2016-046, an active generation interconnection request with a point of interconnection (POI) on the Ironwood to Clark County 345 kV line.

The GEN-2016-046 project is proposed to interconnect in the Sunflower Electric Power Corporation (SUNC) control area with a capacity of 299 MW as shown in Table ES-1 below. This Study has been requested by the Interconnection Customer to evaluate the modification of GEN-2016-046 from the previously studied 130 x GE 116 2.3 MW to a turbine configuration of 62 x Nordex 149 4.8 MW wind turbines for total capacity of 297.6 MW. In addition, the modification request included changes to the collection system, generator step-up transformers, main substation transformer, the generation interconnection line, and reactive power devices. The modification request changes are shown in Table ES-2.

**Table ES-1: GEN-2016-046 Existing Configuration**

| Request | Capacity (MW) | Existing Generator Configuration | Point of Interconnection |
|---|---|---|---|
| GEN-2016-046 | 299 | 130 x GE 116 2.3 MW = 299 MW | Tap on Ironwood (539803) to Clark County (539800) 345 kV (G16-046-TAP 560080) |

**Table ES-2: GEN-2016-046 Modification Request**

<table>
<tr><th>Facility</th><th>Existing</th><th colspan="2">Modification</th></tr>
<tr><td>Point of Interconnection</td><td>Tap on Ironwood (539803) to Clark County (539800) 345 kV (G16-046-TAP 560080)</td><td colspan="2">Tap on Ironwood (539803) to Clark County (539800) 345 kV (G16-046-TAP 560080)</td></tr>
<tr><td>Configuration/Capacity</td><td>130 x GE 116 2.3 MW = 299 MW</td><td colspan="2">62 x Nordex 149 4.8 MW = 297.6 MW</td></tr>
<tr><td>Generation Interconnection Line</td><td>Length = 5.5 miles<br>R = 0.000300 pu<br>X = 0.002600 pu<br>B = 0.028180 pu</td><td colspan="2">Length = 4.99 miles<br>R = 0.000275 pu<br>X = 0.002354 pu<br>B = 0.044582 pu</td></tr>
<tr><td rowspan="2">Main Substation Transformer</td><td rowspan="2"><u>345/34.5 kV Transformer:</u><br>X = 10%, R = 0.24%, Winding 200 MVA, Rate 333 MVA</td><td colspan="2"><u>345/115 kV Transformer:</u><br>X = 4.5%, R = 0.1%, Winding 210 MVA, Rating 350 MVA</td></tr>
<tr><td><u>115/34.5 kV Transformer:</u><br>X = 10%, R = 0.18%, Winding 102 MVA, Rating 170 MVA</td><td><u>115/34.5 kV Transformer:</u><br>X = 10%, R = 0.18%, Winding 102 MVA, Rating 170 MVA</td></tr>
<tr><td>GSU Transformer</td><td>Gen 1 Equivalent Qty: 130:<br>X = 5.7%, R = 0.8%, Rating 332.8 MVA</td><td>Gen 1 Equivalent Qty: 31:<br>X = 8.43%, R = 1.12%, Rating 165.9 MVA</td><td>Gen 2 Equivalent Qty: 31:<br>X = 8.43%, R = 1.12%, Rating 165.9 MVA</td></tr>
<tr><td>Equivalent Collector Line</td><td>R = 0.002750 pu<br>X = 0.003850 pu<br>B = 0.110690 pu</td><td>R = 0.004769 pu<br>X = 0.006878 pu<br>B = 0.051243 pu</td><td>R = 0.008653 pu<br>X = 0.014749 pu<br>B = 0.091819 pu</td></tr>
<tr><td>Reactive Power Devices</td><td>N/A</td><td>1 x 15 MVAR 34.5 kV Capacitor Bank</td><td>1 x 15 MVAR 34.5 kV Capacitor Bank</td></tr>
</table>

SPP determined that power flow should not be performed based on the POI MW injection decrease of 0.99%. However, SPP determined that the turbine change from GE to Nordex turbines required short circuit and dynamic stability analyses.

The scope of this modification request study included a charging current compensation analysis, short circuit analysis, and dynamic stability analysis.

Aneden performed the analyses using the modification request data based on the DISIS-2016-002-2 Group 3 study models:

1. 2017 Winter Peak (2017WP),
2. 2018 Summer Peak (2018SP),
3. 2026 Summer Peak (2026SP)

All analyses were performed using the PTI PSS/E version 33.7 software and the results are summarized below.

The results of the charging current compensation analysis performed using the 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak models showed that the GEN-2016-046 project needed 19.04 MVAr of reactor shunts on the 34.5 kV bus of the project substation, an increase from the 13.9 MVAr found in the DISIS study[1]. 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 or no-wind conditions. The information gathered from the charging current compensation analysis is provided as information to the customer and Transmission Owner. SPP does not require additional reactive requirements based on the results of this analysis.

The results from the short circuit analysis with the updated topology showed that the maximum GEN-2016-046 contribution to three-phase fault currents in the immediate systems at or near GEN-2016-046 was not greater than 0.72 kA for the 2018SP and 2026SP models. All three-phase fault current levels within 5 buses of the POI with the GEN-2016-046 generators online were below 27 kA for the 2018SP and 2026SP models.

The dynamic stability analysis was performed using the three DISIS-2016-002 models 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak. Up to 62 events were simulated, which included three-phase faults, three-phase faults on prior outage cases, and single-line-to-ground faults with stuck breakers faults.

