Generator Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position #AB1-080

Dumont-Olive 345 kV

December 2016

General

St. Joseph Energy Center, LLC proposes to install PJM Project #AB1-080, a 40.0 MW (40.0 MW Capacity) injection capacity uprate to the existing 675 MW PJM Project #X2-052. The increase in output is due to higher than expected efficiency in the turbines. This is a Natural Gas facility connecting to American Electric Power's (AEP) Dumont - Olive 345 kV line (see Figure 1). The proposed location of the X2-052 345 kV interconnection switching station is approximately 1 mile from the Olive 345 kV substation and approximately 14 miles from the Dumont 345 kV substation (see Figure 2).

The requested in-service date is June 1, 2018.

The objective of this System Impact Study is to determine budgetary cost estimates and approximate construction timelines for identified transmission facilities required to increase the proposed generating capacity 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

PJM project X2-052 will pay for the necessary direct connection worked required. No additional attachment facilities are required to accommodate the additional output associated with the AB1-080 request.

Local and Network Impacts

The impact of the proposed injection capacity uprate 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 AB1-080 was evaluated as a 40.0 MW (Capacity 40.0 MW) injection into the X2-052 345 kV switching station (which is cut into the Dumont – Olive 345 kV line) in the AEP area. Project AB1-080 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-080 was studied with a commercial probability of 100%.

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1 http://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

Network Impacts

The Queue Project AB1-080 was evaluated as a 40.0 MW (Capacity 40.0 MW) injection into the X2-052 Tap 345 kV substation (which is a tap of the Dumont – Olive 345 kV line) in the AEP area. Project AB1-080 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-080 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2019

Generator Deliverability

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

None

Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies for the full energy output)

	Contingency		Affected	Facility	Bus				Loading		Rating		MW	FG
#	Type	Name	Area	Description	From	To	Cir.	PF	Initial	Final	Type	MVA	Con.	App.
1	LFFB	2978_C2_05DUMONT 765-B	AEP - AEP	X2-052 TAP-05DUMONT 345 kV line	909144	243219	2	AC	94.06	95.68	ER	1409	22.51	1
2	LFFB	112-65-BT4-5__	AEP - AEP	X2-052 TAP-05DUMONT 345 kV line	909144	243219	2	AC	85.46	87.14	ER	1409	23.53	
3	LFFB	112-65-BT3-4__	AEP - AEP	X2-052 TAP-05DUMONT 345 kV line	909144	243219	2	AC	85.45	87.14	ER	1409	23.53	

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

None

Short Circuit

(Summary of impacted circuit breakers)

None

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO Impacts:

MISO Impacts to be determined during the Facilities Study.

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

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.

Not Applicable

Light Load Analysis - 2019

Not required.

System Reinforcements

Short Circuit

None

Stability and Reactive Power Requirement

No Mitigations required. See full report in Appendix 2 at the end of this report.
Additional attachments 1 through 7 within the report will be provided upon request.

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

None

Contribution to Previously Identified System Reinforcements

1. To resolve the X2-052 Tap – Dumont 345 kV line overloads: The upgrade is to perform a sag study which shows remediation work will include the replacement of tower 20 with a custom steel pole and the removal of swing angle brackets on 2 structures (PJM Network Upgrade n4512). Cost estimate is $1.0775M. New SE rating to be 1868 MVA. This overload is caused by the AB1 Queue and the AB1 queue will share the cost as follows:

Queue	MW contribution	Percentage of Cost	$ cost ($1.0775 M)
AB1-006	21.9	5.44%	0.059
AB1-080	22.5	5.59%	0.060
AB1-089	41.0	10.18%	0.110
AB1-090	41.0	10.18%	0.110
AB1-091	43.6	10.83%	0.117
AB1-121	142.5	35.39%	0.381
AB1-122	90.2	22.40%	0.241

Light Load Load Flow Analysis Reinforcements

New System Reinforcements

None

Contribution to Previously Identified 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, a 40.0 MW (40.0 MW Capacity) injection capacity uprate to the existing 675 MW PJM Project #X2-052 will require additional interconnection charges. PJM Project #X2-052 will pay for the necessary direct connection work required.

Estimated Local/Network Upgrades Cost: $60,000

Total Estimated Cost for Project AB1-080: $60,000

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. Final estimates are also subject to change if other AB1 Queue projects withdraw.

**Figure 1: Point of Interconnection (Elderberry 345 kV Switching Station (To be constructed for PJM Project X2-052)
Single-Line Diagram**

