# *Generation Interconnection System Impact Study Report*

# *For*

# *PJM Generation Interconnection Request Queue Position AB2-083*

# *Delano 138kV*

**January 2018**

## General

Community Energy Solar Development, LLC (Community Energy) proposes to install PJM Project #AB2-083, a 40 MW (27.2 MW Capacity) solar generating facility in Ross County, Ohio (see Figure 2). The generating facility will consist of eighteen (18) 2.2 MW inverters. The point of interconnection is at the Delano 138 kV substation (see Figure 1).

The requested Backfeed date is September 30, 2017.
The requested in service date is October 31, 2017.

The objective of this System Impact Study is to determine budgetary cost estimates and approximate construction timelines for identified transmission facilities required to connect the proposed generating facilities to the AEP transmission system. These reinforcements include the Attachment Facilities, Local Upgrades, and Network Upgrades required to maintain the reliability of the AEP transmission system. Stability analysis is included as part of this study.

## Attachment Facilities

### Point of Interconnection (Delano 138 kV Substation)

To accommodate the interconnection at the Delano 138 kV substation, the substation will have to be expanded requiring the installation of a new 138 kV circuit breaker, extending the two 138 kV buses, and starting a new string, associated protection and control equipment, SCADA, and 138 kV revenue metering.

Direct Connection to the Delano 138 kV Substation Work and Cost:

- Expand the substation, start a new string, install one new 138 kV circuit breaker, and extend the 138 kV buses (see Figure 1). Installation of associated protection and control equipment, SCADA, and 138 kV revenue metering will also be required. n5420
- **Estimated Station Cost: $500,000**
- **Estimated 138 kV Revenue Metering Cost: $150,000**
- **Note:** An additional 138 kV circuit breaker may be required; Protection Engineering will determine that in later studies.

Protection and Relay Work and Cost:

- Install line protection and controls at the Delano 138 kV substation. n5421
- **Estimated Cost: $300,000**

It is understood that Community Energy is responsible for all costs associated with this interconnection. The costs above are reimbursable to AEP. The cost of Community Energy's generating plant and the costs for the line connecting the generating plant to Community Energy's switching station are not included in this report; these are assumed to be Community Energy's responsibility.

The Generation Interconnection Agreement does not in or by itself establish a requirement for American Electric Power to provide power for consumption at the developer's facilities. A separate agreement may be reached with the local utility that provides service in the area to ensure that infrastructure is in place to meet this demand and proper metering equipment is installed. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

**Local and Network Impacts for the Point of Interconnection**

The impact of the proposed generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet performance parameters prescribed in the AEP FERC Form 715[1] and Connection Requirements for AEP Transmission System[2]. Therefore, these criteria were used to assess the impact of the proposed facility on the AEP System. The Queue Project AB2-083 was evaluated as a 40.0 MW (Capacity 27.2 MW) injection into the Delano 138 kV substation in the AEP area. Project AB2-083 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB2-083 was studied with a commercial probability of 100%. Potential network impacts were as follows:

# Summer Peak Analysis - 2020

## Generator Deliverability

*(Single or N-1 contingencies for the Capacity portion only of the interconnection)*

None.

## Light Load Analysis

*Light Load Studies to be conducted during later study phases (applicable to wind, coal, nuclear, and pumped storage projects).*

To be determined during later study phases

## Multiple Facility Contingency

*(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)*

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1 https://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/GuideLines/AEP_East_FERC_715_2016_Final_Part_4.pdf

2 https://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/Requirements/AEP_Interconnection_Requirements_rev1.pdf

None.

## Short Circuit

*(Summary of impacted circuit breakers)*

None.

## Affected System Analysis & Mitigation

### LGEE Impacts:

None

### MISO Impacts:

MISO Impacts to be determined during later study phases (as applicable).

### Duke, Progress & TVA Impacts:

None

### OVEC Impacts:

None

## Contribution to Previously Identified Overloads

*(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)*

None.

## Steady-State Voltage Requirements

*(Summary of the VAR requirements based upon the results of the steady-state voltage studies)*

None.

## Stability and Reactive Power Requirement for Low Voltage Ride Through

*(Summary of the VAR requirements based upon the results of the dynamic studies)*

None.

## New System Reinforcements

*(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)*

None.

## Contribution to Previously Identified System Reinforcements

*(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)*

None.

## Potential Congestion due to Local Energy Deliverability

*PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.*

*Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified*

None.

### Schedule

It is anticipated that the time between receipt of executed agreements and Commercial Operation may range from 12 to 18 months if no line work is required. If line work is required, construction time would be between 24 to 36 months after signing an interconnection agreement.

**Note:** The time provided between anticipated normal completion of System Impact, Facilities Studies, subsequent execution of ISA and ICSA documents, and the proposed Backfeed Date is shorter than usual and may be difficult to achieve.

