Generator Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position #AB2-145

Axton 138 kV

January 2018

General

Southern Power Company proposes to install PJM Project #AB2-145, a 572.0 MW (572.0 MW Capacity) 1x1 Combined Cycle natural gas generating facility in Pittsylvania County, Virginia (see Figure 2). The point of interconnection is a direct connection to AEP's Axton 138 kV yard of the Axton substation (see Figures 1).

AB2-145 has the potential to affect the City of Danville facilities therefore PJM will have to coordinate studies of Danville facilities.

The requested Backfeed date is January 1, 2020.
The requested in service date is January 1, 2021.

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 (Axton 138 kV Substation)

To accommodate the interconnection at the Axton 138 kV substation, the substation will have to be expanded requiring the installation of two (2) new 138 kV circuit breakers. Installation of associated protection and control equipment, SCADA, and 138 kV revenue metering will also be required.

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

- To accommodate the interconnection at the Axton 138 kV substation, the substation will have to be expanded requiring the installation of two (2) new 138 kV circuit breakers. Installation of associated protection and control equipment, SCADA, and 138 kV revenue metering will also be required.

- **Estimated Station Cost: $2,000,000 (Network Upgrade n5509)**

Non-Direct Connection Cost Estimate

The total preliminary cost estimate for Non-Direct Connection work is given in the following tables below:

For AEP building Direct Connection cost estimates:

Network Upgrade Number	Description	Estimated Cost
n5510	138 kV Revenue Metering	**$250,000**
n5511	Upgrade line protection and controls at the Axton 138 kV Substation	**$250,000**
	Total	**$500,000**

Table 1

It is understood that Southern Power Company is responsible for all costs associated with this interconnection. The cost of Southern Power Company's generating plant and the costs for the line connecting the generating plant to Southern Power Company's switching station are not included in this report; these are assumed to be Southern Power Company'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 AB2-145 was evaluated as a 572.0 MW (Capacity 572.0 MW) injection into the Axton 138 kV substation in the AEP area. Project AB2-145 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB2-145 was studied with a commercial probability of 100%. Potential network impacts were as follows:

1 http://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/docs/2017/AEP_East%20FERC%20715_2017_Final_Part%204.pdf

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

Network Impacts

The Queue Project AB2-145 was evaluated as a 572.0 MW (Capacity 572.0 MW) injection into the Axton 138 kV substation in the AEP area. Project AB2-145 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB2-145 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2020

AB2-145 Contingincies	
Contingency Name	**Description**
5459_B2_TOR156_WOMOAB	CONTINGENCY '5459_B2_TOR156_WOMOAB' OPEN BRANCH FROM BUS 242544 TO BUS 242712 CKT 1 / 242544 05AXTON 138 242712 05MARTN2 138 1 OPEN BRANCH FROM BUS 242614 TO BUS 242638 CKT 1 / 242614 05COLLIN 138 242638 05FIELDALE1 138 1 OPEN BRANCH FROM BUS 242614 TO BUS 242712 CKT 1 / 242614 05COLLIN 138 242712 05MARTN2 138 1 OPEN BRANCH FROM BUS 242712 TO BUS 243977 CKT 1 / 242712 05MARTN2 138 243977 05MART 115 34.5 1 OPEN BRANCH FROM BUS 243977 TO BUS 243979 CKT 1 / 243977 05MART 115 34.5 243979 05MART2-30 34.5 1 OPEN BRANCH FROM BUS 243977 TO BUS 243980 CKT 1 / 243977 05MART 115 34.5 243980 05MORRIS-N 34.5 1 END
5461_B2_TOR156B_MOAB	CONTINGENCY '5461_B2_TOR156B_MOAB' OPEN BRANCH FROM BUS 242544 TO BUS 242712 CKT 1 / 242544 05AXTON 138 242712 05MARTN2 138 1 END

Generator Deliverability

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

The Queue Project AB2-145 Generator Deliverability													
	Contingency		Affected	Facility	Bus				Loading		Rating		MW
#	Type	Name	Area	Description	From	To	Cir.	PF	Initial	Final	Type	MVA	Con.
1	N-1	5461_B2_TOR156B_ MOAB	AEP - AEP	05STOCKT - 05MARTN1 138 kV line	242816	242711	1	AC	59.27	105.9	ER	202	95.68
2	N-1	5459_B2_TOR156_W OMOAB	AEP - AEP	05STOCKT - 05MARTN1 138 kV line	242816	242711	1	AC	56.66	102.76	ER	202	94.71

- The Martinsville circuit breaker C is the limiting element: Scheduled to be replace in 2018.

Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck 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

Short Circuit

(Summary of impacted circuit breakers)

None

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO Impacts:

None

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

None

Stability Analysis

Insufficient damping was observed for several contingencies, and the low damping is attributable to the addition of the AB2-145 Queue Project. Tuning of relevant PSS is recommended to improve damping. Southern Power Company is responsible for this mitigation.

Results show that connecting AB2-145 queue project at Axton 138 kV can eliminate the tripping issues encountered when the project is connected to Axton 765 kV.

See Attachment 1 at the end of this report for detailed analysis

Voltage Variations

None

Delivery of Energy Portion of Interconnection Request

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.

Only the most severely overloaded conditions are listed. 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 will study all overload conditions associated with the overloaded element(s) identified.

None

Additional Limitations of Concern

None

New System Reinforcements

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.

Conclusion

Based upon the results of this System Impact Study, the construction of the 572.0 MW (572.0 MW Capacity) 1x1 combined cycle natural gas generating facility of Southern Power Company (PJM Project #AB2-145) will require the following additional interconnection charges. This plan of service will interconnect the proposed natural gas generating facility in a manner that will provide operational reliability and flexibility to both the AEP system and the Southern Power Company generating facility.

Cost Breakdown for Point of Interconnection (Axton 138 kV Substation)			
	Network Upgrade Number	**Description**	**Estimated Cost**
Attachment Facilities	**N5509**	Expand Axton 138 kV Substation	$2,000,000
Non-Direct Connection Cost Estimate	**N5510**	138 kV Revenue Metering	$250,000
	N5511	Upgrade line protection and controls at the Axton 138 kV Substation	$250,000
	N/A	Insufficient damping was observed for several contingencies, and the low damping is attributable to the addition of the AB2-145 Queue Project. Tuning of relevant PSS is recommended to improve damping. Southern Power Company is responsible for this mitigation.	N/A
		Total Estimated Cost for Project AB2-145	**$2,500,000**

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.