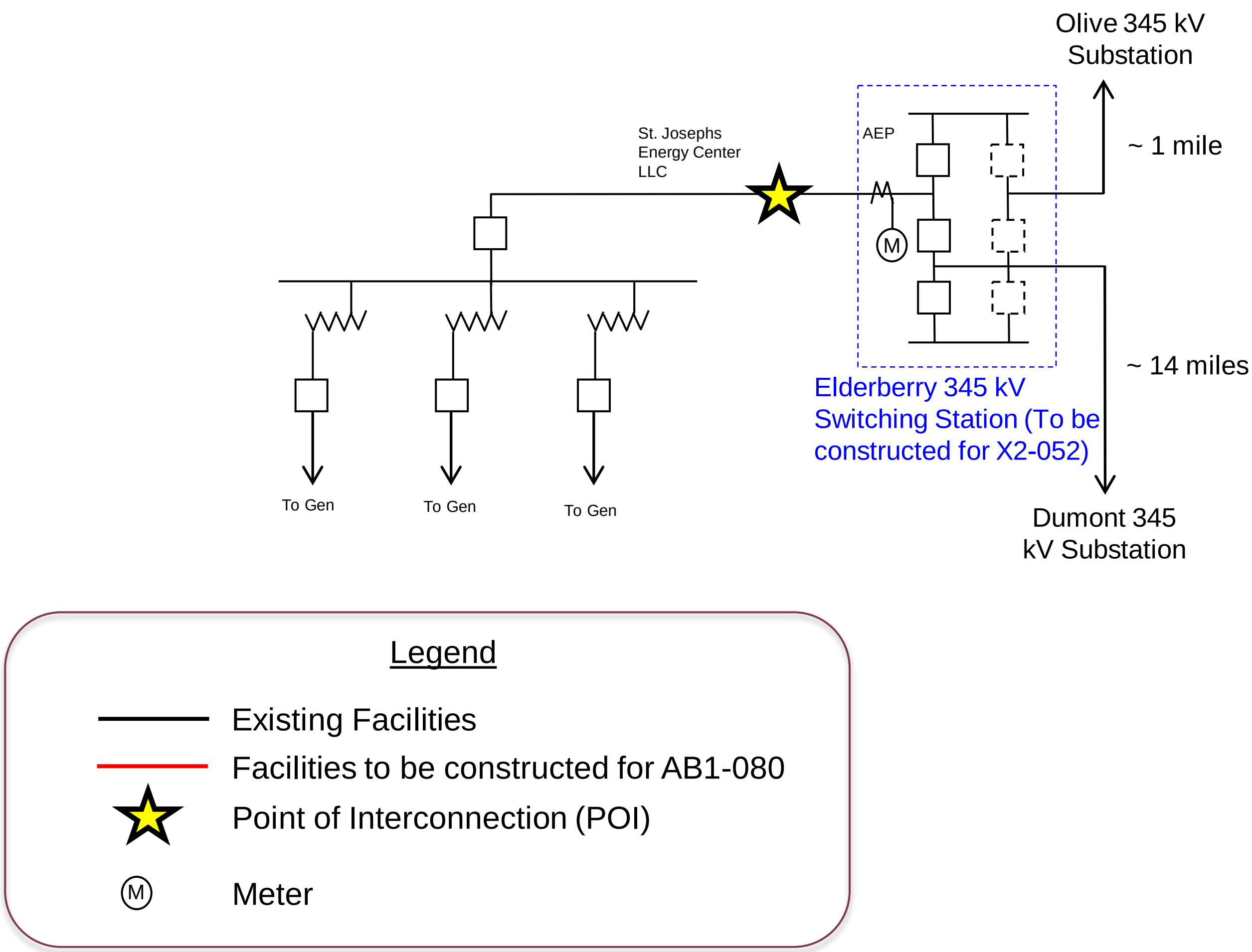
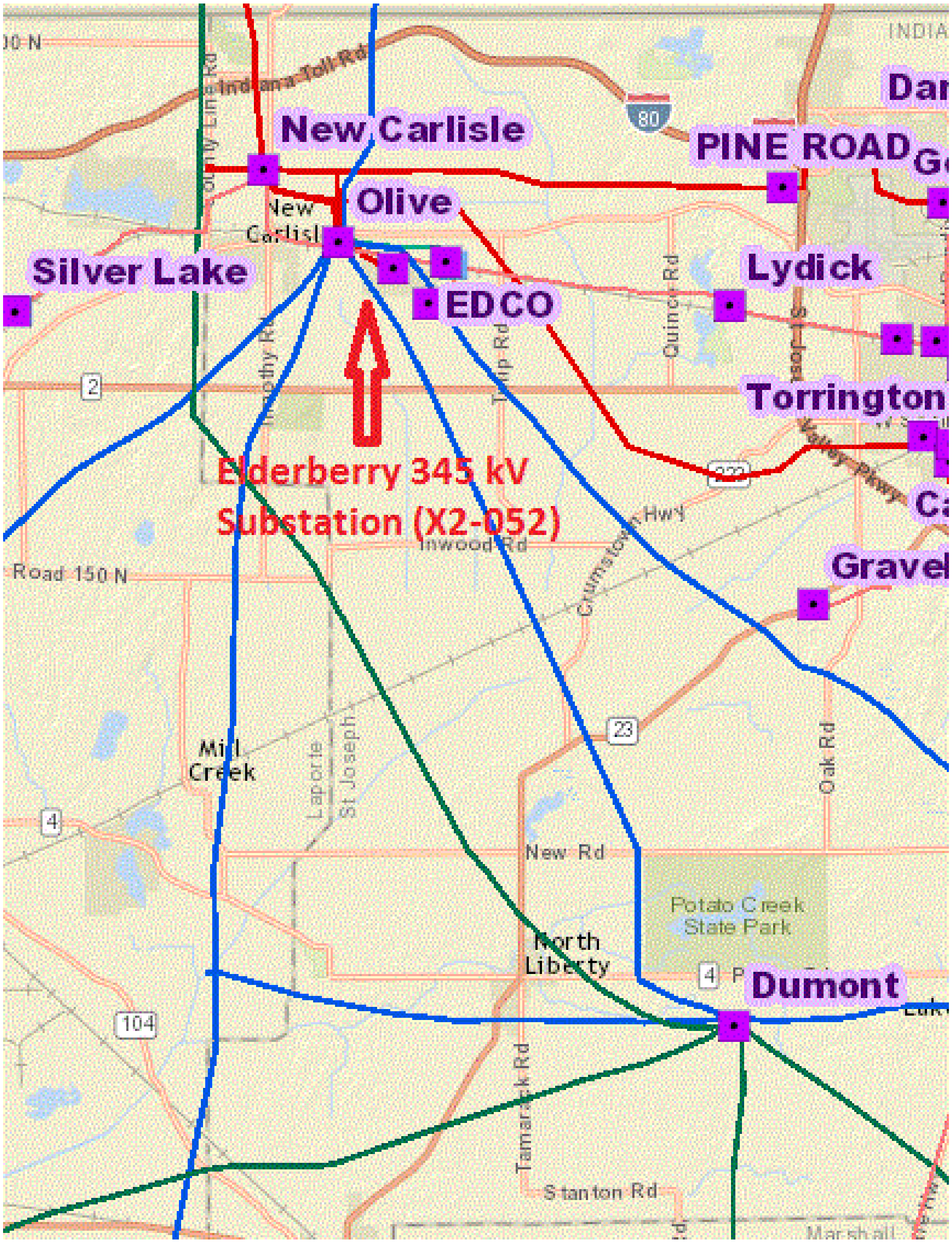


Figure 2: Customer Facility Location/Site Plan



Appendices

The following appendices contain additional information about each flowgate presented in the body of the report. For each appendix, a description of the flowgate and its contingency was included for convenience. However, the intent of the appendix section is to provide more information on which projects/generators have contributions to the flowgate in question. Although this information is not used "as is" for cost allocation purposes, it can be used to gage other generators impact.