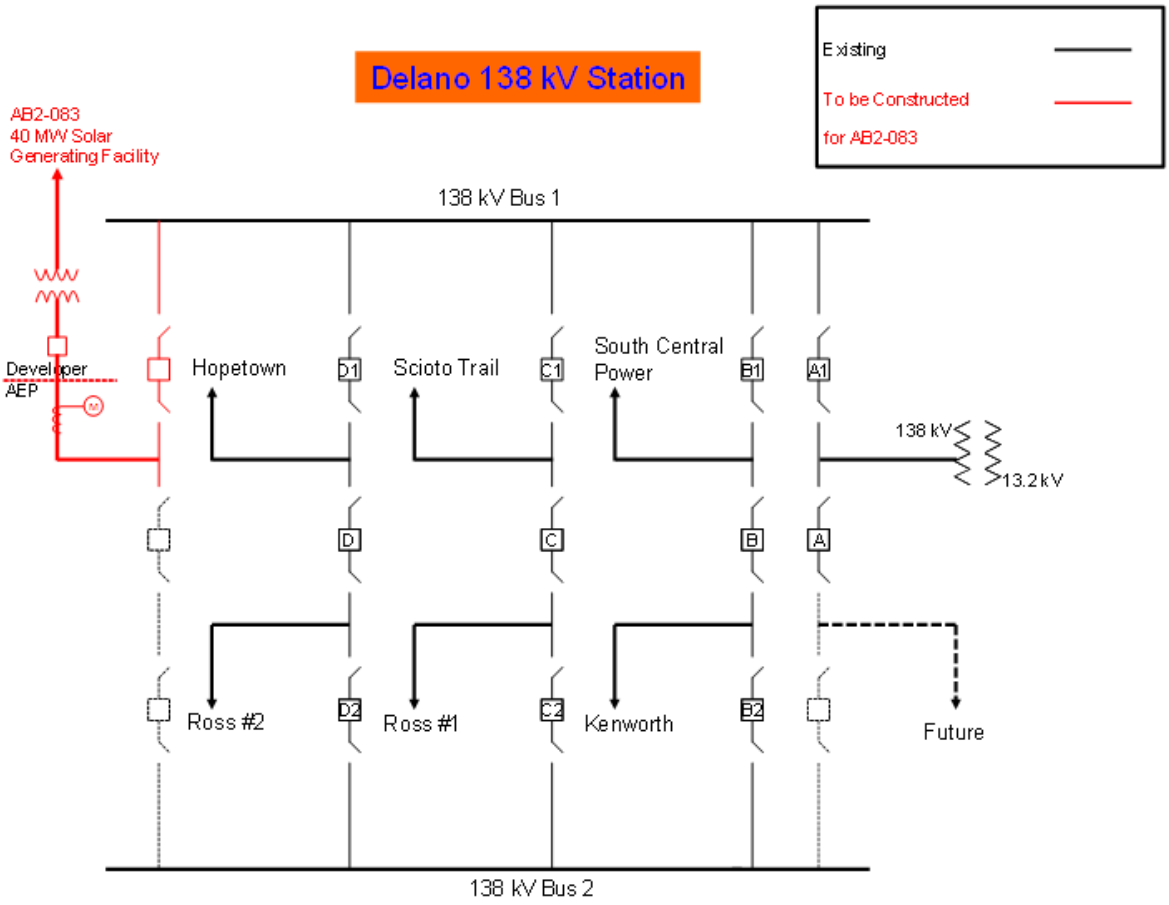
### Conclusion

Based upon the results of this System Impact Study, the construction of the 40.0 MW (27.2 MW Capacity) solar generating facility of Community Energy (PJM Project #AB2-083) will require the following additional interconnection charges. This plan of service will interconnect the proposed solar generating facility in a manner that will provide operational reliability and flexibility to both the AEP system and the Community Energy generating facility.

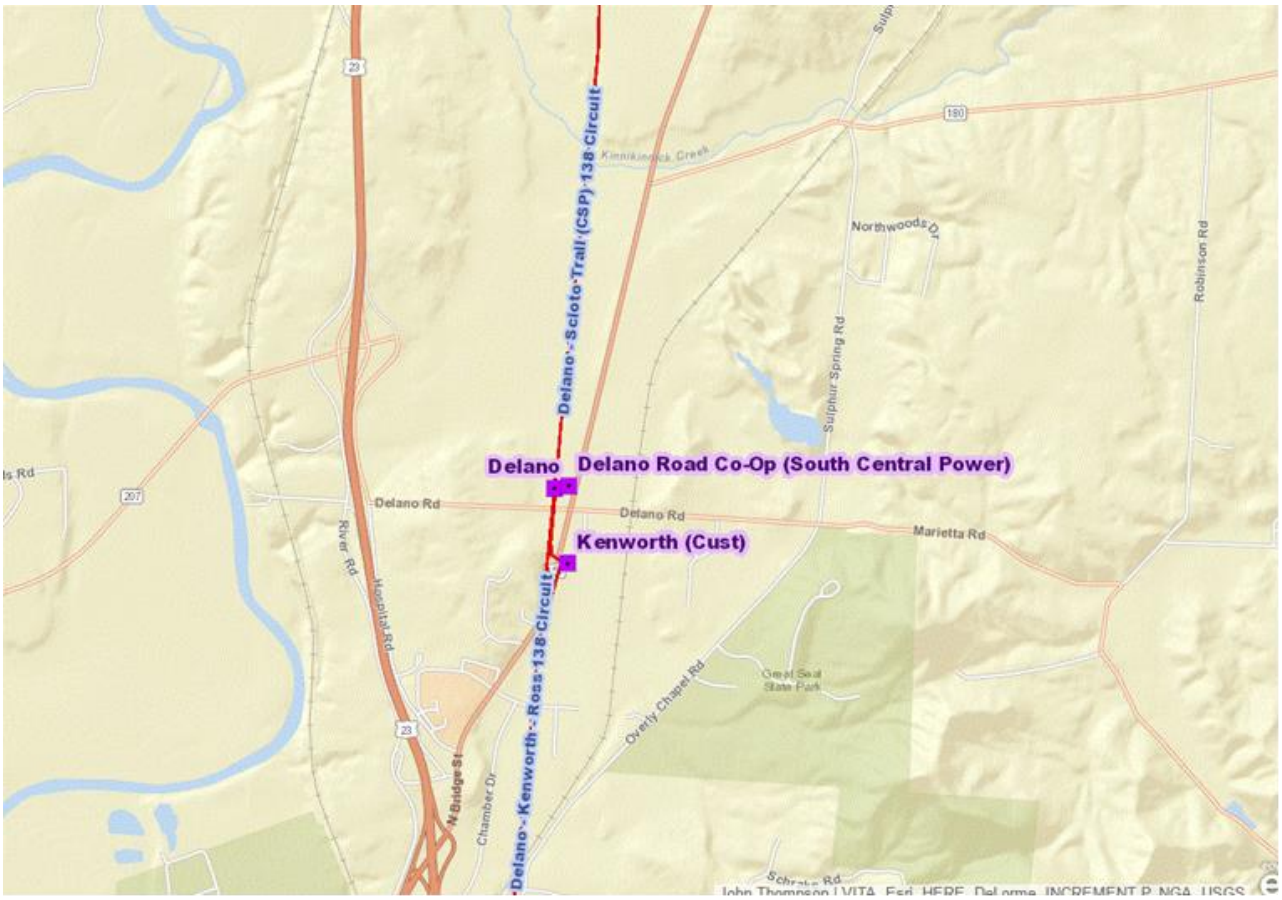
| Cost Breakdown for Point of Interconnection (Delano 138 kV Substation) | | |
|---|---|---|
| **Attachment Cost** | Expand Delano 138 kV Substation | **$500,000** |
| **Non-Direct Connection Cost Estimate** | 138 kV Revenue Metering | **$150,000** |
| | Install line protection and controls at the Delano 138 kV substation | **$300,000** |
| | **Total Estimated Cost for Project AB2-083** | **$950,000** |