Figure 1: Point of Interconnection (Axton 138 kV Substation) Single-Line Diagram

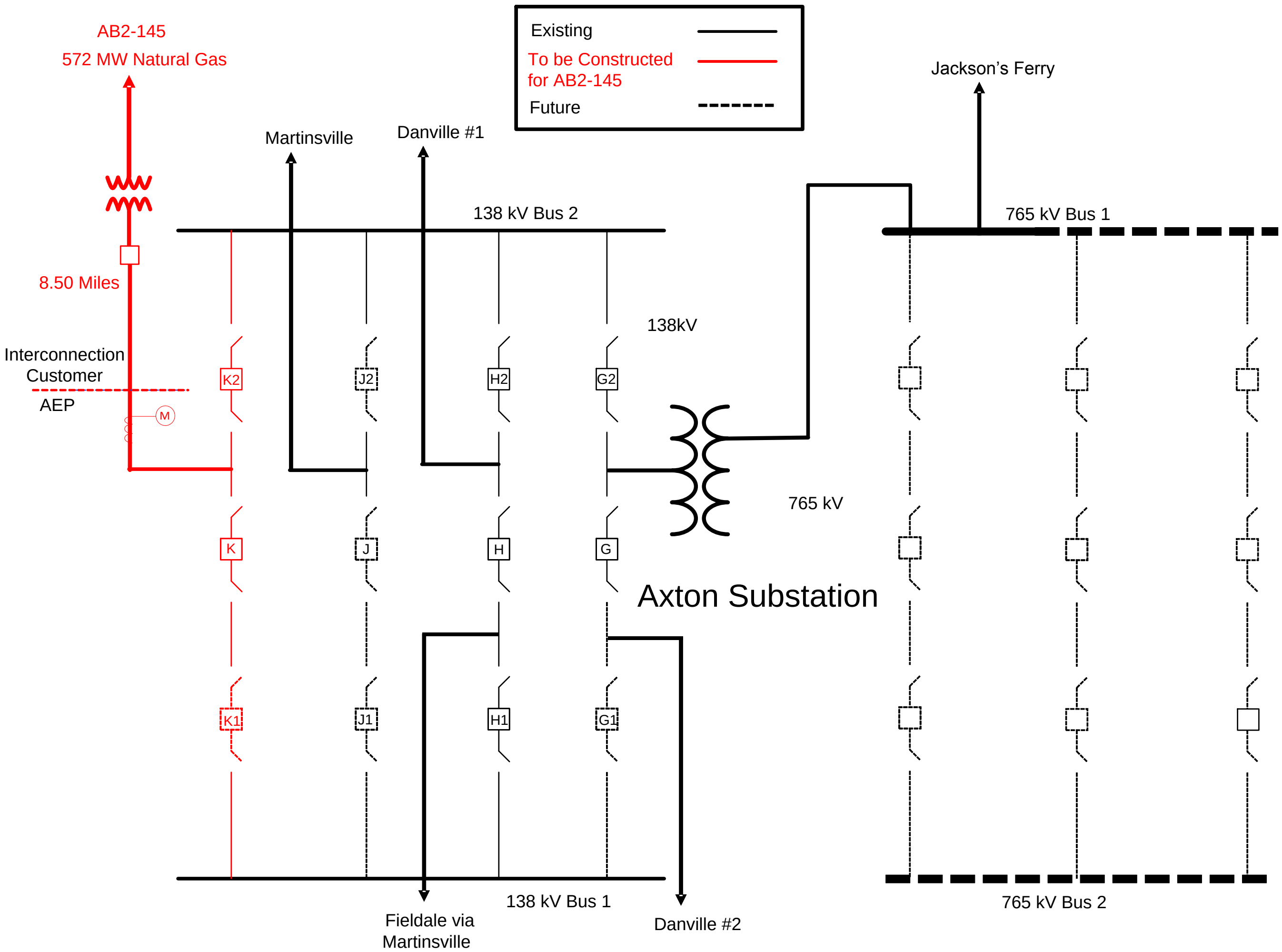
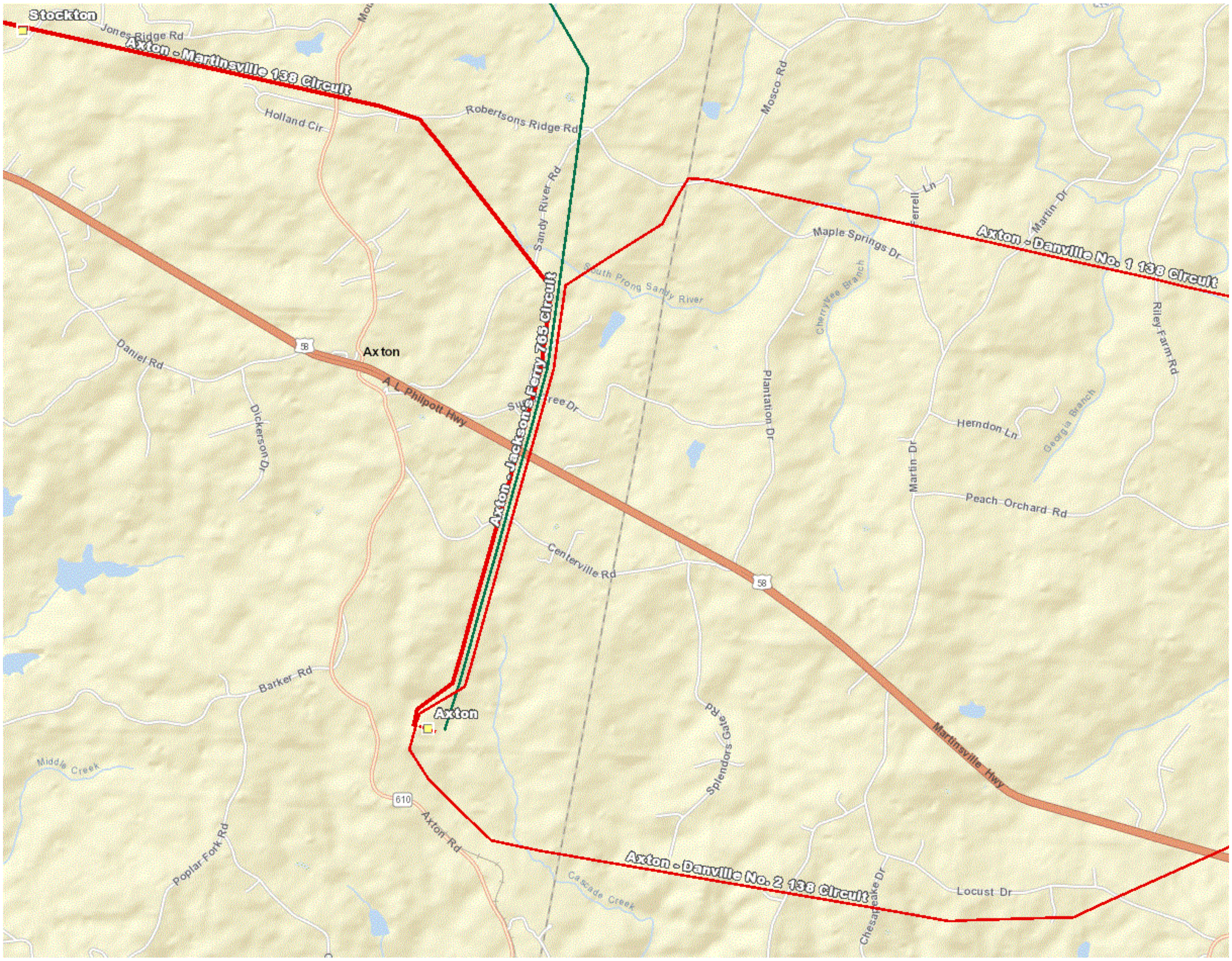


Figure 2: Point of Interconnection (Axton 138 Substation)



Light Load Analysis - 2020

Light Load Studies to be conducted during later study phases (as required by PJM Manual 14B).