It should be noted the generator contributions presented in the appendices sections are full contributions, whereas in the body of the report, those contributions take into consideration the commercial probability of each project.

Appendix 1

(AEP - AEP) The X2-052 TAP-05DUMONT 345 kV line (from bus 909144 to bus 243219 ckt 2) loads from 94.06% to 95.68% (AC power flow) of its emergency rating (1409 MVA) for the line fault with failed breaker contingency outage of '2978_C2_05DUMONT 765-B'. This project contributes approximately 22.51 MW to the thermal violation.

CONTINGENCY '2978_C2_05DUMONT 765-B'
  OPEN BRANCH FROM BUS 243206 TO BUS 907040 CKT 1 / 243206 05DUMONT 765 907040 X1-020 TAP 765 1
  OPEN BRANCH FROM BUS 243206 TO BUS 270644 CKT 1 / 243206 05DUMONT 765 270644 WILTON ; 765 1
  END

Bus Number	*Bus Name*	*Full Contribution*
247900	*05FR-11G E*	*7.53*
247901	*05FR-12G E*	*7.41*
247902	*05FR-21G E*	*7.92*
247903	*05FR-22G E*	*7.58*
247904	*05FR-3G E*	*15.35*
247905	*05FR-4G E*	*11.54*
246909	*05MDL-1G C*	*0.5*
247906	*05MDL-1G E*	*17.48*
246910	*05MDL-2G C*	*0.25*
247907	*05MDL-2G E*	*8.67*
246976	*05MDL-3G C*	*0.25*
247912	*05MDL-3G E*	*9.06*
246979	*05MDL-4G C*	*0.5*
247913	*05MDL-4G E*	*8.65*
274859	*EASYR;U1 E*	*6.96*
274860	*EASYR;U2 E*	*6.96*
290051	*GSG-6; E*	*6.53*
275149	*KEMPTON ;1E*	*11.17*
274881	*KEMPTON ;1U*	*2.79*
290108	*LEEDK;1U E*	*15.08*
274850	*MENDOTA H;RU*	*3.76*
275148	*MILKS GRV;1E*	*11.17*
274880	*MILKS GRV;1U*	*2.79*
293061	*N-015 E*	*9.61*
293644	*O-022 E1*	*6.28*
293645	*O-022 E2*	*12.18*
290021	*O-050 E*	*12.15*
294392	*P-010 E*	*12.21*
294763	*P-046 E*	*5.88*
274830	*PWR VTREC;1U*	*3.78*

Bus Number	*Bus Name*	*Full Contribution*
274831	*PWR VTREC;2U*	*3.78*
274722	*S-055 E*	*6.91*
884780	*S-058 C*	*27.03*
884782	*S-058 C1*	*27.03*
884781	*S-058 E*	*89.14*
884783	*S-058 E1*	*89.14*
295111	*SUBLETTE E*	*1.7*
890570	*U3-026 C1*	*19.*
890571	*U3-026 C2*	*19.*
291984	*U4-033*	*0.49*
274814	*UNIV PK N;0U*	*0.57*
274805	*UNIV PK N;1U*	*0.57*
274806	*UNIV PK N;2U*	*0.57*
274807	*UNIV PK N;3U*	*0.57*
274808	*UNIV PK N;4U*	*0.57*
274809	*UNIV PK N;5U*	*0.57*
274810	*UNIV PK N;6U*	*0.57*
274811	*UNIV PK N;7U*	*0.57*
274812	*UNIV PK N;8U*	*0.57*
274813	*UNIV PK N;9U*	*0.57*
274815	*UNIV PK N;XU*	*0.57*
274816	*UNIV PK N;YU*	*0.57*
900371	*V4-046*	*1.48*
900381	*V4-047*	*1.48*
900391	*V4-048*	*1.68*
900401	*V4-049*	*1.68*
903432	*W3-046*	*3.99*
903434	*W3-046*	*3.69*
903435	*W3-046*	*3.99*
903436	*W3-046*	*3.69*
274873	*WALNR;1U*	*1.52*
294500	*WALNR;1U E*	*6.07*
274874	*WALNR;2U*	*1.52*
294502	*WALNR;2U E*	*6.07*
295109	*WESTBROOK E*	*3.5*
909145	*X2-052*	*43.56*
914321	*Y2-103*	*27.63*
915011	*Y3-013 1*	*2.3*
915021	*Y3-013 2*	*2.3*
915031	*Y3-013 3*	*2.3*
LTF	*Z1-043*	*18.73*
916502	*Z1-106 E1*	*0.77*
916504	*Z1-106 E2*	*0.77*
916512	*Z1-107 E*	*1.6*
916522	*Z1-108 E*	*1.53*

Bus Number	*Bus Name*	*Full Contribution*
LTF	*Z1-112*	*6.56*
916651	*Z1-127 1*	*1.02*
916652	*Z1-127 2*	*0.6*
917451	*Z2-081*	*1.02*
917531	*Z2-090 C*	*0.03*
917532	*Z2-090 E*	*0.34*
917711	*Z2-114 C*	*0.4*
917712	*Z2-114 E*	*0.4*
918051	*AA1-018 C OP*	*1.55*
918052	*AA1-018 E OP*	*10.4*
918251	*AA1-040 1*	*0.78*
918261	*AA1-040 2*	*0.79*
LTF	*AA1-071*	*4.37*
918611	*AA1-078*	*2.36*
918972	*AA1-116 E*	*1.6*
918982	*AA1-117 E*	*1.6*
919591	*AA2-035 C OP*	*79.96*
919811	*AA2-067 OP*	*0.75*
920112	*AA2-107 E*	*1.52*
920272	*AA2-123 E*	*1.51*
930041	*AB1-006 C*	*2.85*
930042	*AB1-006 E*	*19.05*
930391	*AB1-080*	*22.51*
930442	*AB1-085 E*	*1.55*
930481	*AB1-089 C*	*40.96*
930491	*AB1-090 C*	*40.96*
930501	*AB1-091 C OP*	*43.6*
933011	*AB1-121*	*73.13*
933012	*AB1-121*	*69.36*
930761	*AB1-122 CT1*	*45.07*
930762	*AB1-122 CT2*	*45.09*
930972	*AB1-146 E*	*0.15*
931221	*AB1-172*	*0.5*

Appendix 2 - Dynamic Analysis

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Executive Summary

Generator Interconnection Request AB1-080 is for an increase in capacity of the natural gas facility interconnection request X2-052. The uprate increases the Maximum Facility Output (MFO) of the plant from 695 MW to 735 MW. AB1-080 has a Point of Interconnection (POI) at a tap of the 345 kV Olive – Dumont circuit in the American Electric Power (AEP) transmission system, St Joseph County, Indiana.