The results of the dynamic stability analysis showed that there were no damping or voltage recovery violations observed during the simulated faults. Additionally, the project 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.

[1] DISIS-2016-001 Definitive Interconnection System Impact Study Report, February 28, 2017

The requested modification has been determined by SPP to not be a Material Modification. The requested modification does not have a material adverse impact on the cost or timing of any other Interconnection Request with a later Queue priority date.

In accordance with FERC Order No. 827, the generating facility will be required to provide dynamic reactive power within the range of 0.95 leading to 0.95 lagging at the high-side of the generator substation.

It is likely that the customer may be required to reduce its generation output to 0 MW in real-time, 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.

# 1.0 Scope of Study

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2016-046. A Modification Request Impact Study is a generation interconnection study performed to evaluate the impacts of modifying the DISIS study assumptions. The determination of the required scope of the study is dependent upon the specific modification requested and how it may impact the results of the DISIS study. Impacting the DISIS results could potentially affect the cost or timing of any Interconnection Request with a later Queue priority date, deeming the requested modification a Material Modification. The criteria sections below include reasoning as to why an analysis was either included or excluded from the scope of study.

All analyses were performed using the PTI PSS/E version 33.7 software. The results of each analysis are presented in the following sections.

## 1.1 Power Flow

To determine whether power flow analysis is required, SPP evaluates the difference in the real power output at the POI between the existing configuration and the requested modification. Power flow analysis is included if the difference has a significant impact on the results of DISIS study.

## 1.2 Stability Analysis, Short Circuit Analysis

To determine whether stability and short circuit analyses are required, SPP evaluates the difference between the turbine parameters and, if needed, the collector system impedance between the existing configuration and the requested modification. Dynamic stability analysis and short circuit analysis would be required if the differences listed above were determined to have a significant impact on the most recently performed DISIS stability analysis.

## 1.3 Charging Current Compensation Analysis

SPP requires that a charging current compensation analysis be performed on the requested modification configuration as it is a non-synchronous resource. The charging current compensation analysis determines the capacitive effect at the POI caused by the project's collector system and transmission line's capacitance. A shunt reactor size is determined in order to offset the capacitive effect and maintain zero (0) MVAr flow at the POI while the project's generators and capacitors are offline.

## 1.4 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

The GEN-2016-046 Interconnection Customer has requested a modification to its Interconnection Request (IR) with a point of interconnection (POI) on the Ironwood to Clark County 345 kV line. At the time of the posting of this report, GEN-2016-046 is an active IR with a queue status of "IA FULLY EXECUTED/ON SCHEDULE." GEN-2016-046 is a wind farm, has a maximum summer and winter queue capacity of 299 MW, and has Energy Resource Interconnection Service (ERIS).

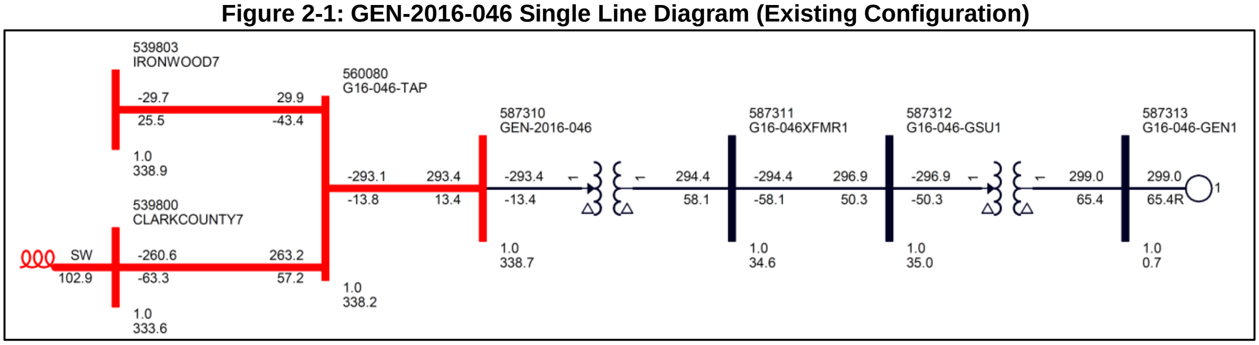
GEN-2016-046 was originally studied as part of Group 3 in the DISIS-2016-001 study. Figure 2-1 shows the power flow model single line diagram for the existing GEN-2016-046 configuration.

The GEN-2016-046 project is proposed to interconnect in the Sunflower Electric Power Corporation (SUNC) control area with a combined nameplate capacity of 299 MW as shown in Table 2-1 below.

**Table 2-1: GEN-2016-046 Existing Configuration**

| Request | Capacity (MW) | Existing Generator Configuration | Point of Interconnection |
|---|---|---|---|
| GEN-2016-046 | 299 | 130 x GE 116 2.3 MW = 299 MW | Tap on Ironwood (539803) to Clark County (539800) 345 kV (G16-046-TAP 560080) |

**Figure 2-1: GEN-2016-046 Single Line Diagram (Existing Configuration)**




This Study has been requested by the Interconnection Customer to evaluate the modification of GEN-2016-046 from the previously studied 130 x GE 116 2.3 MW to a turbine configuration of 62 x Nordex 149 4.8 MW wind turbines for total capacity of 297.6 MW. In addition, the modification request included changes to the collection system, generator step-up transformers, main substation transformer, the generation interconnection line, and reactive power devices. The modification request changes are shown in Figure 2-2 and Table 2-2 below.

