Generator Interconnection
System Impact Study Report

For

PJM Generation Interconnection Request
Queue Position #AA2-116

Cook-East Elkhart 345 kV

June 2016

General

Indeck Energy Services proposes to interconnect a 994 MW (994 MW Capacity) natural gas generating facility to the American Electric Power (AEP) Transmission System. The point of interconnection is located approximately 1 mile west of existing Kenzie Creek 345/138 kV substation as shown in Figures 1 and 2. This Point of interconnection will tie together the Cook – Kenzie Creek 345 kV circuit section and the Cook – East Elkhart 345 kV circuit section via a new switching station as shown in Figure 1. The proposed PJM Project #AA2-116 is located in Cass County, Michigan State.

The requested in-service date is 04/01/2020.

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

A new in-line 345 kV switching station will be constructed approximately 1 mile west from the existing Kenzie Creek 345/138 kV substation in Cass County, Michigan. This new station will tie together the Cook – Kenzie Creek 345-kV circuit section and the Cook – East Elkhart 345-kV circuit section as shown in Figure 1. The new switching station is to consist of six (6) 345 kV circuit breakers physically configured to provide for future expansion to a breaker and half bus arrangement, but initially operated as a ring-bus (Figure 1). The station will also include 345 kV metering, SCADA, and associated equipment. Protection relays in the surrounding area will need to be upgraded to accommodate the addition of the new generating station.

Indeck Energy Services is expected to obtain, at its cost, a station site for the AEP facilities. Indeck Energy Services shall obtain all necessary permits. Ownership of the new in-line switching facility and associated equipment shall be transferred from Indeck Energy Services to AEP upon successful completion of the required work.

A 345 kV line extension is required to loop through the proposed station. The new AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap poles will be required. It is expected that Indeck Energy Services will obtain the supplemental easement when the station property is purchased.

The following work is required to connect PJM Project AA2-116 as shown in Figure 1

Station Cost:

- Construct a new six (6) breaker 345 kV switching station laid out in a breaker and half arrangement including installation of associated disconnect switches, bus work, SCADA and 345 kV revenue metering. (Network Upgrade **n5021**)

    - **Estimated Station Cost: $14,000,000**

Protection and Relaying Cost:

- Line protection and controls will need to be installed at the new 345 kV switching station. Estimated Cost: $1,000,000. (Network Upgrade **n5022**)

- Line protection and controls settings at Cook Circuit # 1 and #2 at Cook 345 kV substation will need to be changed to coordinate with the new 345 kV switching station due to the new generation added. Estimated Cost: $50,000. (Network Upgrade **n5023**)

- Line protection and controls at the Kenzie Creek 345/138 kV Substation will need to be upgraded to coordinate with the new 345 kV switching station due to the new generation added. Estimated Cost: $600,000. (Network Upgrade **n5024**)

- Line protection and controls settings at the East Elkhart 345/138 kV Substation will need to be changed to coordinate with the new 345 kV switching station due to the new generation added. Estimated Cost: $50,000. (Network Upgrade **n5025**)

    - **Estimated Protection and Relaying Cost: $1,700,000**

It is understood that Indeck Energy Services is responsible for all these connection costs associated with interconnecting the PJM project AA2-116 to AEP transmission system. The costs above are reimbursable to AEP. The cost of Indeck Energy resources' generating plant and the costs for the line connecting the generating plant to Indeck Energy Resources switching station are not included in this report; these are assumed to be Indeck Energy Resources' 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 utility to determine if a local service agreement is required.

Local and Network Impacts

The impact of the proposed natural gas fired 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. PJM project AA2-116 was studied as a 994 MW (994 MW capacity) injection to AEP system consistent with the interconnection application. The proposed Project AA2-116 was evaluated for compliance with reliability criteria for summer peak conditions in 2019.

Potential network impacts were as follows:

Normal System (2019 Summer Conditions Capacity Output)

- No problems identified

Single Contingency (2019 Summer Conditions Capacity Output)

- No problems identified

Multiple Contingency (2019 Summer Conditions Capacity Output)

- No problems identified

Contribution to Previously Identified Overloads (2019 Summer Conditions Capacity Output)

- No problems identified

Normal System (2019 Summer Conditions Full Output)

- No problems identified

Single Contingency (2019 Summer Conditions Full Output)

- No problems identified

Multiple Contingency (2019 Summer Conditions Full Output)

- No problems identified

---

1 https://www.aep.com/about/codeofconduct/oasis/transmissionstudies/GuideLines/2015%20AEP%20PJM%20FERC%20715_Final_Part%204.pdf

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

Contribution to Previously Identified Overloads (2019 Summer Conditions Energy Output)

- No problems identified

Short Circuit Analysis

Substation	Circuit Breaker	Comments
Twin Branch 345 kV	J1	Modeled incorrectly
Twin Branch 345 kV	JM	To Be Replaced (2017)
Twin Branch 345 kV	J2	To Be Replaced (2017)
Twin Branch 345 kV	K2	To Be Replaced (2017)
Twin Branch 138 kV	A1	Replaced
Twin Branch 138 kV	A	Replaced
Twin Branch 138 kV	A2	Replaced
Robison Park 138 kV	A1	Replaced
Robison Park 138 kV	A2	Replaced
Robison Park 138 kV	B1	Replaced
Robison Park 138 kV	B2	Replaced
Robison Park 138 kV	C1	Replaced
Robison Park 138 kV	C2	Replaced
Robison Park 138 kV	D1	Replaced
Robison Park 138 kV	D2	Replaced
Robison Park 138 kV	E1	Replaced
Robison Park 138 kV	E2	Replaced
Robison Park 138 kV	F1	Replaced
Sorenson 138 kV	M	Replaced
Sorenson 138 kV	N	Replaced
Sorenson 138 kV	O	Replaced