Not required

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

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

1. To relieve the Stockton – Martinsville 138 kV line overloads: AEP is planning to replace the Martinsville 138 kV breaker 'C' in 2018. This will increase the line ratings to 283/378 MVA SN/SE. AEP has stated they will be submitting this project as a PJM Supplemental project. The AB2-145 customer has no cost responsibility. Note: AB2-145 may need this upgrade in-service in order to be deliverable to the PJM transmission system. If AB2-145 comes into service prior to completion of the upgrade, an interim study may be required.

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)
(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

Additional Interconnection Customer Responsibilities:

1. An Interconnection Customer entering the New Services Queue on or after October 1, 2012 with a proposed new Customer Facility that has a Maximum Facility Output equal to or greater than 100 MW shall install and maintain, at its expense, phasor measurement units (PMUs). See Section 8.5.3 of Appendix 2 to the Interconnection Service Agreement as well as section 4.3 of PJM Manual 14D for additional information.

2. The Interconnection Customer may be required to install and/or pay for metering as necessary to properly track real time output of the facility as well as installing metering which shall be used for billing purposes. See Section 8 of Appendix 2 to the Interconnection Service Agreement as well as Section 4 of PJM Manual 14D for additional information.

Light Load Analysis - 2020

Light Load Studies to be conducted during later study phases (as required by PJM Manual 14B).

Not required

Attachment 1

Stability and Reactive Power Requirement

Executive Summary

Generator Interconnection Request AB2-145 is for a 573 MW Maximum Facility Output (MFO) combined cycle natural gas generation facility. AB2-145 consists of a 1x1 CCGT (1 x 366 MW Combustion turbine and 1 x 219 MW Steam turbine). AB2-145 will connect at one of the following Points of Interconnection (POI):

1) Option 1: Axton 765 kV Substation
2) Option 2: Axton 138 kV Substation

Both options are located in the American Electric Power (AEP) transmission system, Pittsylvania County, Virginia.

This report describes a dynamic simulation analysis of AB2-145 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 light load case, modified to include applicable queue projects. AB2-145 has been dispatched online at maximum power output, with leading power factor.

AB2-145 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria.

56 contingencies were studied under Option 1, each with a 20 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;

No multiple-circuit tower line or relevant high speed reclosing (HSR) contingencies were identified for this study.

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 50 out of 56 of the fault contingencies tested on the 2020 light load case:

a) AB2-145 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 was found that for all contingencies where Axton – Jacksons Ferry 765 kV circuit is tripped out of service the AB2-145 queue project loses synchronism and trips.

Due to the unstable results found at the Option 1 POI, 23 contingencies were studied under Option 2, each with a 20 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 identified for this study.
For 18 out of 23 of the fault contingencies tested on the 2020 light load case:

a) AB2-145 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 was found that post-fault responses of AB2-145 CT and ST units and nearby generating units was insufficiently damped (freq. 0.93 Hz, damping 2%) for contingencies SC2.3N.02, SC2.MA.3N.02, SC2.MB.3N.02, SC2.MC.3N.02, and SC2.MD.3N.02 (loss of Axton – Jacksons Ferry 765 kV circuit). Simulations using a pre-AB2-145 case show that post contingency oscillations have a damping greater than 3%. Therefore the addition of AB2-145 is attributable to the insufficient damping, and tuning of relevant PSS is recommended for improving damping.

1. Introduction

Generator Interconnection Request AB2-145 is for a 573 MW Maximum Facility Output (MFO) combined cycle natural gas generation facility. AB2-145 consists of a 1x1 CCGT (1 x 366 MW Combustion turbine and 1 x 219 MW Steam turbine) with a Point of Interconnection (POI) at one of the following options:

1) Option 1: Axton 765 kV Substation;
2) Option 2: Axton 138 kV Substation;

Both options are located in the American Electric Power (AEP) transmission system, Pittsylvania County, Virginia.

This analysis is effectively a screening study to determine whether the addition of AB2-145 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AB2-145 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

AB2-145 consists of 1 x 366 MW Combustion turbine and 1 x 219 MW Steam turbine to form a 1x1 combined cycle natural gas generating facility.

For POI Option 1 the AB2-145 CT and ST units will be connected to the POI via a 246 MVA 765/25 kV GSU transformer and a 208 MVA 765/18 kV GSU transformer respectively.

For POI Option 2 the AB2-145 CT and ST units will be connected to the POI via a 246 MVA 138/25 kV GSU transformer and a 208 MVA 138/18 kV GSU transformer respectively.

For both POI options AB2-145 connects to Axton Substation in the American Electric Power (AEP) transmission system, Pittsylvania County, Virginia, as shown in Figure 1 and Figure 2.

Table 1 and Table 2 lists the parameters given in the impact study data and the corresponding parameters of the AB2-145 loadflow model for the first and second POI respectively.

Additional project details are provided in Attachments 1 through 4:

- Attachment 1 contains the Impact Study Data which details the proposed AB2-145 project.
- Attachment 2 shows the one line diagram of the AEP network in the vicinity of AB2-145.
- Attachment 3a and 3b provide diagrams of the PSS/E model in the vicinity of AB2-145 for POI Option 1 and 2 respectively.
- Attachment 4 gives the PSS/E loadflow and dynamic models of AB2-145.