This report describes a dynamic simulation analysis of AB1-080 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2019 Light Load case, modified to include applicable queue projects. AB1-080 was dispatched at maximum power output and leading power factor and 0.95 pu voltage at the generator terminals.

AB1-080 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 90 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation (20 second simulation);
b) Three-phase faults with normal clearing time on the intact network and during a scheduled outage of a transmission or generation element;
c) Single-phase faults with phase delayed clearing due to a stuck breaker;
d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from fault due to primary communications/relay failure;
e) Single-phase faults with loss of multiple-circuit tower line.
f) Single-phase bus faults with normal clearing time.

For all simulations, the queue project under study, along with the rest of the PJM system, was required to ride through the fault, with all states returning to an acceptable new condition following the disturbance.

Due to the proximity of the AB1-080 queue project to X3-028 and S57/S58 merchant transmission queue projects, two scenarios have been studied:

Scenario 1

- X3-028 and S57/S58 not dispatched and associated reinforcements not included.
- The full set of contingencies were studied

Scenario 2

- X3-028 and S57/S58 dispatched and associated reinforcements included.
- Re-tested the contingencies from Scenario 1 located at the POI, and any contingencies that caused violations in Scenario 1.

Scenario 1 Results:

The results indicate that for the fault contingencies in Scenario 1 tested on the 2019 Light Load case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3% for all contingencies, except 1T.07, 1D.09 and 1D.10 which showed insufficient damping on AB1-006 PELEC.

- These contingencies were tested without the uprate of AB1-080 and insufficient damping was still evident. Therefore, this issue is not associated with the addition of AB1-080.

b) AB1-006 and T127 exhibit an unstable recovery for 1T.07 due to low post-contingent terminal voltages. Runs without the AB1-080 uprate show this issue still occurs, and is therefore not associated with the addition of AB1-080.

c) The AB1-080 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

d) 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).

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

Scenario 2 Results:

The results indicate that for the fault contingencies in Scenario 2 tested on the 2019 Light Load case:

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

b) The AB1-080 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

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.

1. Introduction

Generator Interconnection Request AB1-080 is for an increase in capacity of the natural gas facility interconnection request X2-052. The uprate increases the Maximum Facility Output (MFO) of the plant from 695 MW to 735 MW. AB1-080 has a Point of Interconnection (POI) at a tap of the 345 kV Olive – Dumont circuit in the American Electric Power (AEP) transmission system, St Joseph County, Indiana.

This analysis is effectively a screening study to determine whether the addition of AB1-080 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AB1-080 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

Generator Interconnection Request AB1-080 is for an increase capacity of the natural gas facility interconnection request X2-052. The uprate increases the Maximum Facility Output (MFO) of the plant from 695 MW to 735 MW. AB1-080 has a Point of Interconnection (POI) at the existing X2-052 345 kV Substation, which taps the 345 kV Olive – Dumont circuit in the American Electric Power (AEP) transmission system, St Joseph County, Indiana.

Table 1 lists the generator uprate between queue projects X2-052 and AB1-080. Figure 1 shows the simplified one-line diagram of the AB1-080 loadflow model. Table 2 lists the parameters given in the impact study data and the corresponding parameters of the AB1-080 loadflow model.

The dynamic models for the AB1-080 plant are based on the PSSE defined model supplied by PJM, as indicated by the Developer.

Additional project details are provided in Attachments 1 through 4:

- Attachment 1 contains the Impact Study Data which details the proposed AB1-080 project.
- Attachment 2 shows the one-line diagram of the AEP network in the vicinity of AB1-080.
- Attachment 3 provides a diagram of the PSS/E model in the vicinity of AB1-080.
- Attachment 4 gives the AB1-080 PSS/E loadflow and dynamic models of the AB1-080 plant.

Table 1: AB1-080 Uprate to X2-052

	MW (Gross)				**Increased Generation Due to**
	CT1	**CT2**	**ST**	**Total**	
Pre-uprate (X2-052)	230	230	235	695	Capacity increase
AB1-080 Increase	9	9	22	40	Higher than expected efficiency of the turbines. No change in electric or mechanical data from the original X2-052 project

