Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position Z2-083

"Mickleton 230 kV"
(Revised)

December 2017

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The Interconnection Customer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

This report is being revised to include the results of the Stability and Light Load Analysis and re-tool results which removed previous overloads.

West Deptford Energy, LLC, the Interconnection Customer (IC), has proposed a 74 MWE (74 MWC) upgrade to their prior queue projects Q90 and W4-015 located in Gloucester County, New Jersey.
The natural gas fueled generating facility consists of two combustion turbines (U1-CT and U2-CT) and a single steam turbine generator (U3-ST) arranged in a 2X1 combined cycle configuration.

The 74 MW increase will be attained through modifications to Units 1 and 2 CTs. When the modifications are complete, the generating facility will have a combined output of 934 MW Maximum Facility Output (MFO) and 786 MW Capacity (MWC).

PJM studied Z2-083 as a 74 MW injection into the Atlantic City Electric system at the Mickleton 230 kV substation and evaluated it for compliance with reliability criteria for summer peak conditions in 2018. The proposed in-service date for the 74 MW uprate is June 1, 2018.

Point of Interconnection

Z2-083 will utilize the same Point of Interconnection as prior queue projects Q90 and W4-015 at the Atlantic City Electric Company's Mickleton 230 kV substation (see Attachment 1).

Direct Connection Requirements

Transmission Owner Scope of Direct Connection Work

No additional Transmission Owner work is required for the Z2-083 upgrade.

Interconnection Customer Scope of Direct Connection Work

The Interconnection Customer (IC) is responsible for all design and construction related to activities on their side of the Point of Interconnection. Site preparation, including grading and an access road, as necessary, is assumed to be by the IC. Route selection, line design, and right-of-way acquisition of the direct connect facilities is not included in this report, and is the responsibility of the IC. The Interconnection Customer will be responsible for contributing to future O & M costs associated with the direct connect facilities.

Protective relaying and metering design and installation must comply with PHI's applicable standards. The IC is also required to provide revenue metering and real-time telemetering data to PJM in conformance with the requirements contained in PJM Manuals M-01 and M-14 and the PJM Tariff. PHI will require the capability to remotely trip the generator from its System Operations facility. The interconnected customer will grant its permission for PJM to send PHI all telemetry that the Interconnection Customer sends to PJM. In addition, a direct data line will be required to send PHI the telemetry data. The Interconnection Customer will be required to make provisions for a voice quality phone line within approximately 3 feet of each PHI metering position to facilitate remote interrogation and data collection.

Transmission Network Impacts

Potential transmission network impacts are as follows:

Generator Deliverability

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

None

Multiple Facility Contingency

*(Double Circuit Tower Line, Line with Failed Breaker and, Bus Fault contingencies for the **Full** energy output.*

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

Stability Analysis

No issues identified. See Attachment 2 for full report.

Light Load Analysis

No issues identified.

System Reinforcements

New System Reinforcements
(Upgrades required to mitigate reliability criteria violations, i.e. "Network Impacts," initially caused by the addition of this project's generation)

None

Contribution to Previously Identified System Reinforcements
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project.