The estimates are preliminary in nature, as they were determined without the benefit of detailed engineering studies. Final estimates will require an on-site review and coordination to determine final construction requirements.

# Attachment 1. Single Line Diagram



# Attachment 2. Project Location



# Attachment 3. Dynamic Simulation Analysis

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## Executive Summary

Generator Interconnection Request AB2-083 is for a 40 MW Maximum Facility Output (MFO) solar powered generating facility with a Point of Interconnection (POI) at the Delano 138 kV substation in the American Electric Power (AEP) transmission system, Ross County, Ohio.

This report describes a dynamic simulation analysis of AB2-083 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 summer peak case, modified to include applicable queue projects. AB2-083 has been dispatched online at maximum power output, with 1.0 pu voltage at the generator bus.

AB2-083 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 76 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation (20 second);

b) Three phase faults with normal clearing time;

c) Single phase faults with stuck breaker;

d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from the fault due to primary communications/relay failure;

e) Single phase bus faults with normal clearing time.

f) Single phase faults with loss of multiple-circuit tower line

No relevant High Speed Reclosing (HSR) contingencies were found.

For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.

For all 76 of the fault contingencies tested on the 2020 summer peak case:

a) AB2-083 was able to ride through the faults (except for faults where protective action trips a generator(s)),

b) Post-contingency oscillations were positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recovered to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element tripped, other than those either directly connected or designed to trip as a consequence of that fault.

It is recommended that the ‘DGSMod’ model parameter be changed to full (1.0) in order to produce a faster active power response at the queue project during fault recovery.

No mitigations were found to be required.

# 1. Introduction

Generator Interconnection Request AB2-083 is for a 40 MW Maximum Facility Output (MFO) solar generation plant. AB2-083 consists of 20 x SMA Sunny Central 2200-US 2.0 MW inverters with a Point of Interconnection (POI) at the Delano 138 kV substation in the American Electric Power (AEP) transmission system, Ross County, Ohio.

This analysis is effectively a screening study to determine whether the addition of AB2-083 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AB2-083 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

## 2. Description of Project

AB2-083 consists of 20 x SMA Sunny Central 2200-US 2.0 MW inverters. AB2-083 will be connected to the POI via a 138/34.5/0.385 kV 25/33/42 MVA main collector transformer and an equivalent lumped 34.5/0.385 kV 44 MVA representing 20 x 2.2 MVA GSU transformers.

The AB2-083 Point of Interconnection (POI) is the Delano 138 kV substation in the American Electric Power (AEP) transmission system, Ross County, Ohio, as shown in Figure 1.Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AB2-083 loadflow model.

The dynamic model for the AB2-083 plant is based on the 'SMASC_C126_33_IVF111.dll' user defined model supplied by PJM, as inficated by the Developer in the System Impact Study Data Form.

Additional project details are provided in Attachments 1 through 4:

- Attachment 1 contains the Impact Study Data which details the proposed AB2-083 project.
- Attachment 2 shows the one-line diagram of the AEP network in the vicinity of AB2-083.
- Attachment 3 provides a diagram of the PSS/E model in the vicinity of AB2-083.
- Attachment 4 gives the PSS/E loadflow and dynamic models of AB2-083.