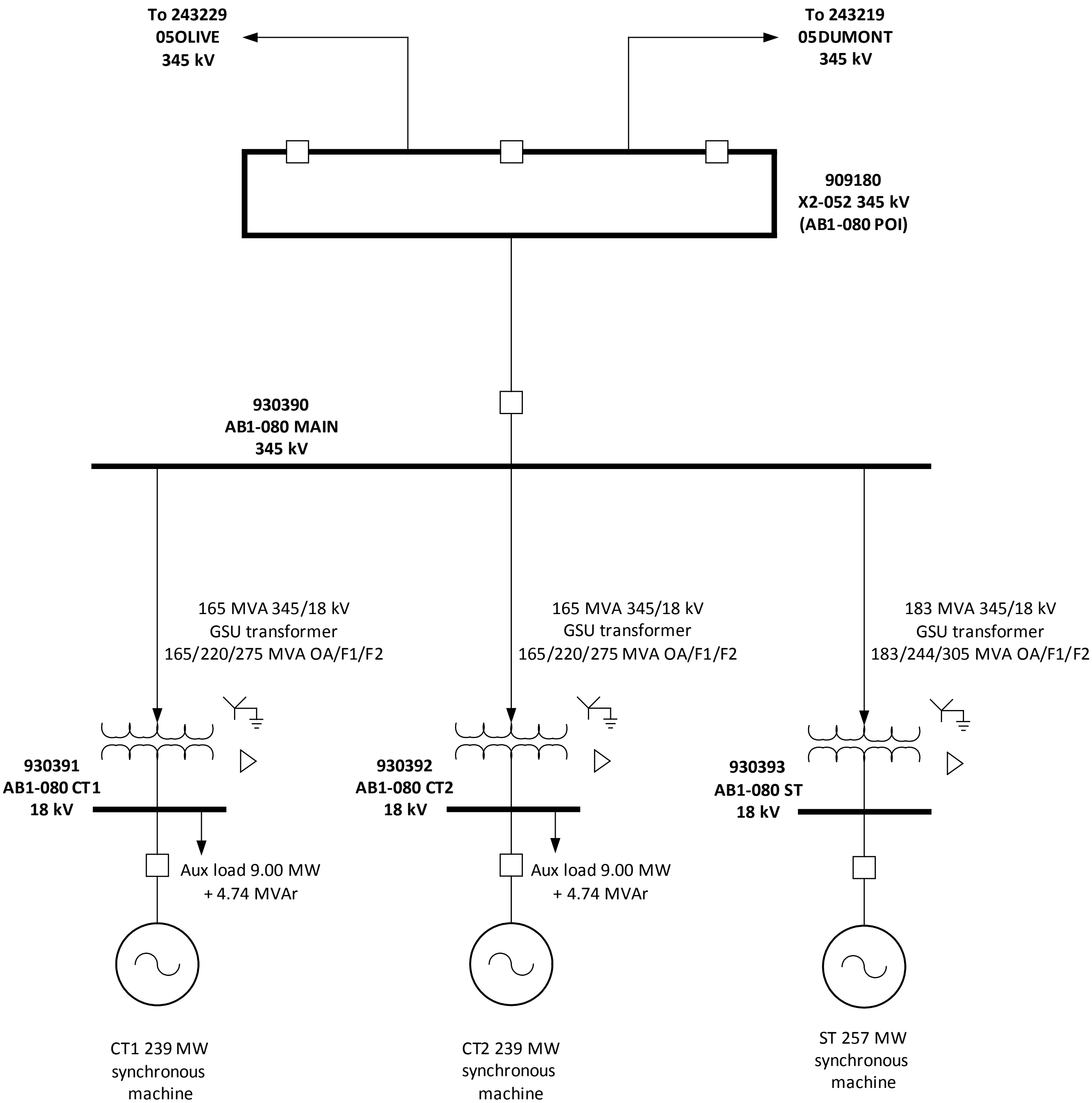

Figure 1: AB1-080 Plant Model

Table 2: AB1-080 Plant Model

	Impact Study Data	Model
Combustion Turbine Generator	2 x 239 MW Combustion Turbine generators MVA base = 288 MVA Vt = 18 kV Unsaturated sub-transient reactance = 0.2069 pu @ MVA base	2 x 239 MW Generators Pgen 239 MW Pmax 239 MW Pmin 0 MW Qgen -46.6 MVAr Qmax 150 MVAr Qmin -82 MVAr Mbase 288 MVA Zsorce j0.2069 pu @ Mbase
Steam Turbine Generator	257 MW Steam Turbine generator MVA base = 306 MVA Vt = 18 kV Unsaturated sub-transient reactance = 0.2198 pu @ MVA base	257 MW Generator Pgen 252.7 MW Pmax 252.7 MW Pmin 0 MW Qgen -56.6 MVAr Qmax 160 MVAr Qmin -118 MVAr Mbase 306 MVA Zsorce j0.2198 pu @ Mbase
Combustion Turbine Generator GSU Transformers	2 x 345/18 kV Transformers Rating = 165/220/275 MVA Transformer base = 165 MVA Impedance = 0.0017 + j0.1100 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %	2 x 345/18 kV Transformers Rating = 165/220/275 MVA Transformer base = 165 MVA Impedance = 0.0017 + j0.1100 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %
Steam Turbine Generator GSU Transformers	345/18 kV transformer Rating = 183/244/305 MVA Transformer base = 183 MVA Impedance = 0.0017 + j0.1100 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %	345/18 kV transformer Rating = 183/244/305 MVA Transformer base = 183 MVA Impedance = 0.0017 + j0.1100 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %
Auxiliary load	18.00 MW + 9.48 MVAr	9.00 MW + 4.74 MVAr at CT1 and CT2 bus.

3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 32.2.4.
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 2019 Light Load case with the following modifications:

a) Addition of all applicable queue projects prior to AB1-080.

b) Addition of AB1-080 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AB1-080.

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

The AB1-080 initial conditions are listed in Table 3, indicating maximum power output, with AB1-080 units regulating to leading power factor at the generator bus.

Table 3: AB1-080 machine initial conditions

Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
930391	AB1-080 CT1	1	239	-46.6	0.95	1.0193
930392	AB1-080 CT2	1	239	-46.6	0.95	1.0193
390393	AB1-080 ST	1	257	-56.6	0.95	1.0193

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AB1-080 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AB1-080 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

Table 4 to Table 15 list the contingencies that were studied, with clearing times as per the AEP Transmission Planning Criteria. Each contingency was studied over a 10 second simulation time interval. Contingencies studied included:

a) Steady state operation (20 second simulation);

b) Three-phase faults with normal clearing time on the intact network and during a scheduled outage of a transmission or generation element;

c) Single-phase faults with phase delayed clearing due to a stuck breaker;

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

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

f) Single-phase bus faults with normal clearing time.

No relevant Tower or High Speed Reclosing (HSR) contingencies were identified.
Buses at which the faults listed above were applied are:

- AB1-080 POI 345 kV
- Olive 345 kV
- Dumont 345 kV

The following three phase faults with normal clearing time were performed under network intact conditions and with prior outage of AB1-080 POI – Olive 345 kV circuit:

1. Fault at Dumont 345 kV on AB1-080 POI circuit.
2. Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-1.
3. Fault at Dumont 345 kV on Sorenson circuit.
4. Fault at Dumont 345 kV on Stillwell circuit.
5. Fault at Dumont 345 kV on Twin Branch circuit No.1.

The following three phase faults with normal clearing time were performed under network intact conditions and with prior outage of AB1-080 POI – Dumont 345 kV circuit:

1. Fault at Olive 345 kV on D.C. Cook circuit.
2. Fault at Olive 345 kV on Green Acres circuit.
3. Scenario 1: Fault at Olive 345 kV on Meadow Lake SW circuit and
   Scenario 2: Fault at Olive 345 kV on Reynolds No.2 circuit.
4. Scenario 1: Fault at Olive 345 kV on Reynolds - Meadow Lake SW circuit and
   Scenario 2: Fault at Olive 345 kV on Reynolds No.1 circuit.
5. Fault at Olive 345 kV on University Park circuit.
6. Fault at Olive 345 kV on Olive 345/138 kV Transformer T-2.