None

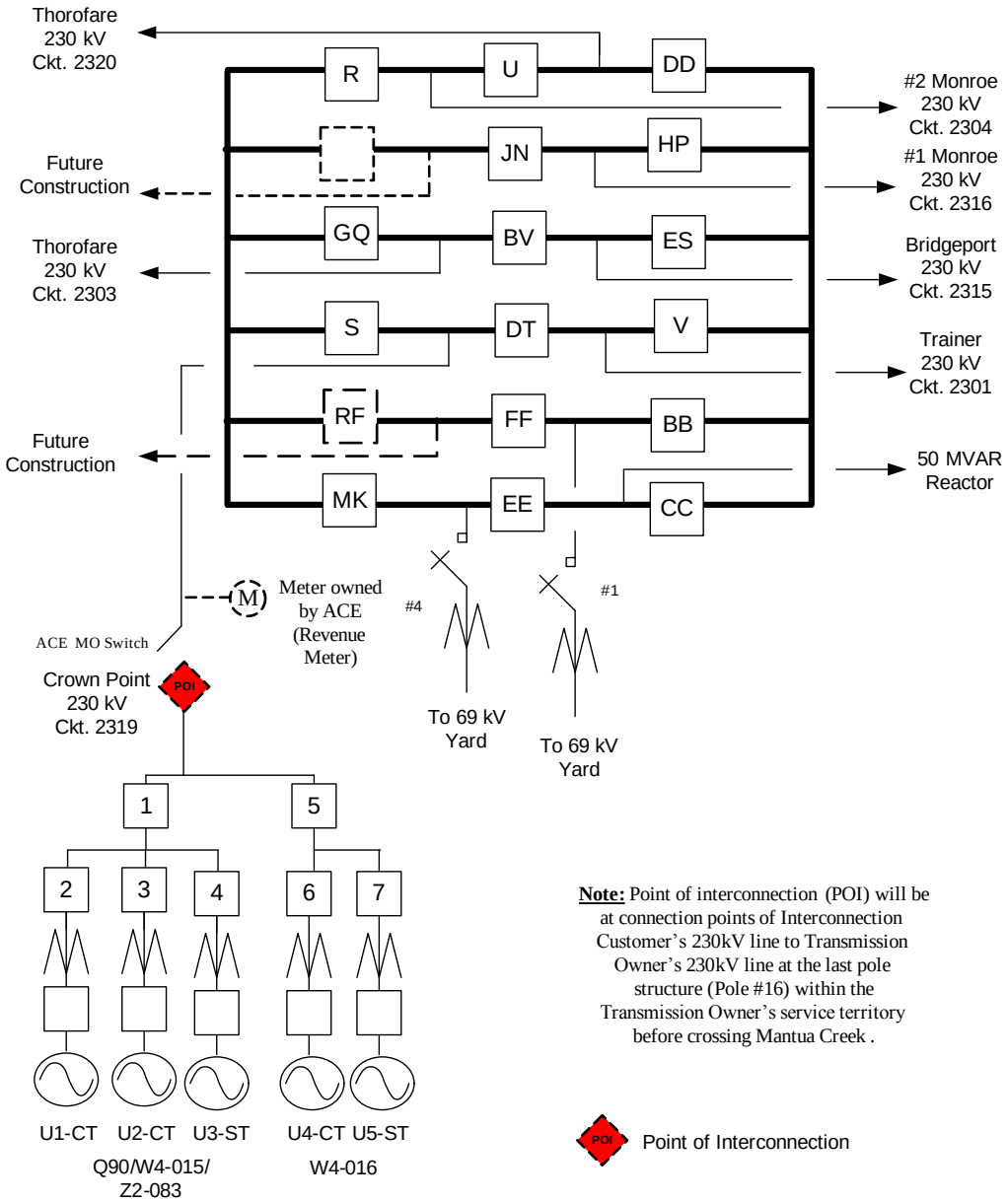
Potential Congestion due to Local Energy Deliverability
(PJM also studied the delivery of the energy portion of the surrounding generation. Any potential problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with Network Upgrades to eliminate the operational restriction at their discretion by submitting a Transmission Interconnection Request. Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full deliverability for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which analyzes all overload conditions associated with the identified overloaded element(s). As a result of the aggregate energy resources in the area, the following violations were identified:

These are ***not*** required reliability upgrades.

None

Attachment 1

Z2-083
Mickleton 230kV



Note: Point of interconnection (POI) will be at connection points of Interconnection Customer's 230kV line to Transmission Owner's 230kV line at the last pole structure (Pole #16) within the Transmission Owner's service territory before crossing Mantua Creek .

August 2017

Attachment 2

Z2-083 Stability Analysis

Executive Summary

Generator Interconnection Request Z2-083 is for the upgrade of prior queue projects Q90, W4-015 and W4-016. Z2-083 is the uprating of the natural gas fueled cross compound facility at Mickleton 230 kV from 1200 MW to 1274 MW Maximum Facility Output (MFO) and has a Point of Interconnection (POI) at Mickleton 230 kV Substation located in the Atlantic City Energy Company's (AE) system, in Gloucester County, New Jersey. Z2-083 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of Z2-083 as part of the overall system impact study.

The load flow scenario for the analysis was the 2018 light load case. Generation in the vicinity of Z2-083 and within the PJM500 system (area 225 in the PSS/E case) has been dispatched online at maximum output (PMAX).

Z2-083 was tested for compliance with NERC, PJM and other applicable criteria. 96 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation

b) Three phase faults with normal clearing time

c) Three phase faults with loss of multiple-circuit tower line

d) Single phase faults with stuck breaker

e) Single phase faults with delayed (Zone 2) clearing at remote end due to primary relaying failure

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.