**Figure 2-2: GEN-2016-046 Single Line Diagram (Modification Configuration)**

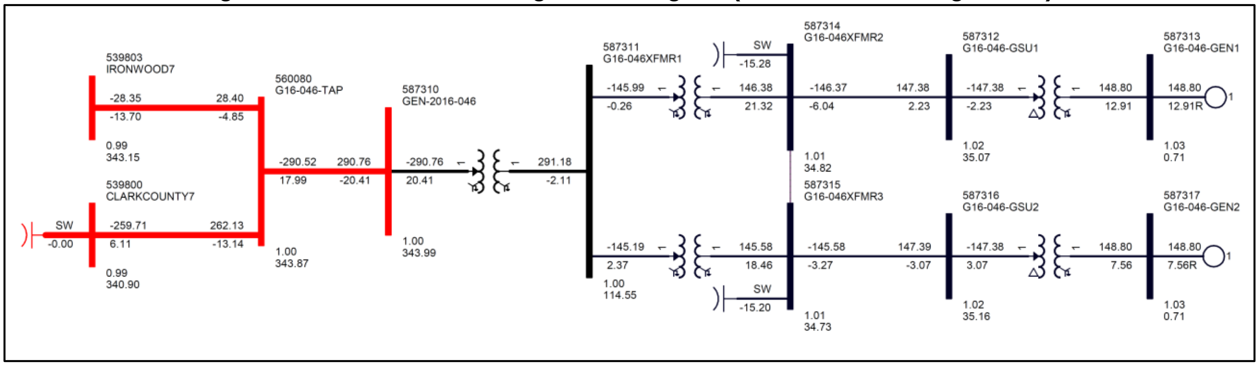



**Table 2-2: GEN-2016-046 Modification Request**

| Facility | Existing | Modification | |
|---|---|---|---|
| Point of Interconnection | Tap on Ironwood (539803) to Clark County (539800) 345 kV (G16-046-TAP 560080) | Tap on Ironwood (539803) to Clark County (539800) 345 kV (G16-046-TAP 560080) | |
| Configuration/Capacity | 130 x GE 116 2.3 MW = 299 MW | 62 x Nordex 149 4.8 MW = 297.6 MW | |
| Generation Interconnection Line | Length = 5.5 miles<br>R = 0.000300 pu<br>X = 0.002600 pu<br>B = 0.028180 pu | Length = 4.99 miles<br>R = 0.000275 pu<br>X = 0.002354 pu<br>B = 0.044582 pu | |
| Main Substation Transformer | <u>345/34.5 kV Transformer:</u><br>X = 10%, R = 0.24%, Winding 200 MVA, Rate 333 MVA | <u>345/115 kV Transformer:</u><br>X = 4.5%, R = 0.1%, Winding 210 MVA, Rating 350 MVA | |
| | | <u>115/34.5 kV Transformer:</u><br>X = 10%, R = 0.18%, Winding 102 MVA, Rating 170 MVA | <u>115/34.5 kV Transformer:</u><br>X = 10%, R = 0.18%, Winding 102 MVA, Rating 170 MVA |
| GSU Transformer | Gen 1 Equivalent Qty: 130:<br>X = 5.7%, R = 0.8%, Rating 332.8 MVA | Gen 1 Equivalent Qty: 31:<br>X = 8.43%, R = 1.12%, Rating 165.9 MVA | Gen 2 Equivalent Qty: 31:<br>X = 8.43%, R = 1.12%, Rating 165.9 MVA |
| Equivalent Collector Line | R = 0.002750 pu<br>X = 0.003850 pu<br>B = 0.110690 pu | R = 0.004769 pu<br>X = 0.006878 pu<br>B = 0.051243 pu | R = 0.008653 pu<br>X = 0.014749 pu<br>B = 0.091819 pu |
| Reactive Power Devices | N/A | 1 x 15 MVAR 34.5 kV Capacitor Bank | 1 x 15 MVAR 34.5 kV Capacitor Bank |

# 3.0 Existing vs Modification Comparison

To determine which analysis is required, the differences between the existing configuration and the requested modification were evaluated.

Aneden performed this comparison and the resulting analyses using a set of modified study models developed based on the modification request data and the DISIS-2016-002-2 Group 3 study models.

The methodology and results of the comparisons are described below. The analysis was completed using PSS/E version 33.7 software.

## 3.1 POI Injection Comparison

The real power injection at the POI was determined using PSS/E for both the existing configuration and the requested modification with updates for GEN-2016-046. The percentage change in the POI injection before and after the modification request was then compared. If the MW difference was determined to be significant, power flow analysis would be performed to assess the impact of the modification request.

SPP determined that power flow analysis was not required due to the insignificant change (decrease of 0.99%) in the real power output at the POI between the existing configuration and requested modification shown in Table 3-1.

**Table 3-1: GEN-2016-046 POI Injection Comparison**

| Interconnection Request | Existing POI Injection from Project (MW) | MRIS POI Injection from Project (MW) | POI Injection Difference from Project % |
|---|---|---|---|
| GEN-2016-046 | 293.1 | 290.2 | -0.99% |

## 3.2 Turbine Parameters Comparison

SPP determined that the turbine change from GE to Nordex turbines required short circuit and dynamic stability analyses as the stability responses of the existing configuration and the requested modification's configuration may differ. The generator dynamic model for the modification can be found in Appendix A.

As short circuit and dynamic stability analyses were required, a turbine parameters comparison was not needed for the determination of the scope of the study.

## 3.3 Equivalent Impedance Comparison Calculation

As the turbine change determined that short circuit and dynamic stability analyses were required, an equivalent impedance comparison was not needed for the determination of the scope of the study.