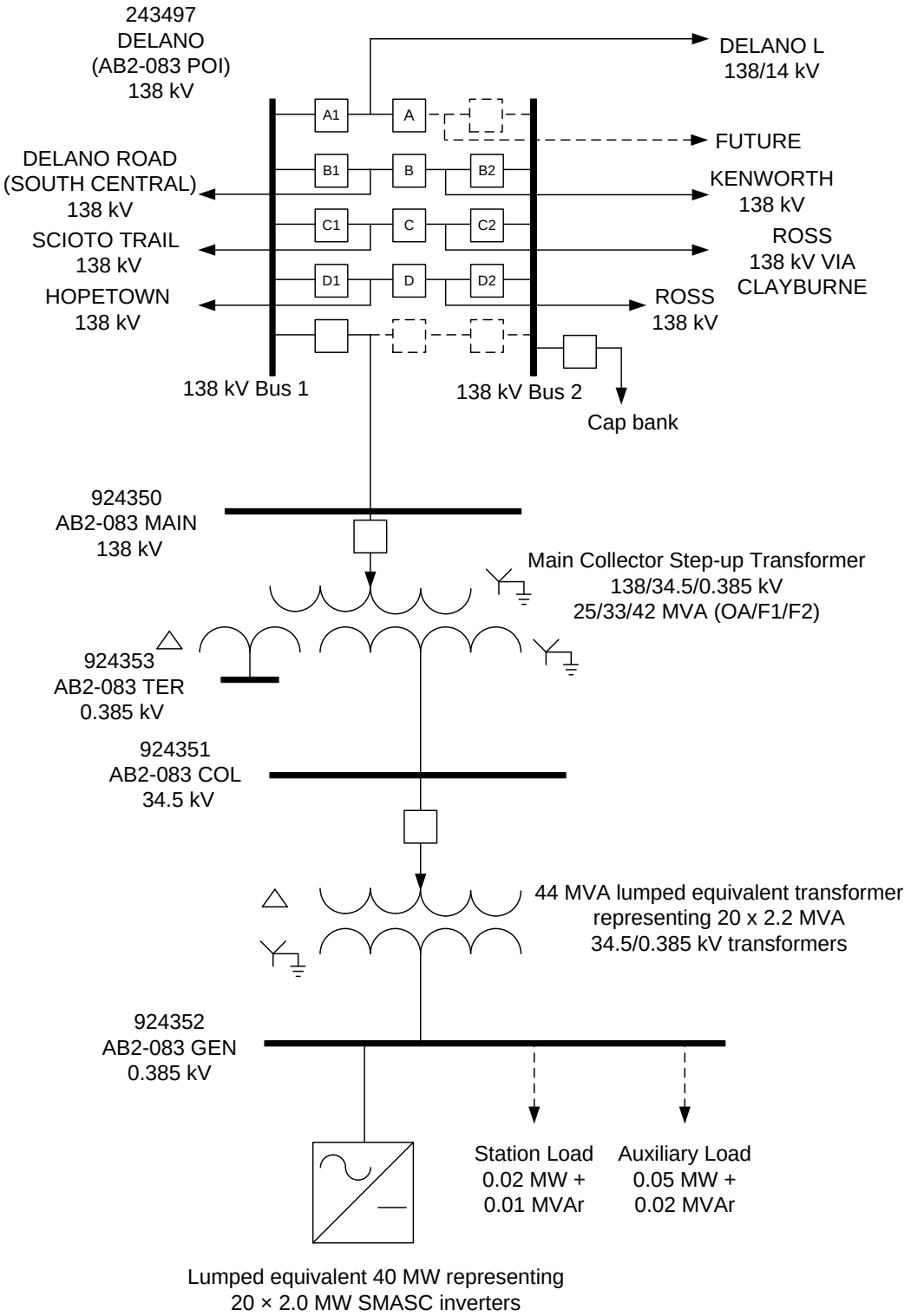


**Figure 1: AB2-083 Plant Model**

**Table 1: AB2-083 Plant Model**

| | Impact Study Data | Model |
|---|---|---|
| Inverter Type | 20 × 2.0 MW SMA Sunny Central 2200-US inverters<br><br>MVA base = 44 MVA<br>Vt = 0.385 kV<br><br>Unsaturated sub-transient reactance = j10000 pu @ MVA base | Lumped equivalent representing 20 × 2.0 MW SMA Sunny Central 2200-US inverters<br><br>Pgen 40 MW<br>Pmax 40 MW<br>Pmin 0 MW<br>Qmax 13.147 MVAr<br>Qmin -13.147 MVAr<br>Mbase 44 MVA<br>Zsource j10000 pu @ Mbase |
| GSU transformer(s) | 20 x 34.5/0.385 kV 2.2 MVA transformers<br><br>Rating = 2.2 MVA<br><br>Transformer base = 2.2 MVA (OA)<br><br>Impedance = 0.006875 + j0.055 pu @ MVA base<br><br>Number of taps = 5<br>Tap step size = 2.5% | Lumped equivalent representing 20 x 34.5/0.385 kV 2.2 MVA transformers<br><br>Transformer base = 44 MVA<br><br>Rating = 44 MVA<br><br>Impedance = 0.006875 + j0.055 pu @ MVA base<br><br>Number of taps = 5<br>Tap step size = 2.5% |
| Main collector step-up transformer | 1 x 138/34.5/0.385 kV Three winding transformer YN/YN/d<br><br>Rating = 25/33/42 MVA (OA/F1/F2)<br><br>Transformer base = 25 MVA<br><br>Impedance @ MVA base<br>High to Low = 0.0034 + j0.085 pu<br>High to Tertiary = 0.00612 + j0.153 pu<br>Low to Tertiary = 0.00236 + j0.059 pu<br><br>Number of taps = 5<br>Tap step size = 2.5% | 1 x 138/34.5/0.385 kV Three winding transformer<br><br>Rating = 25/33/42 MVA<br><br>Transformer base = 25 MVA<br><br>Impedance @ MVA base<br>High to Low = 0.0034 + j0.085 pu<br>High to Tertiary = 0.00612 + j0.153 pu<br>Low to Tertiary = 0.00236 + j0.059 pu<br><br>Number of taps = 5<br>Tap step size = 2.5% |
| Station load | 0.02 MW + 0.02 MVAr | 0.02 MW + 0.02 MVAr |
| Auxiliary load | 0.05 MW + 0.05 MVAr | 0.05 MW + 0.05 MVAr |
| Transmission line | N/A | |

## 3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.0.

The load flow scenario and fault cases for this study are based on PJM's Regional Transmission Planning Process[3].