The results indicate that for the all fault contingencies tested on the 2018 light load case met the recovery criteria:

a) Z2-083 was able to ride through the faults (except for faults where protective action tripped Z2-083),

b) the system with Z2-083 included was found to be transiently stable

No mitigations were found to be required.

1. Introduction

Generator Interconnection Request Z2-083 is for the upgrade of prior queue projects Q90, W4-015 and W4-016. Z2-083 is the uprating of the natural gas fueled cross compound facility at Mickleton 230 kV from 1200 MW to 1274 MW Maximum Facility Output (MFO) and has a Point of Interconnection (POI) at Mickleton 230 kV Substation located in the Atlantic City Energy Company's (AE) system, in Gloucester County, New Jersey. PJM contracted Power Systems Consultants (PSC) to carry out this dynamic simulation analysis of Z2-083 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of Z2-083 will meet the dynamic requirements of the NERC and PJM reliability standards.

In this report the Z2-083 project and how it is proposed to be connected to the grid is 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

Z2-083 will utilize the same POI as prior queue projects Q90, W4-015 and W4-016 at the AE's Mickleton 230 kV substation.

Z2-083 CT will be connected to the POI via a 160 MVA 230/18 kV generator step up (GSU) transformer. Z2-083 ST will be connected to the POI via a 160 MVA 230/16.5 kV generator step up (GSU) transformer. The Z2-083 POI will be at Mickleton 230 kV busbar as shown in Figure 1.

Table 1 lists the parameters given in the impact study data and the corresponding parameters of the Z2-083 loadflow model.

The dynamic models for the Z2-083 plant are based on standard PSS/E models, with parameters supplied by the Developer.

Additional project details are provided in Attachments 1 through 4:

- Attachment 1 contains the Impact Study Data which details the proposed Z2-083 project.
- Attachment 2 shows the one line diagram of the AE network in the vicinity of Z2-083.
- Attachment 3 provides a diagram of the PSS/E model in the vicinity of Z2-083.
- Attachment 4 gives the Z2-083 loadflow and dynamic models.