# 4.0 Charging Current Compensation Analysis

The charging current compensation analysis was performed for GEN-2016-046 to determine the capacitive charging effects during reduced generation conditions (unsuitable wind speeds, unsuitable solar irradiance, insufficient state of charge, idle conditions, curtailment, etc.) at the generation site and to size shunt reactors that would reduce the project reactive power contribution to the POI to approximately zero.

## 4.1 Methodology and Criteria

The GEN-2016-046 generators and capacitors (if any) were switched out of service while other collector system elements remained in-service. A shunt reactor was tested at the project's collection substation 34.5 kV bus to set the MVAr flow into the POI to approximately zero. The size of the shunt reactor is equivalent to the charging current value at unity voltage and the compensation provided is proportional to the voltage effects on the charging current (i.e. for voltages above unity, reactive compensation is greater than the size of the reactor).

## 4.2 Results

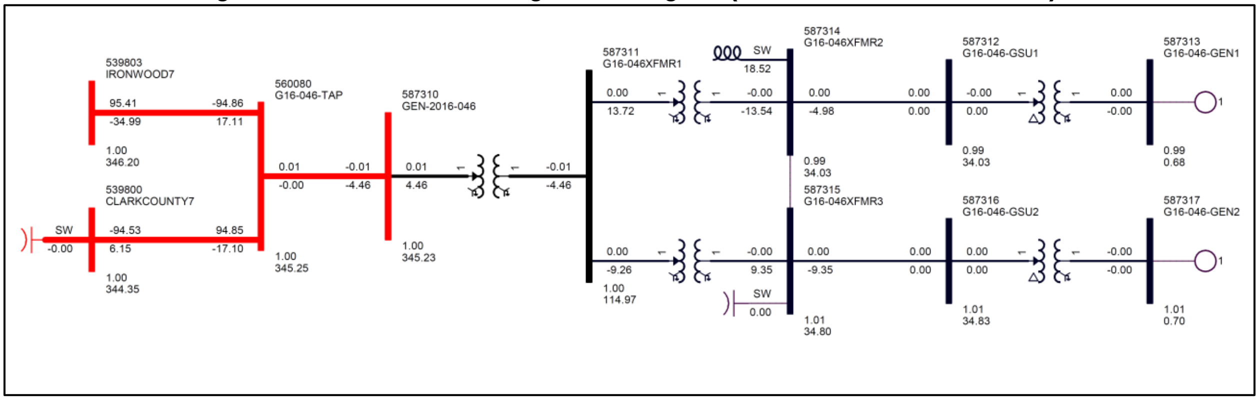
The results from the analysis showed that the GEN-2016-046 project needed an approximately 19.04 MVAr shunt reactor at the project substation, to reduce the POI MVAr to zero. This is an increase from the 13.9 MVAr found in the DISIS study[2]. Figure 4-1 illustrates the shunt reactor size needed to reduce the POI MVAr to approximately zero with the updated topology. The final shunt reactor requirements for GEN-2016-046 is shown in Table 4-1.

The information gathered from the charging current compensation analysis is provided as information to the customer and Transmission Owner. SPP does not require additional reactive requirements based on the results of this analysis.

**Table 4-1: Shunt Reactor Size for Low Wind Study (Modification)**

| Machine | POI Bus Number | POI Bus Name | Reactor Size (MVAr) | | |
|---|---|---|---|---|---|
| | | | 17WP | 18SP | 26SP |
| GEN-2016-046 | 560080 | G16-046-TAP | 19.04 | 19.04 | 19.04 |

**Figure 4-1: GEN-2016-046 Single Line Diagram (Modification Shunt Reactor)**

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[2] DISIS-2016-001 Definitive Interconnection System Impact Study Report, February 28, 2017

# 5.0 Short Circuit Analysis

A short circuit study was performed using the 2018SP and 2026SP models for GEN-2016-046. The detailed results of the short circuit analysis are provided in Appendix B.

## 5.1 Methodology

The short circuit analysis included applying a 3-phase fault on buses up to 5 levels away from the 345 kV POI bus. The PSS/E "Automatic Sequence Fault Calculation (ASCC)" fault analysis module was used to calculate the fault current levels with and without GEN-2016-046 online.

## 5.2 Results

The results of the short circuit analysis for the 2018SP and 2026SP models are summarized in Table 5-1 through Table 5-3 respectively. The GEN-2016-046 POI bus fault current magnitudes are provided in Table 5-1 showing a maximum fault current of 11.16 kA.

The maximum fault current calculated within 5 buses of the GEN-2016-046 POI was less than 27 kA for the 2018SP and 2026SP models respectively. The maximum GEN-2016-046 contribution to three-phase fault current was about 6.9% and 0.72 kA.