The selected load flow scenario is the RTEP 2020 summer peak case with the following modifications:

a) Addition of all applicable queue projects prior to AB2-083.

b) Addition of AB2-083 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AB2-083.

d) Dispatch of units in the PJM system to maintain slack generators within limits.

e) Merchant transmission projects X3-028 and S57/S58 set online and at maximum power import into PJM.

The AB2-083 initial conditions are listed in Table 2, indicating maximum power output, with 1.0 pu voltage at the generator bus.

**Table 2: AB2-083 machine initial conditions**

| Bus | Name | Unit | PGEN | QGEN | ETERM | POI Voltage |
|---|---|---|---|---|---|---|
| 924352 | AB2-083 GEN | 1 | 40 MW | 1.8368 MVAr | 1.00 pu | 0.9972 pu |

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AB2-083 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AB2-083 is given in Attachment 5.

[3] Manual 14B: PJM Region Transmission Planning Process, Rev 33, May 5 2016, Attachment G: PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

## 4. Fault Cases

Tables 3 to 11 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 10 second simulation time interval.

The studied contingencies include:

a) Steady state operation (20 second);

b) Three phase faults with normal clearing time;

c) Single phase faults with stuck breaker;

d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from the fault due to primary communications/relay failure;

e) Single phase bus faults with normal clearing time;

f) Single phase faults with loss of multiple-circuit tower line.

No relevant high speed reclosing (HSR) contingencies were identified for the study.

The contingencies listed above were applied to:

- Delano (AB2-083 POI) 138 kV
- Scioto Trail 138 kV
- Ross 138 kV
- Hopetown 138 kV

The three phase faults with normal clearing time were performed under network intact conditions.

The three phase faults with normal clearing time with prior outages were considered as below:

| Prior outage | Fault/Trip |
|---|---|
| Delano – Ross 138 kV | Delano – Dupont - Scioto Trail 138 kV circuit |
| Delano – Ross 138 kV | Delano – Clayburne Switch – Ross 138 kV circuit |
| Delano – Ross 138 kV | Delano – Hopetown 138 kV |
| Delano – Scioto Trail 138 kV | Delano – Clayburne Switch – Ross 138 kV circuit |
| Delano – Scioto Trail 138 kV | Delano – Hopetown 138 kV |
| Delano – Hopetown – Biers Run 138 kV | Delano – Clayburne Switch – Ross 138 kV circuit |

Additional delayed (Zone 2) clearing at remote end faults were applied on lines from Scippo 138 kV, Poston 138 kV, Mulberry 138 kV, Biers Run 138 kV, Delano Road 138 kV, Kenworth 138 kV, Scioto Trail 138 kV, Ross 138 kV and Hopetown 138 kV towards Delano (AB2-083 POI) 138 kV.

Clearing times listed in Tables 3 to 11 are as per Revision 19 of "*2016 Revised Clearing times for each PJM company"* spreadsheet.

Attachment 2 contains the one-line diagrams of the AEP networks in the vicinity of AB2-083, showing where faults were applied.

The positive sequence fault impedances for single line to ground faults were derived from the stability case directly by using the ASCC fault calculation method and zero/positive sequence impedance ratio provided by PJM.

## 5. Evaluation Criteria

This study is focused on AB2-083, along with the rest of the PJM system, maintaining synchronism and having all states return to an acceptable new condition following the disturbance. The recovery criteria applicable to this study are as per PJM's Regional Transmission Planning Process and Transmission Owner criteria:

a) AB2-083 is able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AB2-083 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

## 6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Table 3 through Table 11.

For all 76 of the fault contingencies tested on the 2020 summer peak case:

a) AB2-083 was able to ride through the faults (except for faults where protective action trips AB2-083),

b) Post-contingency oscillations were positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recovered to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element tripped, other than those either directly connected or designed to trip as a consequence of that fault.

Delayed recovery of PELEC response of AB2-083 was observed in all contingencies when using model parameters provided by the Developer. AB2-089 was retested with the 'DSGMod' model parameter changed to full (1.0), resulting a more acceptable post-fault PELEC response.

## 6. Recommendations and Mitigations

No adverse impacts attributable to the queue project under study were found and as such, no mitigations were found to be required.

It is recommended that the 'DGSMod' model parameter be changed to full (1.0) in order to produce a faster active power response at the queue project during fault recovery. Plots from the dynamic simulations with DGSMod set to 1 are provided in Attachment 6b.

## Table 3: Steady State Operation

| Fault ID | Duration | Result No Mitigation |
|---|---|---|
| SS.01 | Steady state 20 sec | Stable |