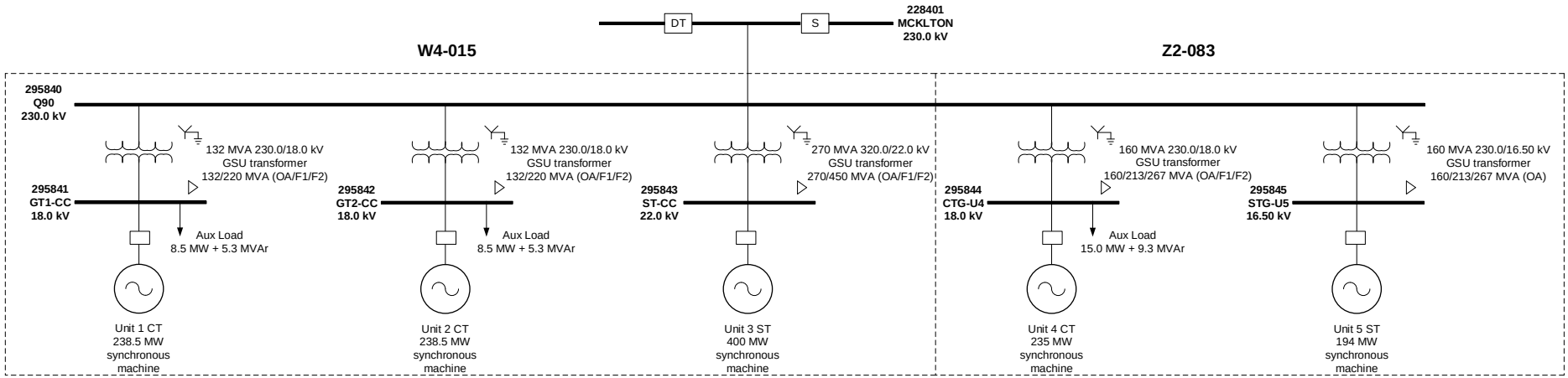


Figure 1: Z2-083 Plant Model

Table 1: Z2-083 Plant Model

	Impact Study Data	Model
Combustion turbine generator	235 MW combustion turbine generator MVA base = 265 MVA Vt = 18.0 kV Unsaturated sub-transient reactance = j0.1905 pu @ MVA base	235 MW combustion turbine generator Pgen 235 MW Pmax 235 MW Pmin 120 MW Qgen 45.1 MVAr Qmax 115 MVAr Qmin -95 MVAr Mbase 265 MVA Zsorce j0.1905 pu @ Mbase
Steam turbine generator	194 MW steam turbine generator MVA base = 248 MVA Vt = 16.50 kV Unsaturated sub-transient reactance = j0.1965 pu @ MVA base	194 MW steam turbine generator Pgen 194 MW Pmax 194 MW Pmin 78 MW Qgen 45.1 MVAr Qmax 135 MVAr Qmin -105 MVAr Mbase 248 MVA Zsorce j0.1965 pu @ Mbase
Combustion turbine GSU transformer	230/18 kV transformer Rating = 160/213/267 MVA (OA/F1/F2) Transformer base = 160 MVA Impedance = 0.00 + j7.00 % @ 160 MVA Number of taps = 5 Tap step size = 2.5 %	230/18 kV transformer Rating = 160/213/267 MVA (OA/F1/F2) Transformer base = 160 MVA Impedance = 0.00 + j0.07 pu @ 160 MVA Number of taps = 5 Tap step size = 2.5%

Steam turbine GSU transformer	230/16.5 kV transformer Rating = 160/213/267 MVA (OA/F1/F2) Transformer base = 160 MVA Impedance = 0.00 + j7.00 % @ 160 MVA Number of taps = 5 Tap step size = 2.5 %	230/16.5 kV transformer Rating = 160/213/267 MVA (OA/F1/F2) Transformer base = 160 MVA Impedance = 0.00 + j0.07 pu @ 160 MVA Number of taps = 5 Tap step size = 2.5%
Auxiliary load	15 MW + 9.3 MVAr	15 MW + 9.3 MVAr
Station service load	N/A	Not modeled
Transmission line	N/A	Not modeled

3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis will be carried out using PSS/E Version 32.2.3.
The load flow scenario and fault cases for this study are based on PJM's Region Transmission Planning Process[1] and discussions with PJM.
The selected load flow scenario is the 2018 light load case and has been modified with:

a) Addition of all applicable queue projects prior to Z2-083.

b) Addition of Z2-083 loadflow and dynamic data.

c) Removal of withdrawn and subsequent queue projects in the vicinity of Z2-083.

The Z2-083 initial conditions are listed in Table 2 and the loadflow model is shown in Figure 1.

Table 2: Z2-083 machine initial conditions

Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
295844	CTG-U4	1	235 MW	-38.2 MVAr	0.97 pu	1.008 pu
295845	STG-U5	1	194 MW	-49.9 MVAr	0.97 pu	1.008 pu

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of Z2-083 has been dispatched online at maximum output (PMAX). Units within the PJM system were redispatched in order to maintain slack generators within limits. The dispatch of generation in the vicinity of Z2-083 is shown in Attachment 5.

[1] Manual 14B: PJM Region Transmission Planning Process, Rev 19, September 15 2011, Attachment G: PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

4. Fault Cases

Tables 4 to 7 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

b) Three phase faults with normal clearing time

c) Three phase faults with loss of multiple-circuit tower line

d) Single phase faults with stuck breaker

e) Single phase faults with delayed clearing at remote end due to primary relaying failure

The contingencies listed above were applied to:

- Z2-083 POI 230 kV
- Mickleton 230 kV
- Trainer 230 kV
- Bridgeport 230 kV
- Thorofare 230 kV
- Monroe 230 kV
- Mickleton 69 kV
- Mantua 69 kV
- Valero 69 kV
- Paulsboro 69 kV
- River 69 kV

In addition single phase faults, with delayed (Zone 2) clearing at remote end, were applied to:

- Chichester 230 kV
- Pedricktown 230 kV
- Deptford 230 kV
- New Freedom 230 kV

Clearing times listed in Tables 4 to 7 are as per Revision 7 of "*2011 Revised Clearing times for each PJM company"* spreadsheet supplied by PJM.
Attachment 2 contains the one-line diagrams of the AE network in the vicinity of Z2-083.
The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case provided by PJM.