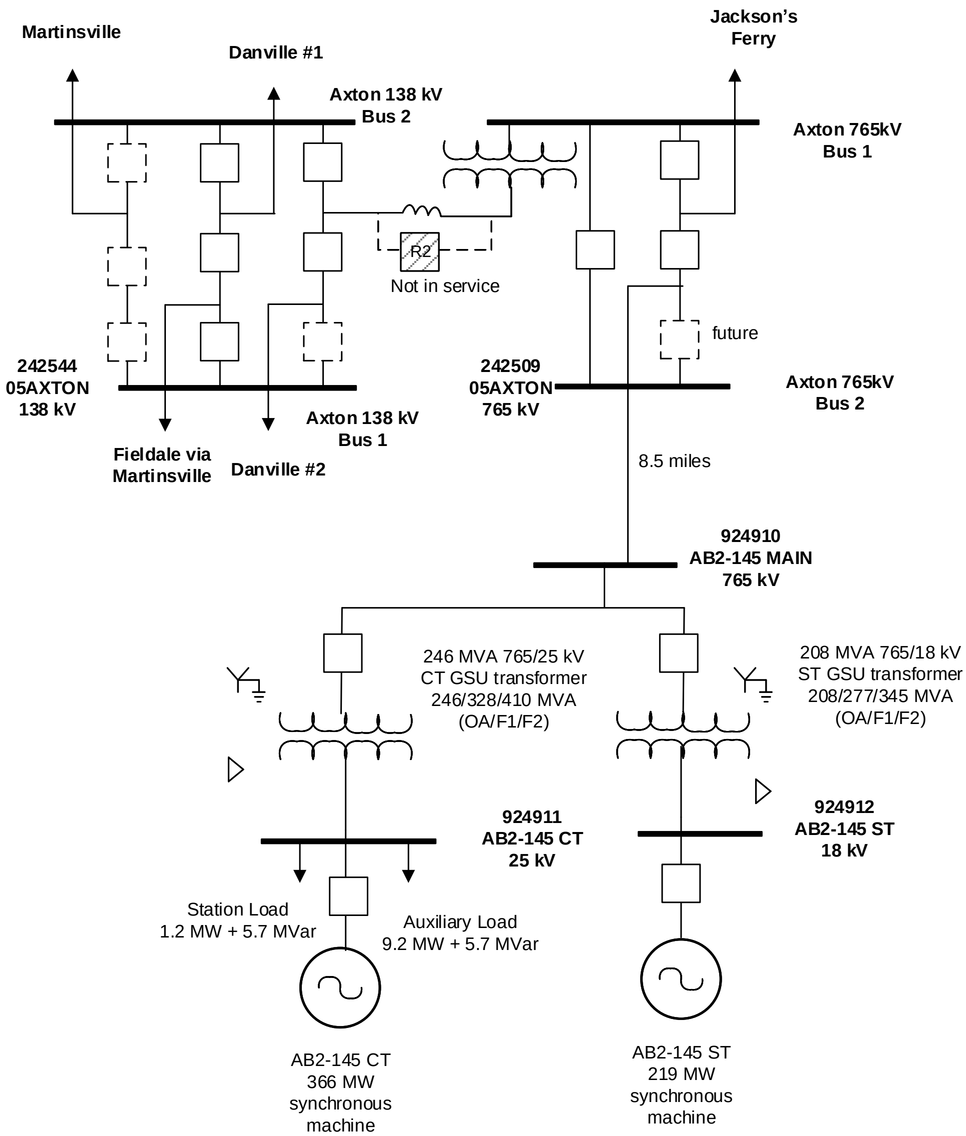


Figure 1: AB2-145 Plant Model – POI 1

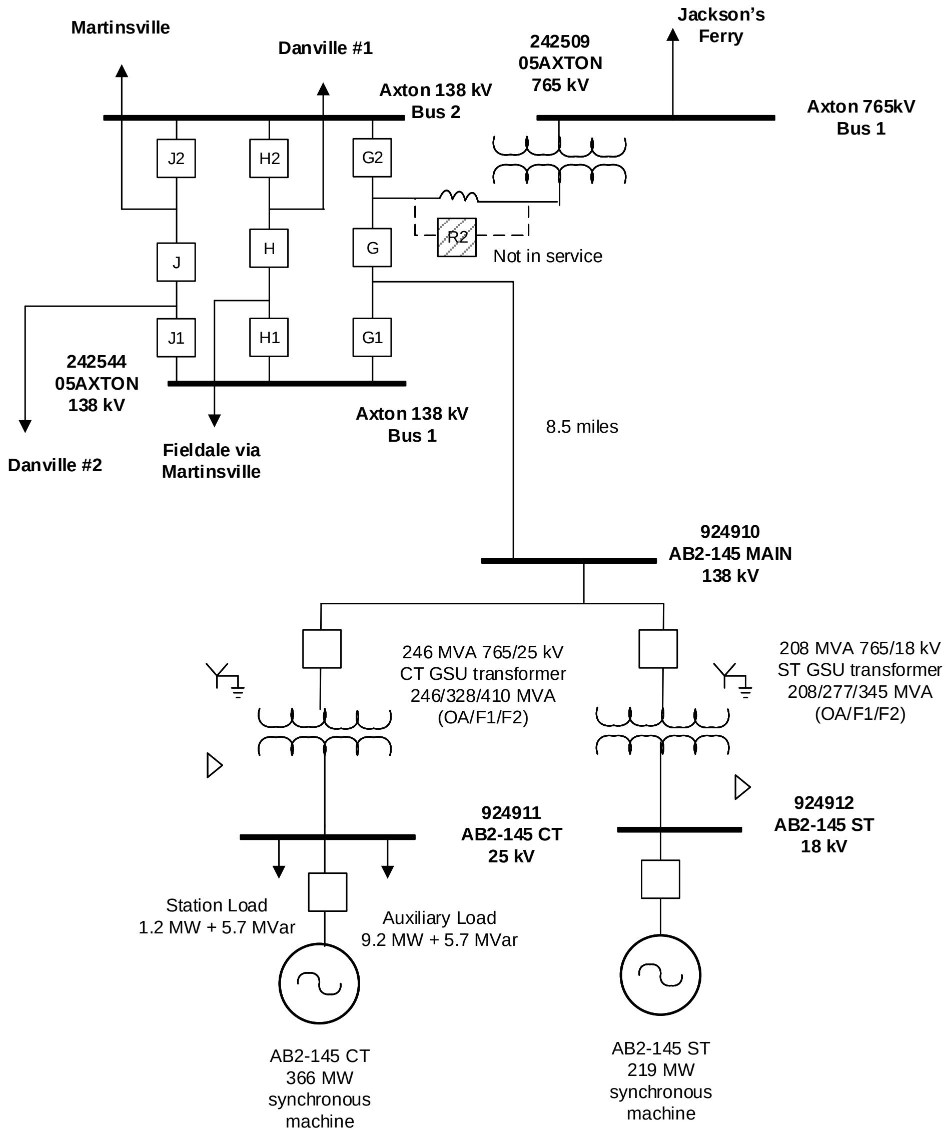


Figure 2: AB2-145 Plant Model – POI 2

Table 1: AB2-145 Plant Model – POI 1

	Impact Study Data	Model
Generators	1 x 366 MW Combustion turbine MVA base = 402.5 MVA Vt = 25 kV Unsaturated sub-transient reactance = 0.225 pu @ MVA base	1 x 366 MW generators Pgen 366 MW Pmax 366 MW Pmin 0.0 MW Qmax 170 MVAr Qmin -130 MVAr Mbase 402.5 MVA Zsorce 0.0023 + j0.225 pu @ Mbase
	1 x 219 MW Steam turbine MVA base = 330 MVA Vt = 18 kV Unsaturated sub-transient reactance = 0.215 pu @ MVA base	1 x 219 MW generator Pgen 219 MW Pmax 219 MW Pmin 0.0 MW Qmax 210 MVAr Qmin -140 MVAr Mbase 330 MVA Zsorce 0.0028 + j0.215 pu @ Mbase
Combustion turbine GSU transformer	1 x 765/25 kV two winding transformer Rating = 246/328/410 MVA (OA/F1/F2) Transformer base = 246 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 19 kV	1 x 765/25 kV two winding transformer Rating = 246/328/410 MVA (OA/F1/F2) Transformer base = 246 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 2.5%