## Table 4: Three-phase Faults with Normal Clearing

| Fault ID | Fault description | Clearing Time Near & Remote (Cycles) | Result No Mitigation |
|---|---|---|---|
| 3N.01 | Fault at Delano 138 kV (AB2-083 POI) on AB2-083 circuit (Trips AB2-083 unit 1 and Delano 28.8 MVAr cap bank). | 5.5 | Stable |
| 3N.02 | Fault at Delano 138 kV (AB2-083 POI) on Delano L 138/13.2 kV Transformer. | 5.5 | Stable |
| 3N.03 | Fault at Delano 138 kV (AB2-083 POI) on Delano Road (S. C. Co-op) circuit. | 5.5 | Stable |
| 3N.04 | Fault at Delano 138 kV (AB2-083 POI) on Kenworth circuit (Trips Kenworth load 2). | 5.5 | Stable |
| 3N.05 | Fault at Delano 138 kV (AB2-083 POI) on Dupont - Scioto Trail circuit (Trips Dupont south load). | 5.5 | Stable |
| 3N.06 | Fault at Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). | 5.5 | Stable |
| 3N.07 | Fault at Delano 138 kV (AB2-083 POI) on Hopetown circuit. | 5.5 | Stable |
| 3N.08 | Fault at Delano 138 kV (AB2-083 POI) on Ross circuit. | 5.5 | Stable |
| 3N.09 | Fault at Scioto Trail 138 kV on Dupont – Delano (AB2-083 POI) circuit (Trips Dupont south load). | 5.5 | Stable |
| 3N.10 | Fault at Scioto Trail 138 kV on Scioto Trail 138/13.2 kV Transformer (Trips Scioto Trail – Dupont Tap circuit). | 5.5 | Stable |
| 3N.11 | Fault at Scioto Trail 138 kV on Dupont – Scippo circuit (Trips Dupont north load). | 5.5 | Stable |
| 3N.12 | Fault at Ross 138 kV on Delano (AB2-083 POI) circuit. | 5.5 | Stable |
| 3N.13 | Fault at Ross 138 kV on Clayburne Switch – Delano (AB2-083 POI) circuit (Trips Kenworth load 1). | 5.5 | Stable |
| 3N.14 | Fault at Ross 138 kV on Bloomingville Switch – Poston circuit (Trips Bloomingville load). | 5.5 | Stable |
| 3N.15 | Fault at Ross 138 kV on Mulberry circuit. | 5.5 | Stable |
| 3N.16 | Fault at Ross 138 kV on Ross 138/12 kV Transformer 2. | 5.5 | Stable |
| 3N.17 | Fault at Ross 138 kV on Ross 138/69 kV Transformer 3. | 5.5 | Stable |

| Fault ID | Fault description | Clearing Time Near & Remote (Cycles) | Result No Mitigation |
|---|---|---|---|
| 3N.18 | Fault at Hopetown 138 kV on Delano circuit. | 5.5 | Stable |
| 3N.19 | Fault at Hopetown 138 kV on Biers Run circuit. | 5.5 | Stable |

## Table 5: Single-phase Faults with Stuck Breaker, Single Phase Delayed Clearing

| Fault ID | Fault description | Clearing Time Normal & Delayed (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1B.01 | Fault at Delano 138 kV (AB2-083 POI) on AB2-083 circuit (Trips AB2-083 unit 1 and Delano 28.8 MVAr cap bank). Breaker D2 stuck. Fault cleared with loss of Ross circuit. | 5.5 / 16 | Stable |
| 1B.02 | Fault at Delano 138 kV (AB2-083 POI) on AB2-083 circuit (Trips AB2-083 unit 1 and Delano 28.8 MVAr cap bank). Breaker C2 stuck. Fault cleared with loss of Clayburne Switch – Ross circuit and Kenworth load 1. | 5.5 / 16 | Stable |
| 1B.03 | Fault at Delano 138 kV (AB2-083 POI) on AB2-083 circuit (Trips AB2-083 unit 1 and Delano 28.8 MVAr cap bank). Breaker B2 stuck. Fault cleared with loss of Kenworth circuit and Kenworth load 2. | 5.5 / 16 | Stable |
| 1B.04 | Fault at Delano 138 kV (AB2-083 POI) on AB2-083 circuit (Trips AB2-083 unit 1 and Delano 28.8 MVAr cap bank). Breaker A stuck. Fault cleared with loss of Delano L 138/13.2 kV Transformer. | 5.5 / 16 | Stable |
| 1B.05 | Fault at Delano 138 kV (AB2-083 POI) on AB2-083 circuit (Trips AB2-083 unit 1 and Delano 28.8 MVAr cap bank). Breaker stuck to Delano 138 kV bus section 1. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |
| 1B.06 | Fault at Delano 138 kV (AB2-083 POI) on Delano L 138/13.2 kV Transformer. Breaker A stuck. Fault cleared with loss of AB2-083 and Delano 28.8 MVAr cap bank. | 5.5 / 16 | Stable |
| 1B.07 | Fault at Delano 138 kV (AB2-083 POI) on Delano L 138/13.2 kV Transformer. Breaker A1 stuck. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |
| 1B.08 | Fault at Delano 138 kV (AB2-083 POI) on Delano Road (S. C. Co-op) circuit. Breaker B stuck. Fault cleared with loss of Kenworth circuit and Kenworth load 2. | 5.5 / 16 | Stable |
| 1B.09 | Fault at Delano 138 kV (AB2-083 POI) on Delano Road (S. C. Co-op) circuit. Breaker B1 stuck. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |
| 1B.10 | Fault at Delano 138 kV (AB2-083 POI) on Kenworth circuit (Trips Kenworth load 2). Breaker B stuck. Fault cleared with loss of Delano Road (S. C. Co-op) circuit. | 5.5 / 16 | Stable |