**Table 5-1: POI Short Circuit Results**

| Case | GEN-OFF Current (kA) | GEN-ON Current (kA) | Max kA Change | Max %Change |
|---|---|---|---|---|
| 2018SP | 10.42 | 11.14 | 0.72 | 6.9% |
| 2026SP | 10.44 | 11.16 | 0.72 | 6.9% |

**Table 5-2: 2018SP Short Circuit Results**

| Voltage (kV) | Max. Current (kA) | Max kA Change | Max %Change |
|---|---|---|---|
| 115 | 21.8 | 0.04 | 0.3% |
| 138 | 23.3 | -0.05 | -0.2% |
| 230 | 12.3 | 0.14 | 1.2% |
| 345 | 26.1 | 0.72 | 6.9% |
| **Max** | **26.1** | **0.72** | **6.9%** |

**Table 5-3: 2026SP Short Circuit Results**

| Voltage (kV) | Max. Current (kA) | Max kA Change | Max %Change |
|---|---|---|---|
| 115 | 22.6 | 0.04 | 0.3% |
| 138 | 23.3 | -0.05 | -0.2% |
| 230 | 12.4 | 0.14 | 1.2% |
| 345 | 26.4 | 0.72 | 6.9% |
| **Max** | **26.4** | **0.72** | **6.9%** |

# 6.0 Dynamic Stability Analysis

Aneden performed a dynamic stability analysis to identify the impact of the turbine configuration change and other modifications to the GEN-2016-046 project. The analysis was performed according to SPP's Disturbance Performance Requirements shown in Appendix C. The modification details are described in Section 2.0 above and the dynamic modeling data is provided in Appendix A. The simulation plots can be found in Appendix D.

## 6.1 Methodology and Criteria

The dynamic stability analysis was performed using models developed with the requested 62 x Nordex 149 4.8 MW (NXK8BJ) configuration for the GEN-2016-046 generating facilities. This stability analysis was performed using PTI's PSS/E version 33.7 software.

The stability models were developed using the models from DISIS-2016-002-2 for Group 3. The modifications requested for the GEN-2016-046 project was used to create modified stability models for this impact study.

The modified dynamics model data for the DISIS-2016-001 Group 3 request, GEN-2016-046, is provided in Appendix A. The modified power flow models and associated dynamics database were initialized (no-fault test) to confirm that there were no errors in the initial conditions of the system and the dynamic data.

During the fault simulations, the active power (PELEC), reactive power (QELEC), and terminal voltage (ETERM) were monitored for GEN-2016-046 and other equally and prior queued projects in Group 3. In addition, voltages of five (5) buses away from the POI of GEN-2016-046 were monitored and plotted. The machine rotor angle for synchronous machines and speed for asynchronous machines within this study area including 520 (AEPW), 524 (OKGE), 525 (WFEC), 526 (SPS), 531 (MIDW), 534 (SUNC), 536 (WERE), 640 (NPPD), 645 (OPPD), 650, (LES), 652 (WAPA) were monitored. In addition, the voltages of all 100 kV and above buses within the study area were monitored.

## 6.2 Fault Definitions

Aneden simulated the faults previously simulated for GEN-2016-046 and selected additional fault events for GEN-2016-046 as required. The new set of faults were simulated using the modified study models. The fault events included three-phase faults, three-phase faults on prior outage cases, and single-line-to-ground faults with stuck breakers. The simulated faults are listed and described in Table 6-1 below. These contingencies were applied to the modified 2017 Winter Peak, 2018 Summer Peak, and the 2026 Summer Peak models.

**Table 6-1: Fault Definitions**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT01-3PH | P1 | 3 phase fault on G16-005-TAP 345 kV (560072) to CLARKCOUNTY7 345 kV (539800) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-3PH | P1 | 3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT23-3PH | P1 | 3 phase fault on G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT24-3PH | P1 | 3 phase fault on G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT25-3PH | P1 | 3 phase fault on CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1, near CLARKCOUNTY7.<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT29-3PH | P1 | 3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT32-3PH | P1 | 3 phase fault on G13-010-TAP 345 kV (562334) to POSTROCK7 345 kV (530583) line CKT 1, near G13-010-TAP.<br>a. Apply fault at the G13-010-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT35-3PH | P1 | 3 phase fault on the SPERVIL7 345 kV (531469) to SPEARVL6 230 kV (539695) to SPERTER1 13.8 kV (531468) XFMR CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted transformer. |
| FLT36-3PH | P1 | 3 phase fault on SPERVIL7 345 kV (531469) to BUCKNER7 345 kV (531501) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT37-3PH | P1 | 3 phase fault on the SPERVIL7 345 kV (531469) to SPRVL 3 115 kV (539759) to SPRVL-T 13.8 kV (539960) XFMR CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted transformer. |
| FLT38-3PH | P1 | 3 phase fault on SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |

**Table 6-1 continued**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT39-3PH | P1 | 3 phase fault on SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (539803) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT06-SB | P4 | **Stuck Breaker at G16-005-TAP (560072).**<br>a. Apply single phase fault at G16-005-TAP.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. G16-005-TAP (560072) - CLARKCOUNTY7 (539800) line CKT 1.<br>d. G16-005-TAP (560072) - THISTLE7 (539801) line CKT 1. |
| FLT10-SB | P4 | **Stuck Breaker at CLARKCOUNTY7 (539800).**<br>a. Apply single phase fault at CLARKCOUNTY7.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. CLARKCOUNTY7 (539800) - G16-005-TAP (560072) line CKT 1.<br>d. CLARKCOUNTY7 (539800) - IRONWOOD7 (560002) line CKT 1. |
| FLT26-SB | P4 | **Stuck Breaker at CLARKCOUNTY7 (539800).**<br>a. Apply single phase fault at CLARKCOUNTY7.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. CLARKCOUNTY7 (539800) - G16-046-TAP (560080) line CKT 1.<br>d. CLARKCOUNTY7 (539800) - IRONWOOD7 (560002) line CKT 1. |
| FLT27-SB | P4 | **Stuck Breaker at CLARKCOUNTY7 (539800).**<br>a. Apply single phase fault at CLARKCOUNTY7.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. CLARKCOUNTY7 (539800) - G16-046-TAP (560080) line CKT 1.<br>d. CLARKCOUNTY7 (539800) - G16-005-TAP (560072) line CKT 2. |
| FLT25-PO2 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1, near CLARKCOUNTY7.<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT29-PO2 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT25-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1, near CLARKCOUNTY7.<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |

**Table 6-1 continued**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT9001-3PH | P1 | 3 phase fault on the Ironwood7 345KV (539803) to GEN-2008-124 345kV (579480) line CKT 1, near Ironwood7.<br>a. Apply fault at the Ironwood7 345KV bus.<br>b. Clear fault after 5 cycles by tripping the faulted line.<br>**Trip generator G08-124-GEN1 (579483).**<br>**Trip generator G08-124-GEN2 (579486).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9002-3PH | P1 | 3 phase fault on the Ironwood 345KV (539803) to Ironwood 34.5kv (539807) to Ironwood 13.8kV (539808) XMFR line CKT 1, near Ironwood 345kV.<br>a. Apply fault at the Ironwood 345kV bus.<br>b. Clear fault after 5 cycles by tripping the faulted transformer.<br>**Trip generator IronWD-WTG1 (599030).**<br>**Trip generator IronWD-WTG1 (599033).** |
| FLT9003-3PH | P1 | 3 phase fault on IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1, near IRONWOOD7 345 kV.<br>a. Apply fault at the IRONWOOD7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9004-3PH | P1 | 3 phase fault on the Spearville (531469) to G13-010 Tap 345KV (562334) 345KV line CKT 1, near Spearville.<br>a. Apply fault at the Spearville 345KV bus.<br>b. Clear fault after 5 cycles by tripping the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9005-3PH | P1 | 3 phase fault on the Clark County 345KV (539800) to GEN-2012-024 345KV (583370) line CKT 1, near Clark County.<br>a. Apply fault at the Clark County 345KV bus.<br>b. Clear fault after 5 cycles by tripping the faulted line.<br>**Trip generator G12-024-GEN1 (583373).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9006-3PH | P1 | 3 phase fault on CLARKCOUNTY7 345 kV (539800) to GEN-2011-008 345 kV (582008) line CKT 1, near CLARKCOUNTY7.<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>**Trip generator G11-008-GEN7 (582978).**<br>**Trip generator G11-008-GEN8 (582979).**<br>**Trip generator G11-008-GEN1 (582208).**<br>**Trip generator G11-008-GEN2 (582209).**<br>**Trip generator G11-008-GEN3 (582210).**<br>**Trip generator G11-008-GEN4 (582211).**<br>**Trip generator G11-008-GEN5 (582598).**<br>**Trip generator G11-008-GEN6 (582599).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9007-3PH | P1 | 3 phase fault on GEN-2011-008 345 kV (582008) to G-2011-008-3 345 kV (582908) line CKT 1, near GEN-2011-008.<br>a. Apply fault at the GEN-2011-008 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>**Trip generator G11-008-GEN7 (582978).**<br>**Trip generator G11-008-GEN8 (582979).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9008-3PH | P1 | 3 phase fault on GEN-2011-008 345 kV (582008) to G-2011-008-1 345 kV (582009) line CKT 1, near GEN-2011-008.<br>a. Apply fault at the GEN-2011-008 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>**Trip generator G11-008-GEN1 (582208).**<br>**Trip generator G11-008-GEN2 (582209).**<br>**Trip generator G11-008-GEN3 (582210).**<br>**Trip generator G11-008-GEN4 (582211).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |

**Table 6-1 continued**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT9009-3PH | P1 | 3 phase fault on GEN-2011-008 345 kV (582008) to G-2011-008-2 345 kV (582708) line CKT 1, near GEN-2011-008.<br>a. Apply fault at the GEN-2011-008 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>**Trip generator G11-008-GEN5 (582598).**<br>**Trip generator G11-008-GEN6 (582599).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9010-3PH | P1 | 3 phase fault on the G16-005-TAP 345KV (560072) to GEN-2016-005 (587040) 345KV line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345KV bus.<br>b. Clear fault after 5 cycles by tripping the faulted line.<br>**Trip generator G16-005-GEN1 (587044).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9011-3PH | P1 | 3 phase fault on the Ironwood2 345KV (560002) to GEN-2011-016 345kV (582016) line CKT 1, near Ironwood2.<br>a. Apply fault at the Ironwood2 345KV bus.<br>b. Clear fault after 5 cycles by tripping the faulted line.<br>**Trip generator G11-016-GEN1 (582316).**<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-PO1 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT25-PO1 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1, near CLARKCOUNTY7.<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT29-PO1 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT38-PO1 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1;**<br>3 phase fault on SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-PO2 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |

**Table 6-1 continued**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT38-PO2 | P6 | **Prior Outage of G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1;**<br>3 phase fault on SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-PO3 | P6 | **Prior Outage of IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT25-PO3 | P6 | **Prior Outage of IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1, near CLARKCOUNTY7.<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT29-PO3 | P6 | **Prior Outage of IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT38-PO3 | P6 | **Prior Outage of IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1;**<br>3 phase fault on SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-PO4 | P6 | **Prior Outage of SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT23-PO4 | P6 | **Prior Outage of SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT24-PO4 | P6 | **Prior Outage of SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |

**Table 6-1 continued**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT29-PO4 | P6 | **Prior Outage of SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9003-PO4 | P6 | **Prior Outage of SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1, near IRONWOOD7 345 kV.<br>a. Apply fault at the IRONWOOD7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT02-PO5 | P6 | **Prior Outage of CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to THISTLE7 345 kV (539801) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT23-PO5 | P6 | **Prior Outage of CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT24-PO5 | P6 | **Prior Outage of CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT29-PO5 | P6 | **Prior Outage of CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9003-PO5 | P6 | **Prior Outage of CLARKCOUNTY7 345 kV (539800) to IRONWOOD7 345 kV (560002) line CKT 1;**<br>3 phase fault on IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1, near IRONWOOD7 345 kV.<br>a. Apply fault at the IRONWOOD7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT01-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on G16-005-TAP 345 kV (560072) to CLARKCOUNTY7 345 kV (539800) line CKT 1, near G16-005-TAP.<br>a. Apply fault at the G16-005-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |

**Table 6-1 continued**

| Fault ID | Planning Event | Fault Descriptions |
|---|---|---|
| FLT23-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on G16-046-TAP 345 kV (560080) to CLARKCOUNTY7 345 kV (539800) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT24-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on G16-046-TAP 345 kV (560080) to IRONWOOD7 345 kV (539803) line CKT 1, near G16-046-TAP.<br>a. Apply fault at the G16-046-TAP 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT29-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on CLARKCOUNTY7 345 kV (539800) to G16-005-TAP 345 kV (560072) line CKT 1, near CLARKCOUNTY7<br>a. Apply fault at the CLARKCOUNTY7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT38-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on SPERVIL7 345 kV (531469) to IRONWOOD7 345 kV (560002) line CKT 1, near SPERVIL7 345 kV.<br>a. Apply fault at the SPERVIL7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9003-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on IRONWOOD7 345 kV(539803) to SPERVIL7 345 kV (531469) line CKT 1, near IRONWOOD7 345 kV.<br>a. Apply fault at the IRONWOOD7 345 kV bus.<br>b. Clear fault after 5 cycles and trip the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT9004-PO6 | P6 | **Prior Outage of CLARKCOUNTY7 (539800) to G16-005-TAP (560072) line CKT 2;**<br>3 phase fault on the Spearville (531469) to G13-010 Tap 345KV (562334) 345KV line CKT 1, near Spearville.<br>a. Apply fault at the Spearville 345KV bus.<br>b. Clear fault after 5 cycles by tripping the faulted line.<br>c. Wait 20 cycles, and then re-close the line in (b) back into the fault.<br>d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault. |
| FLT1005-SB | P4 | **Stuck Breaker at Ironwood2 (560002)**<br>a. Apply single phase fault at Ironwood2 345kV bus.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. Ironwood2 345kV Bus. |
| FLT1006-SB | P4 | **Stuck Breaker at Ironwood (539803)**<br>a. Apply single phase fault at Ironwood 345kV bus.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. Ironwood 345kV Bus. |
| FLT1007-SB | P4 | **Stuck Breaker at SPERVIL7 (531469)**<br>a. Apply single phase fault at SPERVIL7.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. SPERVIL7 (531469) - BUCKNER7 (531501) line CKT 1.<br>d. SPERVIL7 345 kV (531469) to SPEARVL6 230 kV (539695) to SPERTER1 13.8 kV (531468) XFMR CKT 1. |
| FLT1008-SB | P4 | **Stuck Breaker at SPERVIL7 (531469)**<br>a. Apply single phase fault at SPERVIL7.<br>b. Clear fault after 16 cycles and trip the following elements.<br>c. SPERVIL7 (531469) - G13-010-TAP (562334) line CKT 1.<br>d. SPERVIL7 (531469) - IRONWOOD7 (539803) line CKT 1. |

## 6.3 Results

Table 6-2 shows the results of the fault events simulated for each of the three modified cases. The associated stability plots are provided in Appendix D.

**Table 6-2: GEN-2016-046 Dynamic Stability Results**

| Fault ID | 17WP | | | 18SP | | | 26SP | | |
|---|---|---|---|---|---|---|---|---|---|
| | Voltage Recovery | Voltage Violation | Stable | Voltage Recovery | Voltage Violation | Stable | Voltage Recovery | Voltage Violation | Stable |
| FLT01-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT02-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT23-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT24-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT25-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT32-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT35-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT36-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT37-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT38-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT39-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9001-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9002-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9003-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9004-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9005-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9006-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9007-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9008-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9009-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9010-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9011-3PH | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT06-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT10-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT26-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT27-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT1005-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT1006-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT1007-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT1008-SB | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT02-PO1 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT25-PO1 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-PO1 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT38-PO1 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT25-PO2 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-PO2 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT02-PO2 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT38-PO2 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT02-PO3 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT25-PO3 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-PO3 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |

**Table 6-2 continued**

| Fault ID | 17WP | | | 18SP | | | 26SP | | |
|---|---|---|---|---|---|---|---|---|---|
| | Voltage Recovery | Voltage Violation | Stable | Voltage Recovery | Voltage Violation | Stable | Voltage Recovery | Voltage Violation | Stable |
| FLT38-PO3 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT02-PO4 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT23-PO4 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT24-PO4 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-PO4 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9003-PO4 | Pass | Pass | Stable* | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT02-PO5 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT23-PO5 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT24-PO5 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-PO5 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9003-PO5 | Pass | Pass | Stable* | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT01-PO6 | Pass | Fail** | Stable | Pass | Fail** | Stable | Pass | Pass | Stable |
| FLT02-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT25-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT23-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT24-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT29-PO6 | Pass | Fail** | Stable | Pass | Fail** | Stable | Pass | Pass | Stable |
| FLT38-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9003-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |
| FLT9004-PO6 | Pass | Pass | Stable | Pass | Pass | Stable | Pass | Pass | Stable |

***RELAY SLNOS1 # 1 tripped 523853 [FINNEY 7 345.00] TO 531449 [HOLCOMB7 345.00] CKT 1 during the fault**
****Steady state low voltage violations observed**

During a few prior outage conditions, FLT9003-PO4 and FLT9003-PO5, the SLNOS1 #1 relay tripped the Finney to Holcomb 345 kV Circuit 1 line during the fault. This was observed in both the pre and post modification cases, so it was not attributed to this modification request.