Steam turbine GSU transformer	1 x 765/18 kV two winding transformer Rating = 208/277/345 MVA (OA/F1/F2) Transformer base = 208 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 19 kV	1 x 765/18 kV two winding transformer Rating = 208/277/345 MVA (OA/F1/F2) Transformer base = 208 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	9.2 MW + 5.7 MVAr	1 x (9.2 MW + 5.7 MVAr) modeled at low side of combustion turbine GSU
Station load	1.2 MW + 5.7 MVAr	1 x (1.2 MW + 5.7 MVAr) modeled at low side of combustion turbine GSU
Transmission line	8.5 miles	Impedance = 0.000724 + j0.0044 Charging = 2.54302

Table 2: AB2-145 Plant Model – POI 2

	Impact Study Data	**Model**
Generators	1 x 366 MW Combustion turbine MVA base = 402.5 MVA Vt = 25 kV Unsaturated sub-transient reactance = 0.225 pu @ MVA base	1 x 366 MW generators Pgen 366 MW Pmax 366 MW Pmin 0.0 MW Qmax 170 MVAr Qmin -130 MVAr Mbase 402.5 MVA Zsorce Mbase 0.0023 + j0.225 pu @ Mbase
	1 x 219 MW Steam turbine MVA base = 330 MVA Vt = 18 kV Unsaturated sub-transient reactance = 0.215 pu @ MVA base	1 x 219 MW generator Pgen 219 MW Pmax 219 MW Pmin 0.0 MW Qmax 210 MVAr Qmin -140 MVAr Mbase 330 MVA Zsorce Mbase 0.0028 + j0.215 pu @ Mbase

Combustion turbine GSU transformer	1 x 138/25 kV two winding transformer Rating = 246/328/410 MVA (OA/F1/F2) Transformer base = 246 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 19 kV	1 x 138/25 kV two winding transformer Rating = 246/328/410 MVA (OA/F1/F2) Transformer base = 246 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Steam turbine GSU transformer	1 x 138/18 kV two winding transformer Rating = 208/277/345 MVA (OA/F1/F2) Transformer base = 208 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 19 kV	1 x 138/18 kV two winding transformer Rating = 208/277/345 MVA (OA/F1/F2) Transformer base = 208 MVA Impedance = 0.00212 + j0.08497 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	9.2 MW + 5.7 MVAr	1 x (9.2 MW + 5.7 MVAr) modeled at low side of combustion turbine GSU
Station load	1.2 MW + 5.7 MVAr	1 x (1.2 MW + 5.7 MVAr) modeled at low side of combustion turbine GSU
Transmission line	8.5 miles	Impedance = 0.001622 + j0.007477 Charging = 0.001988

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 light load case with the following modifications:

a) Addition of all applicable queue projects prior to AB2-145.
b) Addition of AB2-145 queue project.
c) Removal of withdrawn and subsequent queue projects in the vicinity of AB2-145.
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 AB2-145 initial conditions are listed in Table 3, indicating maximum power output, with leading power factor.

Table 3: AB2-145 machine initial conditions

POI	Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
1	924911	AB2-145 CT	1	366 MW	-79.37 MVAr	0.95 pu	0.99 pu
	924912	AB2-145 ST	1	219 MW	-84.06 MVAr	0.95 pu	0.99 pu
2	924911	AB2-145 CT	1	366 MW	-8.32 MVAr	0.97 pu	0.99 pu
	924912	AB2-145 ST	1	219 MW	-8.32 MVAr	0.98 pu	0.99 pu

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AB2-145 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AB2-145 is given in Attachment 5 for POI 1 and POI 2.
Two scenarios were studied based on the AB2-145 POI connection:

- Scenario 1 – AB2-145 is connecting at Axton 765 kV Substation.
- Scenario 2 - AB2-145 is connecting at Axton 138 kV Substation.

[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 4 to 22 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 20 second simulation time interval.
The studied contingencies under Scenario 1 include:

g) Steady state operation (20 second);

h) Three phase faults with normal clearing time;

i) Single phase faults with stuck breaker;

j) 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;

k) Single phase bus faults with normal clearing time;

No multiple-circuit tower line or relevant high speed reclosing (HSR) contingencies were identified for this study.
The contingencies listed above were applied to:

- Axton 765 kV (AB2-145 POI)
- Jacksons Ferry 765 kV
- Axton 138 kV

The three phase faults with normal clearing time were performed under network intact conditions.
Four additional three phase faults at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit with normal clearing time were performed with prior outage of:

a) Axton – Danville 138 kV circuit #1;

b) Axton – Danville 138 kV circuit #2;

c) Axton – Stockton – Martinsville 138 kV circuit;

d) Axton – Martinsville – Collinsville – Fieldale 138 kV circuit.

The studied contingencies under scenario 2 include:

l) Steady state operation (20 second);

m) Three phase faults with normal clearing time;

n) Single phase faults with stuck breaker;

o) 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;

p) Single phase bus faults with normal clearing time;

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

No relevant high speed reclosing (HSR) contingencies were identified for this study.
The contingencies listed above were applied to:

- Axton 138 kV

The three phase faults with normal clearing time were performed under network intact conditions.
Four additional three phase faults at Axton (AB2-145 POI) 138 kV on Axton 138/765 kV Transformer 1 with normal clearing time were performed with prior outage of:

e) Axton – Danville 138 kV circuit #1;

f) Axton – Danville 138 kV circuit #2;

g) Axton – Stockton – Martinsville 138 kV circuit;

h) Axton – Martinsville – Collinsville – Fieldale 138 kV circuit.

Clearing times listed in Tables 4 to 22 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 network in the vicinity of AB2-145, 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 AB2-145, 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) AB2-145 is able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AB2-145 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 Attachments 6a and 6b, with results summarized in Table 4 through Table 22.

6.1 Scenario 1:

For 50 out of 56 of the fault contingencies tested on the 2020 light load case:

e) AB2-145 was able to ride through the faults (except for faults where protective action trips a generator(s)),

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

g) 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).

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

It was found that for all contingencies where Axton – Jacksons Ferry 765 kV circuit is tripped out of service (3N.02, 04, MA.3N.02, MB.3N.02, MC.3N.02, MD.3N.02) the AB2-145 queue project loses synchronism and trips.