5. Evaluation Criteria

This study is focused on Z2-083, 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 Region Transmission Planning Process:

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

b) The Z2-083 generators should maintain their pre-contingent power output following the fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachments 6, with results summarized in Tables 4 to 7.

The results indicate that for all 96 fault contingencies tested on the 2018 light load case met the recovery criteria:

b) Z2-083 was able to ride through the faults (except for faults where protective action tripped Z2-083),

c) the system with Z2-083 included was found to be transiently stable

No mitigations were found to be required.

Table 3: Steady State Operation

Fault ID	Duration	Z2-083 No Mitigation
SS01	Steady state 20 sec	Stable

Table 4: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Local / Remote End (Cycles)	Result Without Mitigation
3N01	Fault at Mickleton 230 kV POI (Trips Z3-083 and W4-015).	7.0	Stable (Trips Z2-083 & W4-015)
3N02	Fault at Mickleton 230 kV on the Trainer/Delco Tap 2301 circuit.	7.0	Stable
3N03	Fault at Mickleton 230 kV on the Bridgeport 2315 circuit.	7.0	Stable
3N04	Fault at Mickleton 230 kV on the Thorofare-Eagle Point 2303 circuit.	7.0 / 5.0	Stable
3N05	Fault at Mickleton 230 kV on the Thorofare-Deptford 2320 circuit.	7.0 / 5.0	Stable
3N06	Fault at Mickleton 230 kV on the Monroe 2304 circuit.	7.0	Stable
3N07	Fault at Mickleton 230 kV on the Monroe 2316 circuit.	7.0	Stable
3N08	Fault at Mickleton 230 kV on the 230/69 kV transformer T1.	7.0	Stable
3N09	Fault at Mickleton 230 kV on the 230/69 kV transformer T4.	7.0	Stable
3N10	Fault at Trainer 230 kV on the Mickleton/Delco Tap 2301 circuit.	7.0	Stable
3N11	Fault at Trainer 230 kV on the Chichester 220-53 circuit.	7.0	Stable
3N12	Fault at Bridgeport 230 kV on Mickleton 2315 circuit.	7.0	Stable
3N13	Fault at Bridgeport 230 kV on Pedricktown 2311 circuit.	7.0	Stable
3N14	Fault at Deptford 230 kV on Thorofare-Mickleton 2320 circuit.	5.0 / 7.0	Stable
3N15	Fault at Deptford 230 kV on Gloucester V-2274 circuit.	5.0	Stable
3N16	Fault at Monroe 230 kV on Mickleton 2304 circuit.	7.0	Stable
3N17	Fault at Monroe 230 kV on Mickleton 2316 circuit.	7.0	Stable
3N18	Fault at Monroe 230 kV on New Freedom 2305 circuit.	7.0	Stable
3N19	Fault at Monroe 230 kV on 230/138 kV transformer T3.	7.0	Stable
3N20	Fault at Monroe 230 kV on 230/138 kV transformer T4.	7.0	Stable
3N21	Fault at Monroe 230 kV on 230/69 kV transformer T5.	7.0	Stable
3N22	Fault at Monroe 230 kV on 230/69 kV transformer T6.	7.0	Stable
3N23	Fault at Mickleton 69 kV on the Mantua 0748 circuit.	9.0	Stable
3N24	Fault at Mickleton 69 kV on the Valero 0738 circuit.	9.0	Stable
3N25	Fault at Mickleton 69 kV on the Paulsboro/Valero 0746 circuit.	9.0	Stable
3N26	Fault at Mickleton 69 kV on the River 0747 circuit.	9.0	Stable
3N27	Fault at Mantua 69 kV on Mickleton 0748 circuit.	9.0	Stable
3N28	Fault at Mantua 69 kV on Wenonah 0785 circuit.	9.0	Stable
3N29	Fault at Valero 69 kV on Mickleton 0738 circuit.	9.0	Stable
3N30	Fault at Valero 69 kV on Paulsboro/Mickleton 0746 circuit.	9.0	Stable
3N31	Fault at Valero 69 kV on Paulsboro/Mobil Park 0774 circuit.	9.0	Stable
3N32	Fault at Paulsboro 69 kV on Mickleton/Valero 0746 circuit.	9.0	Stable
3N33	Fault at Paulsboro 69 kV on Valero/Mobil Park 0774 circuit.	9.0	Stable
3N34	Fault at Paulsboro 69 kV on Beckett 0722 circuit.	9.0	Stable