| Fault ID | Fault description | Clearing Time Normal & Delayed (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1B.11 | Fault at Delano 138 kV (AB2-083 POI) on Kenworth circuit (Trips Kenworth load 2). Breaker B2 stuck. Fault cleared with loss of AB2-083 and Delano 28.8 MVAr cap bank. | 5.5 / 16 | Stable |
| 1B.12 | Fault at Delano 138 kV (AB2-083 POI) on Dupont - Scioto Trail circuit (Trips Dupont south load). Breaker C stuck. Fault cleared with loss of Clayburne Switch – Ross circuit and Kenworth load 1. | 5.5 / 16 | Stable |
| 1B.13 | Fault at Delano 138 kV (AB2-083 POI) on Dupont - Scioto Trail circuit (Trips Dupont south load). Breaker C1 stuck. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |
| 1B.14 | Fault at Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). Breaker C stuck. Fault cleared with loss of Dupont - Scioto Trail circuit and Dupont south load. | 5.5 / 16 | Stable |
| 1B.15 | Fault at Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). Breaker C2 stuck. Fault cleared with loss of AB2-083 and Delano 28.8 MVAr cap bank. | 5.5 / 16 | Stable |
| 1B.16 | Fault at Delano 138 kV (AB2-083 POI) on Hopetown circuit. Breaker D stuck. Fault cleared with loss of Ross circuit. | 5.5 / 16 | Stable |
| 1B.17 | Fault at Delano 138 kV (AB2-083 POI) on Hopetown circuit. Breaker D1 stuck. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |
| 1B.18 | Fault at Delano 138 kV (AB2-083 POI) on Ross circuit. Breaker D stuck. Fault cleared with loss of Hopetown circuit. | 5.5 / 16 | Stable |
| 1B.19 | Fault at Delano 138 kV (AB2-083 POI) on Ross circuit. Breaker D2 stuck. Fault cleared with loss of AB2-083 and Delano 28.8 MVAr cap bank. | 5.5 / 16 | Stable |
| 1B.20 | Fault at Scioto Trail 138 kV on Dupont – Delano (AB2-083 POI) circuit (Trips Dupont south load). Breaker 2 stuck. Fault cleared with loss of Scioto Trail 138/13.2 kV Transformer. | 5.5 / 16 | Stable |
| 1B.21 | Fault at Scioto Trail 138 kV on Scioto Trail 138/13.2 kV Transformer. Breaker 2 stuck. Fault cleared with loss of Dupont – Delano (AB2-083 POI) circuit and Dupont south load. | 5.5 / 16 | Stable |
| 1B.22 | Fault at Scioto Trail 138 kV on Scioto Trail 138/13.2 kV Transformer. Breaker 1 stuck. Fault cleared with loss of Dupont – Scippo circuit and Dupont north load. | 5.5 / 16 | Stable |

| Fault ID | Fault description | Clearing Time Normal & Delayed (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1B.23 | Fault at Scioto Trail 138 kV on Dupont – Scippo circuit (Trips Dupont north load). Breaker 1 stuck. Fault cleared with loss of Scioto Trail 138/13.2 kV Transformer. | 5.5 / 16 | Stable |
| 1B.24 | Fault at Ross 138 kV on Delano (AB2-083 POI) circuit. Breaker A stuck. Fault cleared with loss of Clayburne Switch – Delano circuit and Kenworth load 1. | 5.5 / 16 | Stable |
| 1B.25 | Fault at Ross 138 kV on Delano (AB2-083 POI) circuit. Breaker A1 stuck. Fault cleared with loss of Ross 43.2 MVAr Cap bank 1. | 5.5 / 16 | Stable |
| 1B.26 | Fault at Ross 138 kV on Clayburne Switch – Delano (AB2-083 POI) circuit (Trips Kenworth load 1). Breaker A stuck. Fault cleared with loss of Delano (AB2-083 POI) circuit. | 5.5 / 16 | Stable |
| 1B.27 | Fault at Ross 138 kV on Clayburne Switch – Delano (AB2-083 POI) circuit (Trips Kenworth load 1). Breaker A2 stuck. Fault cleared with loss of Delano 43.2 MVAr Cap bank 2. | 5.5 / 16 | Stable |
| 1B.28 | Fault at Ross 138 kV on Bloomingville Switch – Poston circuit. Breaker B1 stuck. Fault cleared with loss of Delano 43.2 MVAr Cap bank 1 and Bloomingville load. | 5.5 / 16 | Stable |
| 1B.29 | Fault at Ross 138 kV on Bloomingville Switch – Poston circuit. Breaker B stuck. Fault cleared with loss of Mulberry circuit and Bloomingville load. | 5.5 / 16 | Stable |
| 1B.30 | Fault at Ross 138 kV on Mulberry circuit. Breaker B stuck. Fault cleared with loss of Bloomingville Switch – Poston circuit and Bloomingville load. | 5.5 / 16 | Stable |
| 1B.31 | Fault at Ross 138 kV on Mulberry circuit. Breaker B2 stuck. Fault cleared with loss of Delano 43.2 MVAr Cap bank 2. | 5.5 / 16 | Stable |
| 1B.32 | Fault at Ross 138 kV on Ross 138/12 kV Transformer 2. Breaker D2 stuck. Fault cleared with loss of Delano 43.2 MVAr Cap bank 2. | 5.5 / 16 | Stable |
| 1B.33 | Fault at Ross 138 kV on Ross 138/12 kV Transformer 2. Breaker D stuck. Fault cleared with loss of Ross 138/69 kV Transformer 3. | 5.5 / 16 | Stable |
| 1B.34 | Fault at Ross 138 kV on Ross 138/69 kV Transformer 3. Breaker D stuck. Fault cleared with loss of Ross 138/12 kV Transformer 2. | 5.5 / 16 | Stable |

| Fault ID | Fault description | Clearing Time Normal & Delayed (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1B.35 | Fault at Ross 138 kV on Ross 138/69 kV Transformer 3. Breaker D1 stuck. Fault cleared with loss of Delano 43.2 MVAr Cap bank 1. | 5.5 / 16 | Stable |
| 1B.36 | Fault at Hopetown 138 kV on Delano circuit. Breaker E stuck. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |
| 1B.37 | Fault at Hopetown 138 kV on Biers Run circuit. Breaker B stuck. Fault cleared with no additional circuits lost. | 5.5 / 16 | Stable |