The IC customer confirmed a second POI for AB2-145 and the contingencies were studied with AB2-145 connecting at Axton 138 kV in scenario 2 to investigate if the tripping issue can be eliminated.

6.2 Scenario 2:

For 18 out of 23 of the fault contingencies tested on the 2020 light load case:

e) AB2-145 was able to ride through the faults (except for faults where protective action trips a generator(s)),

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

g) 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).

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

It was found that post-fault responses of AB2-145 CT and ST units and nearby generating units was insufficiently damped (freq. 0.93 Hz, damping 2%) for contingencies SC2.3N.02, SC2.MA.3N.02, SC2.MB.3N.02, SC2.MC.3N.02, and SC2.MD.3N.02 (loss of Axton – Jacksons Ferry 765 kV circuit). Simulations using a pre-AB2-145 case show that post contingency oscillations have a damping greater than 3%. Therefore the addition of AB2-145 is attributable to the insufficient damping.

7. Recommendations and Mitigations

Results show that connecting AB2-145 queue project at Axton 138 kV can eliminate the tripping issues encountered when the project is connected to Axton 765 kV.

Insufficient damping was observed for several contingencies, and the addition of the AB2-145 Queue Project is attributable to the low damping. Tuning of relevant PSS is recommended to improve damping.

8.1 Scenario 1: AB2-145 is connecting at Axton 765 kV Substation

Table 4: Steady State Operation

Fault ID	Duration	Result No Mitigation
SC1.SS.01	Steady state 20 sec	Stable

Table 5: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
SC1.3N.01	Fault at Axton (AB2-145 POI) 765 kV on AB2-145 circuit (Trips AB2-145 CT and ST).	4.5	Stable
SC1.3N.02	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit.	4.5	Loss of Synchronism for AB2-145 CT and ST
SC1.3N.03	Fault at Axton (AB2-145 POI) 765 kV on 765/138 kV Transformer 1 (Trips Axton 138 kV reactor).	4.5	Stable
SC1.3N.04	Fault at Jacksons Ferry 765 kV on Axton circuit.	4.5	Loss of Synchronism for AB2-145 CT and ST
SC1.3N.05	Fault at Jacksons Ferry 765 kV on Broadford circuit.	4.5	Stable
SC1.3N.06	Fault at Jacksons Ferry 765 kV on Cloverdale circuit.	4.5	Stable
SC1.3N.07	Fault at Jacksons Ferry 765 kV on Wyoming circuit.	4.5	Stable
SC1.3N.08	Fault at Jacksons Ferry 765 kV on 765/138 kV Transformer 3.	4.5	Stable
SC1.3N.09	Fault at Jacksons Ferry 765 kV on 765/138 kV Transformer 2.	4.5	Stable
SC1.3N.10	Fault at Jacksons Ferry 765 kV on 765/500 kV Transformer 1 (Trips Jacksons Ferry – Antioch 500 kV circuit[4]).	4.5	Stable
SC1.3N.11	Fault at Jacksons Ferry 765 kV on Jacksons Ferry SVC.	4.5	Stable
SC1.3N.12	Fault at Axton 138 kV on 138/765 kV Transformer 1(Trips Axton 138 kV reactor).	5.5	Stable
SC1.3N.13	Fault at Axton 138 kV on Danville circuit No. 2.	5.5	Stable
SC1.3N.14	Fault at Axton 138 kV on Danville circuit No. 1.	5.5	Stable
SC1.3N.15	Fault at Axton 138 kV on Martinsville (Trips Martinsville 138/34.5 kV Transformer) – Collinsville (Trips Collinsville load) – Fieldale circuit.	5.5	Stable
SC1.3N.16	Fault at Axton 138 kV on Stockton – Martinsville circuit.	5.5	Stable