Fault ID	Fault description	Clearing Time Local / Remote End (Cycles)	Result Without Mitigation
3N35	Fault at River 69 kV on Mickleton 0747 circuit.	9.0	Stable
3N36	Fault at River 69 kV on Monsanto 0763 circuit.	9.0	Stable
3N37	Fault at Eagle Point 230 kV on the Thorofare-Mickleton D-2309 circuit.	5.0 / 7.0	Stable
3N38	Fault at Eagle Point 230 kV on the Gloucester P-2242 circuit.	5.0	Stable

Table 5: Three-phase Faults with Loss of Multiple-circuit Tower Line

Fault ID	Fault description	Clearing Time (Cycles)	Result Without Mitigation
3T01	Fault at Mickleton 230 kV on Monroe 2304 circuit resulting in tower failure. Fault cleared with loss of Mickleton – Monroe 230 kV 2316 circuit. CONTINGENCY 'AE1TOWER'	7.0	Stable
3T02	Fault at Monroe 138 kV on Franklin 1420 circuit resulting in tower failure. Fault cleared with loss of Franklin – Landis 138 kV 1410 circuit. CONTINGENCY 'AE9TOWER'	9.0	Stable

Table 6: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result Without Mitigation
1B01	Fault at Mickleton 230 kV POI (Trips Z3-083 and W4-015). Breaker DT stuck. Fault cleared with the loss of Trainer/Delco Tap 230 kV circuit (loss of Delco Tap 230 kV, Delco unit and Trainer 230/35 kV transformer T6B).	7.0 / 18.5	Stable (Trips Z2-083 & W4-015)
1B02	Fault at Mickleton 230 kV on the Trainer/Delco Tap 2301 circuit. Breaker DT stuck. Fault cleared with the loss of Crown Point 2319 230 kV circuit (loss of Z2-083 and W4-015).	7.0 / 18.5	Stable
1B03	Fault at Mickleton 230 kV on the Bridgeport 2315 circuit. Breaker BV stuck. Fault cleared with the loss of Thorofare-Eagle Point 2303 230 kV circuit.	7.0 / 18.5	Stable
1B04	Fault at Mickleton 230 kV on the Thorofare-Eagle Point 2303 circuit. Breaker BV stuck. Fault cleared with the loss of Bridgeport 2315 230 kV circuit.	7.0 / 18.5	Stable
1B05	Fault at Mickleton 230 kV on the Thorofare-Deptford 2320 circuit. Breaker U stuck. Fault cleared with the loss of Monroe 2304 230 kV circuit.	7.0 / 18.5	Stable
1B06	Fault at Mickleton 230 kV on the Monroe 2304 circuit. Breaker U stuck. Fault cleared with the loss of Thorofare-Deptford 2320 230 kV circuit.	7.0 / 18.5	Stable
1B07	Fault at Mickleton 230 kV on the Monroe 2316 circuit. Breaker JN stuck. Fault cleared with no loss of supply.	7.0 / 18.5	Stable
1B08	Fault at Mickleton 230 kV on the 230/69 kV transformer T1. Breaker FF stuck. Fault cleared with no loss of supply.	7.0 / 18.5	Stable
1B09	Fault at Mickleton 230 kV on the 230/69 kV transformer T4. Breaker EE stuck. Fault cleared with no loss of supply.	7.0 / 18.5	Stable
1B10	Fault at Trainer 230 kV on the Mickleton/Delco Tap 2301 circuit. Breaker 875 stuck. Fault cleared with the loss of Mickleton/Delco Tap 230 kV circuit (loss of Delco Tap 230 kV, Delco unit and Trainer 230/35 kV transformer T6B).	7.0 / 18.5	Stable
1B11	Fault at Trainer 230 kV on the Chichester 220-53 circuit. Breaker 785 stuck. Fault cleared with loss of Trainer transformer T6A.	7.0 / 18.5	Stable
1B12	Fault at Bridgeport 230 kV on Mickleton 2315 circuit. Breaker A stuck. Fault cleared with the loss of Bridgeport 230/23 kV transformer T1 and Pedricktown 230kV circuit.	7.0 / 18.5	Stable
1B13	Fault at Bridgeport 230 kV on Pedricktown 2311 circuit. Breaker A stuck. Fault cleared with the loss of the Mickleton 230 kV circuit and Bridgeport 230/23 kV T2 and 230/13.8 kV T1.	7.0 / 18.5	Stable
1B14	Fault at Deptford 230 kV on Thorofare-Mickleton W-2275 circuit. Breaker X stuck. Fault cleared with the loss of the Gloucester 230 kV circuit.	7.0 / 17	Stable
1B15	Fault at Deptford 230 kV on Gloucester V-2274 circuit. Breaker X stuck. Fault cleared with the loss of the Thorofare-Mickleton W-2275 230 kV circuit.	5.0 / 18.5	Stable
1B16	Fault at Monroe 230 kV on Mickleton 2304 circuit. Breaker II stuck. Fault cleared with the loss of Monroe 230/138 kV transformer T3.	7.0 / 18.5	Stable