In addition, there were low voltage violations observed after the prior outage of Clark County to G16-005-TAP 345KV Circuit 2 line (PO6) followed by FLT01 or FLT29. This voltage violation was observed in both the pre and post modification cases. Previous mitigation identified for this issue include the following system adjustments:

1. Turn off Summit 14.4kV shunt reactor (-27.2MVAR)
2. Turn on Circle 115kV capbank (45MVAR)
3. Turn on WMCPHER3 115kV capbank (45MVAR)
4. Turn on JOHNCR 3 115kV capbank (24MVAR)
5. Turn on NORTHVW3 115kV capbank (45MVAR)
6. Turn on 3 VANBU3 115kV capbank (30MVAR)
7. Adjust HEIZER 230/115kV TF tap ratio and disable automatic voltage regulator
8. Adjust GRTBNDTT 230/115kV TF tap ratio and disable automatic voltage regulator
9. Adjust Ironwood wind farm MPT ratio to allow generator to generate more reactive power
10. Adjust GEN-2016-046 wind farm MPT ratio to allow generator to generate more reactive power

11. Adjust GEN-2011-016 wind farm MPT ratio to allow generator to generate more reactive power
12. Adjust Cimarron wind farm MPT ratio to allow generator to generate more reactive power
13. Adjust Spearville wind farm MPT ratio to allow generator to generate more reactive power

There were no damping or voltage recovery violations observed during the simulated faults. Additionally, the project 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.

# 7.0 Material Modification Determination

In accordance with Attachment V of SPP's Open Access Transmission Tariff, for modifications other than those specifically permitted by Attachment V, SPP shall evaluate the proposed modifications prior to making them and inform the Interconnection Customer in writing of whether the modifications would constitute a Material Modification. Material Modification shall mean (1) modification to an Interconnection Request in the queue that has a material adverse impact on the cost or timing of any other Interconnection Request with a later Queue priority date; or (2) planned modification to an Existing Generating Facility that is undergoing evaluation for a Generating Facility Modification or Generating Facility Replacement, and has a material adverse impact on the Transmission System with respect to: i) steady-state thermal or voltage limits, ii) dynamic system stability and response, or iii) short-circuit capability limit; compared to the impacts of the Existing Generating Facility prior to the modification or replacement.

## 7.1 Results

SPP determined the requested modification is not a Material Modification based on the results of this Modification Request Impact Study performed by Aneden. Aneden evaluated the impact of the requested modification on the prior study results. Aneden determined that the requested modification resulted in similar dynamic stability and short circuit analyses and that the prior study power flow results are not negatively impacted.

This determination implies that any network upgrades already required by GEN-2016-046 would not be negatively impacted and that no new upgrades are required due to the requested modification, thus not resulting in a material adverse impact on the cost or timing of any other Interconnection Request with a later Queue priority date.

# 8.0 Conclusions

The Interconnection Customer for GEN-2016-046 requested a Modification Request Impact Study to assess the impact of the turbine and facility changes to a configuration with a total of 62 x Nordex 149 4.8 MW wind turbines for total capacity of 297.6 MW. In addition, the modification request included changes to the collection system, generator step-up transformers, main substation transformer, the generation interconnection line, and reactive power devices.

SPP determined that power flow should not be performed based on the POI MW injection decrease of 0.99%. However, SPP determined that the turbine change from GE to Nordex turbines required short circuit and dynamic stability analyses.

The scope of this modification request study included a charging current compensation analysis, short circuit analysis, and dynamic stability analysis.

The results of the charging current compensation analysis performed using the 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak models showed that the GEN-2016-046 project needed 19.04 MVAr of reactor shunts on the 34.5 kV bus of the project substation, an increase from the 13.9 MVAr found in the DISIS study[3]. 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 or no-wind conditions. The information gathered from the charging current compensation analysis is provided as information to the customer and Transmission Owner. SPP does not require additional reactive requirements based on the results of this analysis.

The results from the short circuit analysis with the updated topology showed that the maximum GEN-2016-046 contribution to three-phase fault currents in the immediate systems at or near GEN-2016-046 was not greater than 0.72 kA for the 2018SP and 2026SP models. All three-phase fault current levels within 5 buses of the POI with the GEN-2016-046 generators online were below 27 kA for the 2018SP and 2026SP models.

The dynamic stability analysis was performed using the three DISIS-2016-002-2 models 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak. Up to 62 events were simulated, which included three-phase faults, three-phase faults on prior outage cases, and single-line-to-ground faults with stuck breakers faults.

The results of the dynamic stability analysis showed that there were no damping or voltage recovery violations observed during the simulated faults. Additionally, the project 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.

The requested modification has been determined by SPP to not be a Material Modification. The requested modification does not have a material adverse impact on the cost or timing of any other Interconnection Request with a later Queue priority date.

[3] DISIS-2016-001 Definitive Interconnection System Impact Study Report, February 28, 2017

It is likely that the customer may be required to reduce its generation output to 0 MW in real-time, 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.