**Table 6: Single-phase Faults with Delayed Clearing (Zone 2) at Line End Closest to AB2-083 POI**

| Fault ID | Fault description | Clearing Time Normal and Delayed (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1D.01 | Fault at 80% of line from Delano 138 kV (AB2-083 POI) on Delano Road (S. C. Co-op) circuit. Delayed clearing at Delano 138 kV (AB2-083 POI). | 5.5 / 60 | Stable |
| 1D.02 | Fault at 80% of line from Delano 138 kV (AB2-083 POI) on Kenworth circuit (Trips Kenworth load 2). Delayed clearing at Delano 138 kV (AB2-083 POI). | 5.5 / 60 | Stable |
| 1D.03 | Fault at 80% of line from Delano 138 kV (AB2-083 POI) on Dupont - Scioto Trail circuit (Trips Dupont south load). Delayed clearing at Delano 138 kV (AB2-083 POI). | 5.5 / 60 | Stable |
| 1D.04 | Fault at 80% of line from Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). Delayed clearing at Delano 138 kV (AB2-083 POI). | 5.5 / 60 | Stable |
| 1D.05 | Fault at 80% of line from Delano 138 kV (AB2-083 POI) on Hopetown circuit. Delayed clearing at Delano 138 kV (AB2-083 POI). | 5.5 / 60 | Stable |
| 1D.06 | Fault at 80% of line from Delano 138 kV (AB2-083 POI) on Ross circuit. Delayed clearing at Delano 138 kV (AB2-083 POI). | 5.5 / 60 | Stable |
| 1D.07 | Fault at 80% of line from Scioto Trail 138 kV on Dupont – Scippo circuit (Trips Dupont north load). Delayed clearing at Scioto Trail 138 kV. | 5.5 / 60 | Stable |
| 1D.08 | Fault at 80% of line from Ross 138 kV on Bloomingville Switch – Poston circuit. Delayed clearing at Ross 138 kV (Trips Bloomingville load). | 5.5 / 60 | Stable |
| 1D.09 | Fault at 80% of line from Ross 138 kV on Mulberry circuit. Delayed clearing at Ross 138 kV. | 5.5 / 60 | Stable |
| 1D.10 | Fault at 80% of line from Hopetown 138 kV on Biers Run circuit. Delayed clearing at Hopetown 138 kV. | 5.5 / 60 | Stable |

**Table 7: Single-phase Bus Faults with Normal Clearing**

| Fault ID | Fault description | Clearing Time (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1S.01 | Fault at Hopetown 138 kV Bus[4]. Fault cleared with loss of:<br>• Hopetown – Delano circuit.<br>• Hopetown - Biers Run circuit<br>• Hopetown load.<br>CONTINGENCY '8127_C1_05HOPETN 138-1' | 5.5 | Stable |
| 1S.02 | Fault at Scioto Trail 138 kV Bus. Fault cleared with loss of:<br>• Scioto Trail – Dupont – Scippo 138 kV circuit.<br>• Dupont north load.<br>• Scioto Trail 138/13.2 kV Transformer.<br>CONTINGENCY '8136_C1_05SCIOTO 138-12' | 5.5 | Stable |

[4] Not valid per the breaker diagram of Hopetown (Attachment 2). However, this contingency was studied as Hopetown one line is preliminary.

**Table 8: Single-phase Faults with Loss of Multiple-Circuit Tower Line**

| Fault ID | Fault description | Clearing Time (Cycles) | Result No Mitigation |
|---|---|---|---|
| 1T.01 | Fault at Hopetown 138 kV on Biers Run circuit resulting in tower failure. Fault cleared with additional loss of:<br>• Biers Run – Circleville 138 kV circuit.<br><br>CONTINGENCY '8126' | 5.5 | Stable |

**Table 9: Three-phase Faults with Normal Clearing – Prior outage of Delano – Ross 138 kV circuit**

| Fault ID | Fault description | Clearing Time (Cycles) | Result No Mitigation |
|---|---|---|---|
| MA.3N.05 | Fault at Delano 138 kV (AB2-083 POI) on Dupont - Scioto Trail circuit (Trips Dupont south load). | 5.5 | Stable |
| MA.3N.06 | Fault at Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). | 5.5 | Stable |
| MA.3N.07 | Fault at Delano 138 kV (AB2-083 POI) on Hopetown circuit. | 5.5 | Stable |

**Table 10: Three-phase Faults with Normal Clearing – Prior outage of Delano – Scioto Trail (Trips Dupont south load).**

| Fault ID | Fault description | Clearing/HSR Times (Cycles) | Result No Mitigation |
|---|---|---|---|
| MB.3N.06 | Fault at Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). | 5.5 | Stable |
| MB.3N.07 | Fault at Delano 138 kV (AB2-083 POI) on Hopetown circuit. | 5.5 | Stable |

**Table 11: Three-phase Faults with Normal Clearing – Prior outage of Delano – Hopetown – Biers Run 138 kV circuit.**

| Fault ID | Fault description | Clearing/HSR Times (Cycles) | Result No Mitigation |
|---|---|---|---|
| MC.3N.06 | Fault at Delano 138 kV (AB2-083 POI) on Clayburne Switch – Ross circuit (Trips Kenworth load 1). | 5.5 | Stable |