Additional delayed (Zone 2) clearing at remote end faults were applied on lines from D.C. Cook 345 kV, Green Acres 345 kV, University Park 345 kV, Meadow Lake SW

345 kV, Sorenson 345 kV, Twin Branch 345 kV, and Stillwell 345 kV towards the queue project.

Clearing times listed in Tables 4 to 15 are as per Revision 18 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 AB1-080, showing where faults will be applied.

The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case, modified to ensure that connected generators in the vicinity of AB1-080 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

Due to the proximity of the AB1-080 queue project to X3-028 and S57/S58 merchant transmission queue project, two scenarios have been studied:

Scenario 1 - X3-028 and S57/S58 not dispatched and associated reinforcements not included.

- The full set of contingencies were run. If no violations were identified, then Scenario 2 was studied next.
- If violations were identified, then any reinforcements needed to eliminate the violations were firstly determined.
- It was also determined if any of the X3-028 required reinforcements can eliminate the violations seen by next running Scenario 2.

Scenario 2 - X3-028 and S57/S58 dispatched and associated reinforcements included.

- No additional reinforcements determined from Scenario 1 included.
- Re-tested the contingencies at the POI, and any contingencies that caused violations in Scenario 1.

Where reinforcements associated with X3-028 alter circuit layouts for the studied contingencies; these have been noted in the contingency list.

5. Evaluation Criteria

This study is focused on AB1-080, 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) The system with AB1-080 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

b) The AB1-080 is able to ride through faults (except for faults where protective action trips a generator(s)).

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. <u>Summary of Results</u>

<u>Scenario 1</u>

Plots from the dynamic simulations for Scenario 1 are provided in Attachment 6, with results summarized in Table 4 to Table 11.
The results indicate that for the fault contingencies in Scenario 1 tested on the 2019 Light Load case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3% for all contingencies, except 1T.07, 1D.09 and 1D.10 which showed insufficient damping on AB1-006 PELEC.

    -These contingencies were tested without the uprate of AB1-080 and insufficient damping was still evident. Therefore, this issue is not associated with the addition of AB1-080.

b) AB1-006 and T127 exhibit an unstable recovery for 1T.07 due to low post-contingent terminal voltages. Runs without the AB1-080 uprate show this issue still occurs, and is therefore not associated with the addition of AB1-080.

c) The AB1-080 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

d) 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).

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

<u>Scenario 2</u>

Plots from the dynamic simulations for Scenario 2 are provided in Attachment 6, with results summarized in Table 12 to Table 15.
The results indicate that for the fault contingencies in Scenario 2 tested on the 2019 Light Load case:

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

b) The AB1-080 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

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.

No mitigation required.

6.1 Scenario 1 - X3-028 and S57/S58 not dispatched and associated reinforcements not included

6.1.1 Intact Network

Table 4: Steady State Operation

Fault ID	Duration	AB1-080 Scenario 1
SS.01	Steady state 20 sec	Stable

Table 5: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
3N.01	Fault at AB1-080 POI 345 kV on AB1-080 circuit. Trips AB1-080 units CT1, CT2, ST.	4.5	Stable (Trips AB1-080)
3N.02	Fault at AB1-080 POI 345 kV on Olive circuit.	4.5	Stable
3N.03	Fault at AB1-080 POI 345 kV on Dumont circuit.	4.5	Stable
3N.04	Fault at Olive 345 kV on AB1-080 POI circuit.	4.5	Stable
3N.05	Fault at Olive 345 kV on D.C. Cook circuit.	4.5	Stable
3N.06	Fault at Olive 345 kV on Green Acres circuit.	4.5	Stable

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
3N.07	Scenario 1: Fault at Olive 345 kV on Meadow Lake SW circuit.	4.5	Stable
3N.08	Scenario 1: Fault at Olive 345 kV on Reynolds - Meadow Lake SW circuit. Trips Reynolds 345/138 kV Transformer.	4.5	Stable
3N.09	Fault at Olive 345 kV on University Park circuit.	4.5	Stable
3N.10	Fault at Olive 345 kV on Olive 345/138 kV Transformer T-2.	4.5	Stable
3N.11	Fault at Dumont 345 kV on AB1-080 POI circuit.	4.5	Stable
3N.12	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-1.	4.5	Stable

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
3N.13	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-2.	4.5	Stable
3N.14	Fault at Dumont 345 kV on Sorenson circuit.	4.5	Stable
3N.15	Fault at Dumont 345 kV on Twin Branch circuit No. 1.	4.5	Stable
3N.16	Fault at Dumont 345 kV on Twin Branch circuit No. 2.	4.5	Stable
3N.17	Fault at Dumont 345 kV on Stillwell circuit.	4.5	Stable