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result Without Mitigation
1B17	Fault at Monroe 230 kV on Mickleton 2316 circuit. Breaker JJ stuck. Fault cleared with the loss of Monroe 230/138 kV transformer T3.	7.0 / 18.5	Stable
1B18	Fault at Monroe 230 kV on New Freedom 2305 circuit. Breaker DD stuck. Fault cleared with the loss of Monroe 230/138 kV transformer T4.	7.0 / 18.5	Stable
1B19	Fault at Monroe 230 kV on 230/138 kV transformer T3. Breaker JJ stuck. Fault cleared with the loss of Mickleton 230 kV circuit 2316.	7.0 / 18.5	Stable
1B20	Fault at Monroe 230 kV on 230/138 kV transformer T4. Breaker DD stuck. Fault cleared with the loss of New Freedom 230 kV circuit.	7.0 / 18.5	Stable
1B21	Fault at Monroe 230 kV on 230/69 kV transformer T5. Breaker AA stuck. Fault cleared with the loss of Mickleton 230 kV circuit 2316.	7.0 / 18.5	Stable
1B22	Fault at Monroe 230 kV on 230/69 kV transformer T6. Breaker BB stuck. Fault cleared with the loss of Mickleton 230 kV circuit 2304.	7.0 / 18.5	Stable
1B23	Fault at Mickleton 69 kV on the Mantua 0748 circuit. Breaker B stuck. Fault cleared with the loss of Mickleton 230/69 kV transformer T4 and Paulsboro/Valero 69 kV circuit.	9.0 / 24.0	Stable
1B24	Fault at Mickleton 69 kV on the Valero 0738 circuit. Breaker Q stuck. Fault cleared with the loss of Mickleton 230/69 kV transformer T1 and River 69 kV circuit.	9.0 / 24.0	Stable
1B25	Fault at Mickleton 69 kV on the Paulsboro/Valero 0746 circuit. Breaker C stuck. Fault cleared with the loss of Mickleton 230/69 kV transformer T4 and Mantua 69 kV circuit.	9.0 / 24.0	Stable
1B26	Fault at Mickleton 69 kV on the River 0747 circuit. Breaker A stuck. Fault cleared with the loss of Mickleton 230/69 kV transformer T1 and Valero 69 kV circuit.	9.0 / 24.0	Stable
1B27	Fault at Mantua 69 kV on Mickleton 0748 circuit. Breaker A stuck. Fault cleared with the loss of Mantua 69/12.9 kV transformer T1 and Wenonah 69 kV circuit.	9.0 / 24.0	Stable
1B28	Fault at Mantua 69 kV on Wenonah 0785 circuit. Fault cleared with the loss of Mantua 69/12.9 kV transformer T1 and Mickleton 69 kV circuit.	9.0 / 24.0	Stable
1B29	Fault at Valero 69 kV on Mickleton 0738 circuit. Breaker B stuck. Fault cleared with the loss of Valero unit 1.	9.0 / 24.0	Stable
1B30	Fault at Valero 69 kV on Paulsboro/Mickleton 0746 circuit. Breaker 1 stuck. Fault cleared with the loss of Valero unit 1.	9.0 / 24.0	Stable
1B31	Fault at Valero 69 kV on Paulsboro/Mobil Park 0774 circuit. Breaker 2 stuck. Fault cleared with the loss of Valero unit 3.	9.0 / 24.0	Stable
1B32	Fault at Paulsboro 69 kV on Mickleton/Valero 0746 circuit. Breaker O stuck. Fault cleared with the loss of Paulsboro 69/4.3 kV transformer T5.	9.0 / 24.0	Stable
1B33	Fault at Paulsboro 69 kV on Valero/Mobil Park 0774 circuit. Breaker Q stuck. Fault cleared with the loss of Beckett 69 kV circuit, and Paulsboro 69/34 kV transformer T4.	9.0 / 24.0	Stable
1B34	Fault at Paulsboro 69 kV on Beckett 0722 circuit. Breaker P stuck. Fault cleared with the loss of Valero/Mobil Park 69 kV circuit, and Paulsboro 69/34 kV transformer T4.	9.0 / 24.0	Stable