[4] Not in PJM area

Table 6: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
SC1.1B.01	Fault at Axton (AB2-145 POI) 765 kV on AB2-145 circuit (Trips AB2-145 CT and ST). Breaker stuck to Jacksons Ferry circuit. Fault cleared with loss of Jacksons Ferry circuit.	4.5 / 12	Stable
SC1.1B.02	Fault at Axton (AB2-145 POI) 765 kV on AB2-145 circuit (Trips AB2-145 CT and ST). Breaker stuck to Axton 765 kV Bus section 1. Fault cleared with loss of 765/138 kV Transformer 1 and Axton 138 kV reactor.	4.5 / 12	Stable
SC1.1B.03	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit. Breaker stuck to Axton 765 kV Bus section 1. Fault cleared with loss of 765/138 kV Transformer 1, Axton 138 kV reactor and AB2-145 circuit (Trips AB2-145 CT and ST).	4.5 / 12	Stable
SC1.1B.04	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit. Breaker stuck to AB2-145 circuit. Fault cleared with loss of AB2-145 circuit (Trips AB2-145 CT and ST).	4.5 / 12	Stable
SC1.1B.05	Fault at Axton (AB2-145 POI) 765 kV on 765/138 kV Transformer 1. Breaker stuck to AB2-145 circuit. Fault cleared with loss of AB2-145 circuit (Trips AB2-145 CT and ST).	4.5 / 12	Stable
SC1.1B.06	Fault at Axton (AB2-145 POI) 765 kV on 765/138 kV Transformer 1. Breaker stuck to Jacksons Ferry circuit. Fault cleared with loss of Jacksons Ferry circuit and AB2-145 circuit (Trips AB2-145 CT and ST).	4.5 / 12	Stable
SC1.1B.07	Fault at Jacksons Ferry 765 kV on Axton circuit. Breaker A stuck. Fault cleared with loss of Broadford circuit.	4.5 / 12	Stable
SC1.1B.08	Fault at Jacksons Ferry 765 kV on Axton circuit. Breaker A2 stuck. Fault cleared with loss of Jacksons Ferry Bus section 2 (Trips Jacksons Ferry SVC).	4.5 / 12	Stable
SC1.1B.09	Fault at Jacksons Ferry 765 kV on Broadford circuit. Breaker A stuck. Fault cleared with loss of Axton circuit.	4.5 / 12	Stable
SC1.1B.10	Fault at Jacksons Ferry 765 kV on Broadford circuit. Breaker A1 stuck. Fault cleared with loss of Jacksons Ferry Bus section 1 (Trips 765/500 kV Transformer 1).	4.5 / 12	Stable
SC1.1B.11	Fault at Jacksons Ferry 765 kV on Cloverdale circuit. Breaker B stuck. Fault cleared with loss of Jacksons Ferry 765/138 kV Transformer 2.	4.5 / 12	Stable
SC1.1B.12	Fault at Jacksons Ferry 765 kV on Cloverdale circuit. Breaker B2 stuck. Fault cleared with loss of Jacksons Ferry Bus section 2 (Trips Jacksons Ferry SVC).	4.5 / 12	Stable
SC1.1B.13	Fault at Jacksons Ferry 765 kV on Wyoming circuit. Breaker C stuck. Fault cleared with loss of Jacksons Ferry 765/138 kV Transformer 3.	4.5 / 12	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
SC1.1B.14	Fault at Jacksons Ferry 765 kV on Wyoming circuit. Breaker C1 stuck. Fault cleared with loss of Jacksons Ferry Bus section 1 (Trips 765/500 kV Transformer 1).	4.5 / 12	Stable
SC1.1B.15	Fault at Jacksons Ferry 765 kV on 765/138 kV Transformer 3. Breaker C stuck. Fault cleared with loss of Wyoming circuit.	4.5 / 12	Stable
SC1.1B.16	Fault at Jacksons Ferry 765 kV on 765/138 kV Transformer 3. Breaker C2 stuck. Fault cleared with loss of Jacksons Ferry Bus section 2 (Trips Jacksons Ferry SVC).	4.5 / 12	Stable
SC1.1B.17	Fault at Jacksons Ferry 765 kV on 765/138 kV Transformer 2. Breaker B1 stuck. Fault cleared with loss of Jacksons Ferry Bus section 1 (Trips 765/500 kV Transformer 1).	4.5 / 12	Stable
SC1.1B.18	Fault at Jacksons Ferry 765 kV on 765/138 kV Transformer 2. Breaker B stuck. Fault cleared with loss of Cloverdale circuit.	4.5 / 12	Stable
SC1.1B.19	Fault at Jacksons Ferry 765 kV on 765/500 kV Transformer 1 (Trips Jacksons Ferry – Antioch 500 kV circuit[5]). Breaker stuck to Jacksons Ferry bus section 1. Fault cleared with no loss of supply.	4.5 / 12	Stable
SC1.1B.20	Fault at Jacksons Ferry 765 kV on Jacksons Ferry SVC. Breaker stuck to Jacksons Ferry Bus section 2. Fault cleared with no loss of supply.	4.5 / 12	Stable
SC1.1B.21	Fault at Axton 138 kV on 138/765 kV Transformer 1 (Trips Axton 138 kV reactor). Breaker G stuck. Fault cleared with loss of Danville circuit No. 2.	5.5 / 16	Stable
SC1.1B.22	Fault at Axton 138 kV on 138/765 kV Transformer 1 (Trips Axton 138 kV reactor). Breaker G2 stuck. Fault cleared with loss of Axton 138 kV bus section 2 (Trips Stockton – Martinsville circuit).	5.5 / 16	Stable
SC1.1B.23	Fault at Axton 138 kV on Danville circuit No. 2. Breaker G stuck. Fault cleared with loss of Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor).	5.5 / 16	Stable
SC1.1B.24	Fault at Axton 138 kV on Danville circuit No. 2. Breaker H1 stuck. Fault cleared with loss of Martinsville (Trips Martinsville 138/34.5 kV Transformer) – Collinsville (Trips Collinsville load) – Fieldale circuit.	5.5 / 16	Stable
SC1.1B.25	Fault at Axton 138 kV on Danville circuit No. 1. Breaker H stuck. Fault cleared with loss of Martinsville (Trips Martinsville 138/34.5 kV Transformer) – Collinsville (Trips Collinsville load) – Fieldale circuit.	5.5 / 16	Stable
SC1.1B.26	Fault at Axton 138 kV on Danville circuit No. 1. Breaker H2 stuck. Fault cleared with loss of Axton 138 kV bus section 2 (Trips Stockton – Martinsville circuit).	5.5 / 16	Stable

[5] Not in PJM area

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
SC1.1B.27	Fault at Axton 138 kV on Martinsville (Trips Martinsville 138/34.5 kV Transformer) – Collinsville (Trips Collinsville load) – Fieldale circuit. Breaker H stuck. Fault cleared with loss of Danville circuit No. 1.	5.5 / 16	Stable
SC1.1B.28	Fault at Axton 138 kV on Martinsville (Trips Martinsville 138/34.5 kV Transformer) – Collinsville (Trips Collinsville load) – Fieldale circuit. Breaker H1 stuck. Fault cleared with loss of Danville circuit No. 2.	5.5 / 16	Stable
SC1.1B.29	Fault at Axton 138 kV on Stockton – Martinsville circuit. Breaker H2 stuck. Fault cleared with loss of Danville circuit No. 1.	5.5 / 16	Stable
SC1.1B.30	Fault at Axton 138 kV on Stockton – Martinsville circuit. Breaker G2 stuck. Fault cleared with loss of Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor).	5.5 / 16	Stable

Table 7: Single-phase Faults with Delayed Clearing (Zone 2) at Line Closest to AB2-145 POI

Fault ID	Fault description	Clearing Time Normal and Delayed (Cycles)	Result No Mitigation
SC1.1D.01	Fault at 80% of 138 kV line from Axton to Danville circuit No. 2. Delayed clearing at Axton 138 kV.	5.5 / 60	Stable
SC1.1D.02	Fault at 80% of 138 kV line from Axton to Danville circuit No. 1. Delayed clearing at Axton 138 kV.	5.5 / 60	Stable
SC1.1D.03	Fault at 80% of 138 kV line from Axton to Martinsville (Trips Martinsville 138/34.5 kV Transformer) – Collinsville (Trips Collinsville load) – Fieldale. Delayed clearing at Axton 138 kV.	5.5 / 60	Stable
SC1.1D.04	Fault at 80% of 138 kV line from Axton to Stockton – Martinsville circuit. Delayed clearing at Axton 138 kV.	5.5 / 60	Stable

Table 8: Single-phase Bus Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Normal and Delayed (Cycles)	Result No Mitigation
SC1.1S.01	Fault at Jacksons Ferry 765 kV Bus section 2. Fault cleared with loss of: • Jacksons Ferry 765/500 kV Transformer 1. • Jacksons Ferry – Antioch 500 kV circuit. CONTINGENCY '1377_C1_05J.FERR 765-2_WOMOP'	4.5	Stable

Table 9: Three-phase Faults with Normal Clearing – Prior outage of Axton – Danville 138 kV circuit #1

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC1.MA.3N.02	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit.	4.5	Loss of Synchronism for AB2-145 CT and ST

Table 10: Three-phase Faults with Normal Clearing – Prior outage of Axton – Danville 138 kV circuit #2

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC1.MB.3N.02	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit.	4.5	Loss of Synchronism for AB2-145 CT and ST

Table 11: Three-phase Faults with Normal Clearing – Prior outage of Axton – Stockton – Martinsville 138 kV circuit

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC1.MC.3N.02	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit.	4.5	Loss of Synchronism for AB2-145 CT and ST

Table 12: Three-phase Faults with Normal Clearing – Prior outage of Axton – Martinsville – Collinsville – Fieldale 138 kV circuit