Table 6: Single-phase Faults With Stuck Breaker

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	AB1-080 Scenario 1
1B.01	Fault at AB1-080 POI 345 kV on AB1-080 circuit. Breaker stuck to Olive circuit. Fault cleared with loss of Olive circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.02	Fault at AB1-080 POI 345 kV on AB1-080 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.03	Fault at AB1-080 POI 345 kV on Olive circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.04	Fault at AB1-080 POI 345 kV on Dumont circuit. Breaker stuck to Olive circuit. Fault cleared with loss of Olive circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.05	Scenario 1: Fault at Olive 345 kV on AB1-080 POI (-Dumont) circuit. Breaker E stuck. Fault cleared with loss of Reynolds (–Meadow Lake SW) circuit.	4.5 / 15	Stable
1B.06	Fault at Olive 345 kV on AB1-080 POI (- Dumont) circuit. Breaker E1 stuck. Fault cleared with loss of Olive 345/138 kV Transformer T-2.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	AB1-080 Scenario 1
1B.07	Fault at Olive 345 kV on D.C. Cook circuit. Breaker B stuck. Fault cleared with loss of Green Acres circuit.	4.5 / 15	Stable
1B.08	Fault at Olive 345 kV on D.C. Cook circuit. Breaker B1 stuck. Fault cleared with loss of 345/138 kV Transformer T-2.	4.5 / 15	Stable
1B.09	Fault at Olive 345 kV on Green Acres circuit. Breaker B stuck. Fault clear fault cleared with loss of D.C. Cook circuit.	4.5 / 15	Stable
1B.10	Scenario 1: Fault at Olive 345 kV on University Park circuit. Breaker D stuck. Fault cleared with loss of Meadow Lake SW circuit.	4.5 / 15	Stable
1B.11	Fault at Olive 345 kV on University Park circuit. Breaker D1 stuck. Fault cleared with loss of Olive 345/138 kV Transformer T-2.	4.5 / 15	Stable
1B.12	Scenario 1: Fault at Olive 345 kV on Meadow Lake SW circuit. Breaker D stuck. Fault cleared with loss of University Park circuit.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	AB1-080 Scenario 1
1B.13	Scenario 1: Fault at Olive 345 kV on Reynolds – Meadow Lake SW circuit. Breaker E stuck. Fault cleared with loss of AB1-080 circuit.	4.5 / 15	Stable
1B.14	Fault at Olive 345 kV on Olive 345/138 kV Transformer T-2. Breaker B1 stuck. Fault clear fault cleared with loss of D.C. Cook circuit.	4.5 / 15	Stable
1B.15	Fault at Olive 345 kV on Olive 345/138 kV Transformer T-2. Breaker D1 stuck. Fault cleared with loss of University Park circuit.	4.5 / 15	Stable
1B.16	Fault at Olive 345 kV on Olive 345/138 kV Transformer T-2. Breaker E1 stuck. Fault cleared with loss of AB1-080 circuit.	4.5 / 15	Stable
1B.17	Fault at Dumont 345 kV on AB1-080 POI (- Olive) circuit. Breaker G2 stuck. Fault cleared with loss of 765/345 kV Transformer T-2.	4.5 / 15	Stable
1B.18	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-1. Breaker E1 stuck. Fault cleared with loss of Sorenson circuit.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	AB1-080 Scenario 1
1B.19	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-1. Breaker E stuck. Fault cleared with loss of Twin Branch No.2 circuit.	4.5 / 15	Stable
1B.20	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-2. Breaker F2 stuck. Fault cleared with loss of Twin Branch No.1 circuit.	4.5 / 15	Stable
1B.21	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-2. Breaker E2 stuck. Fault cleared with loss of Twin Branch No.2 circuit.	4.5 / 15	Stable
1B.22	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-2. Breaker G2 stuck. Fault cleared with loss of AB1-080 POI (- Olive) circuit.	4.5 / 15	Stable
1B.23	Fault at Dumont 345 kV on Stillwell circuit. Breaker F stuck. Fault cleared with loss of Twin Branch circuit No.1.	4.5 / 15	Stable
1B.24	Fault at Dumont 345 kV on Stillwell circuit. Breaker F1 stuck. Fault cleared with loss of Sorenson circuit.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	AB1-080 Scenario 1
1B.25	Fault at Dumont 345 kV on Sorenson circuit. Breaker E1 stuck. Fault cleared with loss of 765/345 kV Transformer T-1.	4.5 / 15	Stable
1B.26	Fault at Dumont 345 kV on Sorenson circuit. Breaker F1 stuck. Fault cleared with loss of Stillwell circuit.	4.5 / 15	Stable
1B.27	Fault at Dumont 345 kV on Twin Branch No.1 circuit. Break F stuck. Fault cleared with loss of Stillwell circuit.	4.5 / 15	Stable
1B.28	Fault at Dumont 345 kV on Twin Branch No.1 circuit. Break F2 stuck. Fault cleared with loss of 765/345 kV Transformer T-2 and AB1-080 (- Olive) circuits.	4.5 / 15	Stable
1B.29	Fault at Dumont 345 kV on Twin Branch No.2 circuit. Breaker E stuck. Fault cleared with loss of 765/345 kV Transformer T-1.	4.5 / 15	Stable
1B.30	Fault at Dumont 345 kV on Twin Branch No.2 circuit. Breaker E2 stuck. Fault cleared with loss of 765/345 kV Transformer T-2 and AB1-080 (- Olive) circuits.	4.5 / 15	Stable

Table 7: Single-phase Faults With Delayed (Zone 2) Clearing at line end closest to AB1-080 POI

Fault ID	Fault description	Clearing Time normal & delayed (Cycles)	AB1-080 Scenario 1
1D.01	Fault at 80% of line from AB1-080 POI 345 kV on Olive circuit. Delayed clearing at AB1-080 POI.	4.5 / 60	Stable
1D.02	Fault at 80% of line from AB1-080 POI 345 kV on Dumont circuit. Delayed clearing at AB1-080.	4.5 / 60	Stable
1D.03	Fault at 80% of line from Olive 345 kV on D.C. Cook circuit. Delayed clearing at Olive.	4.5 / 60	Stable
1D.04	Fault at 80% of line from Olive 345 kV on Green Acres circuit. Delayed clearing at Olive.	4.5 / 60	Stable
1D.05	Scenario 1: Fault at 80% of line from Olive 345 kV on Meadow Lake SW circuit. Delayed clearing at Olive.	4.5 / 60	Stable
1D.06	Scenario 1: Fault at 80% of line from Olive 345 kV on Reynolds - Meadow Lake SW circuit. Delayed clearing at Olive. Trips Reynolds 345/138 kV Transformer.	4.5 / 60	Stable

Fault ID	Fault description	Clearing Time normal & delayed (Cycles)	AB1-080 Scenario 1
1D.07	Fault at 80% of line from Olive 345 kV on University Park circuit. Delayed clearing at Olive.	4.5 / 60	Stable
1D.08	Fault at 80% of line from Dumont 345 kV on Sorenson circuit. Delayed clearing at Dumont.	4.5 / 60	Stable
1D.09	Fault at 80% of line from Dumont 345 kV on Twin Branch circuit no. 1. Delayed clearing at Dumont.	4.5 / 60	Insufficient damping
1D.10	Fault at 80% of line from Dumont 345 kV on Twin Branch circuit no. 2. Delayed clearing at Dumont.	4.5 / 60	Insufficient damping
1D.11	Fault at 80% of line from Dumont 345 kV on Stillwell circuit. Delayed clearing at Dumont.	4.5 / 60	Stable