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result Without Mitigation
1B35	Fault at River 69 kV on Mickleton 0747 circuit. Breaker B stuck. Fault cleared with the loss of River 69/34.5 kV transformer T1.	9.0 / 24.0	Stable
1B36	Fault at River 69 kV on Monsanto 0763 circuit. Breaker C stuck. Fault cleared with the loss of River 69/34.5 kV transformer T1 and Mickleton 69 kV circuit.	9.0 / 24.0	Stable
1B37	Fault at Eagle Point 230 kV on the Thorofare-Mickleton D-2309 circuit. Breaker 3 stuck. Fault cleared with the loss of the Gloucester P-2242 circuit.	7.0 / 17.0	Stable
1B38	Fault at Eagle Point 230 kV on the Gloucester P-2242 circuit. Breaker 3 stuck. Fault cleared with the loss of the Thorofare-Mickleton D-2309 circuit.	5.0 / 18.5	Stable

Table 7: Single-phase Faults with Delayed (Zone 2) Clearing at Remote End

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result Without Mitigation
1D01	Fault at Z2-083 POI on the Mickleton 230 kV circuit. Delayed clearing at Mickleton.	7.0 / 38	Stable
1D02	Fault at Mickleton 230 kV on the Trainer/Delco Tap 2301 circuit. Delayed clearing at Trainer.	7.0 / 38	Stable
1D03	Fault at Mickleton 230 kV on the Bridgeport 2315 circuit. Delayed clearing at Bridgeport.	7.0 / 38	Stable
1D04	Fault at Mickleton 230 kV on the Thorofare-Eagle Point 2303 circuit. Delayed clearing at Eagle Point.	7.0 / 30	Stable
1D05	Fault at Mickleton 230 kV on the Thorofare-Deptford 2320 circuit. Delayed clearing at Deptford.	7.0 / 30	Stable
1D06	Fault at Mickleton 230 kV on the Monroe 2304 circuit. Delayed clearing at Monroe.	7.0 / 38	Stable
1D07	Fault at Mickleton 230 kV on the Monroe 2316 circuit. Delayed clearing at Monroe.	7.0 / 38	Stable
1D08	Fault at Mickleton 230 kV on the 230/69 kV transformer T1. Delayed clearing at Mickleton 69 kV.	7.0 / 38	Stable
1D09	Fault at Mickleton 230 kV on the 230/69 kV transformer T4. Delayed clearing at Mickleton 69 kV.	7.0 / 38	Stable
1D10	Fault at Mickleton 69 kV on the Mantua 0748 circuit. Delayed clearing at Mantua.	9.0 / 42	Stable
1D11	Fault at Mickleton 69 kV on the Valero 0738 circuit. Delayed clearing at Valero.	9.0 / 42	Stable
1D12	Fault at Mickleton 69 kV on the Paulsboro/Valero 0746 circuit. Delayed clearing at Paulsboro.	9.0 / 42	Stable
1D13	Fault at Mickleton 69 kV on the River 0747 circuit. Delayed clearing at River.	9.0 / 42	Stable
1D14	Fault at Chichester 230 kV on the Trainer 220-53 circuit. Delayed clearing at Trainer.	7.0 / 38	Stable
1D15	Fault at Pedricktown 230 kV on the Bridgeport 2311 circuit. Delayed clearing at Bridgeport.	7.0 / 38	Stable
1D16	Fault at Gloucester 230 kV on the Deptford V-2274 circuit. Delayed clearing at Deptford.	5 / 30	Stable
1D17	Fault at Gloucester 230 kV on the Eagle Point P-2242 circuit. Delayed clearing at Eagle Point.	5 / 30	Stable
1D18	Fault at New Freedom 230 kV on the Monroe 2305 circuit. Delayed clearing at Monroe.	7.0 / 38	Stable