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC1.MD.3N.02	Fault at Axton (AB2-145 POI) 765 kV on Jacksons Ferry circuit.	4.5	Loss of Synchronism for AB2-145 CT and ST

8.2 Scenario 2: AB2-145 is connecting at Axton 138 kV Substation

Table 13: Steady State Operation

Fault ID	Duration	Result No Mitigation
SC2.SS.01	Steady state 20 sec	Stable

Table 14: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
SC2.3N.01	Fault at Axton 138 kV on AB2-145 circuit (Trips AB2-145 CT and ST).	5.5	Stable
SC2.3N.02	Fault at Axton 138 kV on 138/765 kV Transformer 1 (Trips Axton 138 kV reactor and Axton – Jacksons Ferry 765 kV circuit).	5.5	Insufficient damping
SC2.3N.03	Fault at Axton 138 kV on Danville circuit No. 2.	5.5	Stable
SC2.3N.04	Fault at Axton 138 kV on Danville circuit No. 1.	5.5	Stable
SC2.3N.05	Fault at Axton 138 kV on Martinsville – Collinsville – Fieldale circuit (Trips Martinsville 138/34.5 kV Transformer, Martinsville 34.5 kV bus 1 and Collinsville load).	5.5	Stable
SC2.3N.06	Fault at Axton 138 kV on Stockton – Martinsville circuit (Trips Stockton load).	5.5	Stable

Table 15: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
SC2.1B.01	Fault at Axton 138 kV on AB2-145 circuit (Trips AB2-145 CT and ST). Breaker G stuck. Fault cleared with loss of Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor and Axton – Jacksons Ferry 765 kV circuit).	5.5 / 16	Stable
SC2.1B.02	Fault at Axton 138 kV on 138/765 kV Transformer 1. Breaker G stuck. Fault cleared with loss of AB2-145 circuit (Trips AB2-145 CT and ST). Additional loss of Axton 138 kV reactor and Axton – Jacksons Ferry 765 kV circuit.	5.5 / 16	Stable
SC2.1B.03	Fault at Axton 138 kV on Danville circuit No. 2. Breaker J stuck. Fault cleared with loss of Stockton – Martinsville circuit.	5.5 / 16	Stable
SC2.1B.04	Fault at Axton 138 kV on Danville circuit No. 1. Breaker H stuck. Fault cleared with loss of Martinsville – Collinsville – Fieldale circuit (Trips Martinsville 138/34.5 kV Transformer, Martinsville 34.5 kV bus 1 and Collinsville load).	5.5 / 16	Stable
SC2.1B.05	Fault at Axton 138 kV on Martinsville – Collinsville – Fieldale circuit. Breaker H stuck. Fault cleared with loss of Danville circuit No. 1. Additional loss of Martinsville 138/34.5 kV Transformer, Martinsville 34.5 kV bus 1 and Collinsville load.	5.5 / 16	Stable
SC2.1B.06	Fault at Axton 138 kV on Stockton – Martinsville circuit. Breaker J stuck. Fault cleared with loss of Danville circuit No. 2.	5.5 / 16	Stable

Table 16: Single-phase Faults with Delayed Clearing (Zone 2) at Line Closest to AB2-145 POI

Fault ID	Fault description	Clearing Time Normal and Delayed (Cycles)	Result No Mitigation
SC2.1D.01	Fault at 80% of 138 kV line from Axton to Danville circuit No. 2. Delayed clearing at Axton 138 kV.	5.5 / 60	Stable
SC2.1D.02	Fault at 80% of 138 kV line from Axton to Danville circuit No. 1. Delayed clearing at Axton 138 kV.	5.5 / 60	Stable
SC2.1D.03	Fault at 80% of 138 kV line from Axton to Martinsville – Collinsville – Fieldale. Delayed clearing at Axton 138 kV. Fault cleared with loss of Martinsville 138/34.5 kV Transformer and Collinsville load.	5.5 / 60	Stable
SC2.1D.04	Fault at 80% of 138 kV line from Axton to Stockton – Martinsville. Delayed clearing at Axton 138 kV. Fault cleared with loss of Stockton load.	5.5 / 60	Stable

Table 17: Single-phase Bus Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Normal and Delayed (Cycles)	Result No Mitigation
SC2.1S.01	Fault at Jacksons Ferry 765 kV Bus section 2. Fault cleared with loss of: • Jacksons Ferry 765/500 kV Transformer 1. • Jacksons Ferry – Antioch 500 kV circuit. CONTINGENCY '1377_C1_05J.FERR 765-2_WOMOP'	4.5	Stable

Table 18: Single-phase Faults with Loss of Multiple-Circuit Tower Line

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
SC2.1T.01	Fault at Fieldale 138 kV on Thornton – Franklin – Blaine circuit (Trips Thornton loads, Franklin 34.5 kV and 138 kV loads and Franklin 138/34.5 kV Transformer). Fault cleared with additional loss of Fieldale – Oak Level – Grassy Hill – Roanoke 138 kV circuit (Trips Oak Level load and Tank Hill loads). CONTINGENCY '409'	5.5	Stable

Table 19: Three-phase Faults with Normal Clearing – Prior outage of Axton – Danville 138 kV circuit #1

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC2.MA.3N.02	Fault at Axton (AB2-145 POI) 138 kV on Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor and Axton - Jacksons Ferry 765 kV circuit).	5.5	Insufficient damping

Table 20: Three-phase Faults with Normal Clearing – Prior outage of Axton – Danville 138 kV circuit #2

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC2.MB.3N.02	Fault at Axton (AB2-145 POI) 138 kV on Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor and Axton - Jacksons Ferry 765 kV circuit).	5.5	Insufficient damping

Table 21: Three-phase Faults with Normal Clearing – Prior outage of Axton – Stockton – Martinsville 138 kV circuit

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC2.MC.3N.02	Fault at Axton (AB2-145 POI) 138 kV on Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor and Axton - Jacksons Ferry 765 kV circuit).	5.5	Insufficient damping

Table 22: Three-phase Faults with Normal Clearing – Prior outage of Axton – Martinsville – Collinsville – Fieldale 138 kV circuit

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
SC2.MD.3N.02	Fault at Axton (AB2-145 POI) 138 kV on Axton 138/765 kV Transformer 1 (Trips Axton 138 kV reactor and Axton - Jacksons Ferry 765 kV circuit).	5.5	Insufficient damping

Attachments not included with this report, but are available on by request.

Attachment 1. Impact Study Data

Attachment 2. AEP One Line Diagram

Attachment 3a. PSS/E Model One Line Diagram – POI 1

Attachment 3b. PSS/E Model One Line Diagram – POI 2

Attachment 4. AB2-145 PSS/E Dynamic Model

Attachment 5. AB2-145 PSS/E Case Dispatch

Attachment 6a. Plots from Dynamic Simulations – POI 1

Attachment 6b. Plots from Dynamic Simulations – POI 2