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

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
1T.01	Scenario 1: Fault at Olive 345 kV on Meadow Lake SW circuit resulting in tower failure. Fault cleared with loss of Reynolds circuit. CONTINGENCY '8803'	4.5	Stable
1T.02	Fault at Olive 345 kV on the D.C. Cook circuit resulting in tower failure. Fault cleared with the loss of D.C. Cook – Jackson Road circuit. CONTINGENCY '438'	4.5	Stable
1T.03	Fault at Dumont 345 kV on AB1-080 POI circuit resulting in tower failure. Fault cleared with loss of Sorenson circuit. CONTINGENCY '446'	4.5	Stable
1T.04	Fault at Dumont 345 kV on Twin Branch circuit no. 1 resulting in tower failure. Fault cleared with loss of Twin Branch circuit no. 2. CONTINGENCY '450'	4.5	Stable
1T.05	Fault at Dumont 345 kV on the Sorenson circuit resulting in tower failure. Fault cleared with the loss of D.C. Cook – Jackson Road circuit. CONTINGENCY '439'	4.5	Stable
1T.06	Fault at Dumont 345 kV on the Sorenson circuit resulting in tower failure. Fault cleared with the loss of Sorenson – Meridian circuit. CONTINGENCY '449'	4.5	Stable

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
1T.07	Scenario 1: Fault at Meadow Lake SW 345 kV on Olive circuit resulting in tower failure. Fault cleared with loss of Reynolds circuit. CONTINGENCY '8802'	4.5	Insufficient Damping

Table 9: Single-phase Bus Faults With Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
1S.01	Fault at Dumont 345 kV Bus 2. Fault cleared with loss of AB1-080 345 kV circuit and Dumont 765/345 kV transformer No.2. CONTINGENCY '17_C1_05DUMONT 765-2'	4.5	Stable
1S.02	Fault at Dumont 345 kV Bus 1. Fault cleared with loss of Sorenson circuit. CONTINGENCY '3193_C1_05DUMONT 345-1'	4.5	Stable
1S.03	Fault at Olive 345 kV Bus 1. Fault cleared with loss of Olive 345/138 kV transformer T-2 and Olive – Laporte JCT. 138 kV circuit. CONTINGENCY '8168_C1_05OLIVE 138-1'	4.5	Stable

6.1.2 Prior outage of AB1-080 POI – Olive 345 kV circuit

Table 10: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
MA.3N.01	Fault at Dumont 345 kV on AB1-080 POI circuit. Trips AB1-080.	4.5	Stable (Trips AB1-080)
MA.3N.02	Fault at Dumont 345 kV on Dumont 765/345 kV Transformer T-1.	4.5	Stable
MA.3N.03	Fault at Dumont 345 kV on Sorenson circuit.	4.5	Stable
MA.3N.04	Fault at Dumont 345 kV on Stillwell circuit.	4.5	Stable
MA.3N.05	Fault at Dumont 345 kV on Twin Branch circuit No. 1.	4.5	Stable

6.1.3 Prior outage of AB1-080 POI – Dumont 345 kV circuit

Table 11: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
MB.3N.01	Fault at Olive 345 kV on D.C. Cook circuit.	4.5	Stable
MB.3N.02	Fault at Olive 345 kV on Green Acres circuit.	4.5	Stable
MB.3N.03	Scenario 1: Fault at Olive 345 kV on Meadow Lake SW circuit.	4.5	Stable
MB.3N.04	Scenario 1: Fault at Olive 345 kV on Reynolds - Meadow Lake SW circuit. Trips Reynolds 345/138 kV Transformer.	4.5	Stable
MB.3N.05	Fault at Olive 345 kV on University Park circuit.	4.5	Stable

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 1
MB.3N.06	Fault at Olive 345 kV on Olive 345/138 kV Transformer T-2.	4.5	Stable

6.2 Scenario 2 - X3-028 and S57/S58 dispatched and associated reinforcements included

6.2.1 Intact Network

Table 12: Steady State Operation

Fault ID	**Duration**	**AB1-080 Scenario 2**
SS.01	Steady state 20 sec	Stable

Table 13: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	AB1-080 Scenario 2
3N.01	Fault at AB1-080 POI 345 kV on AB1-080 circuit. Trips AB1-080.	4.5	Stable (Trips AB1-080)
3N.02	Fault at AB1-080 POI 345 kV on Olive circuit.	4.5	Stable
3N.03	Fault at AB1-080 POI 345 kV on Dumont circuit.	4.5	Stable

Table 14: Single-phase Faults With Stuck Breaker

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	AB1-080 Scenario 2
1B.01	Fault at AB1-080 POI 345 kV on AB1-080 circuit. Breaker stuck to Olive circuit. Fault cleared with loss of Olive circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.02	Fault at AB1-080 POI 345 kV on AB1-080 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.03	Fault at AB1-080 POI 345 kV on Olive circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)
1B.04	Fault at AB1-080 POI 345 kV on Dumont circuit. Breaker stuck to Olive circuit. Fault cleared with loss of Olive circuit. Trips AB1-080.	4.5 / 15	Stable (Trips AB1-080)

Table 15: Single-phase Faults With Delayed (Zone 2) Clearing at line end closest to AB1-080 POI

Fault ID	Fault description	Clearing Time normal & delayed (Cycles)	AB1-080 Scenario 2
1D.01	Fault at 80% of line from AB1-080 POI 345 kV on Olive circuit. Delayed clearing at AB1-080 POI.	4.5 / 60	Stable
1D.02	Fault at 80% of line from AB1-080 POI 345 kV on Dumont circuit. Delayed clearing at AB1-080.	4.5 / 60	Stable

Attachment 1. Impact Study Data

Attachment 2. AEP One Line Diagram

Attachment 3a. PSS/E Model One Line Diagram - Scenario 1

Attachment 3b. PSS/E Model One Line Diagram - Scenario 2

Attachment 4. AB1-080 PSS/E Dynamic Model

Attachment 5. AB1-080 PSS/E Case Dispatch

Attachment 6. Plots from Dynamic Simulations – Scenario 1

Attachment 7. Plots from Dynamic Simulations – Scenario 2