- The over-duty circuit breakers identified above have either been replaced, will be replaced, or have been modeled incorrectly in ASPEN. AEP is working on updating the ASPEN case to accurately reflect the new circuit breakers and will provide the updated change file to PJM once complete. PJM will need to re-run the short circuit analysis to ensure that the above circuit breakers are no longer over-duty and no new circuit breakers are found to be over-duty.

- Note that the Robison Park and Sorenson 138kV yards have been completely rebuilt in the clear and as a result some circuit breaker name designations will change. For example, Robison Park CB "F1" will be replaced, but the F1 designation will no longer be used. These changes will be reflected in the updated ASPEN change file.

Stability Analysis

- The study results indicate stable and acceptable performance of the proposed project AA2-116 and no adverse effects observed on the surrounding transmission system.

Voltage Variations

- No problems identified.

Additional Limitations of Concern

- No problems identified

Local/Network Upgrades

- 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 interconnection of the PJM #AA2-116 project to AEP transmission system will require the following construction costs.

- **Estimated Station Cost: $14,000,000**
- **Estimated Protection and Relaying Cost: $1,700,000**

- **Total Estimated Cost for Project AA2-116: $15,700,000**

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.

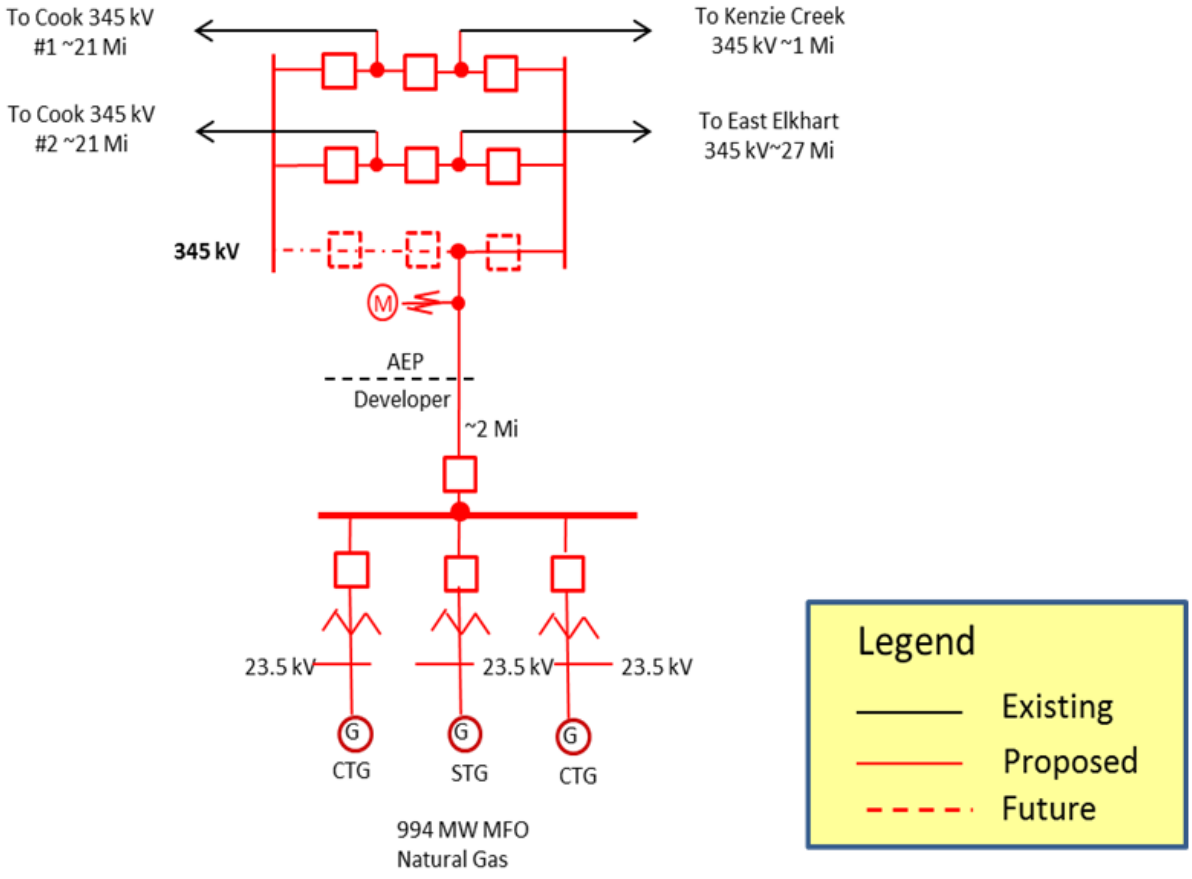

Figure 1 – PJM Queue # AA2-116 Cook-East Elekhart 345 kV Switching Station (Just West of Kenzie Creek 345 kV Station)

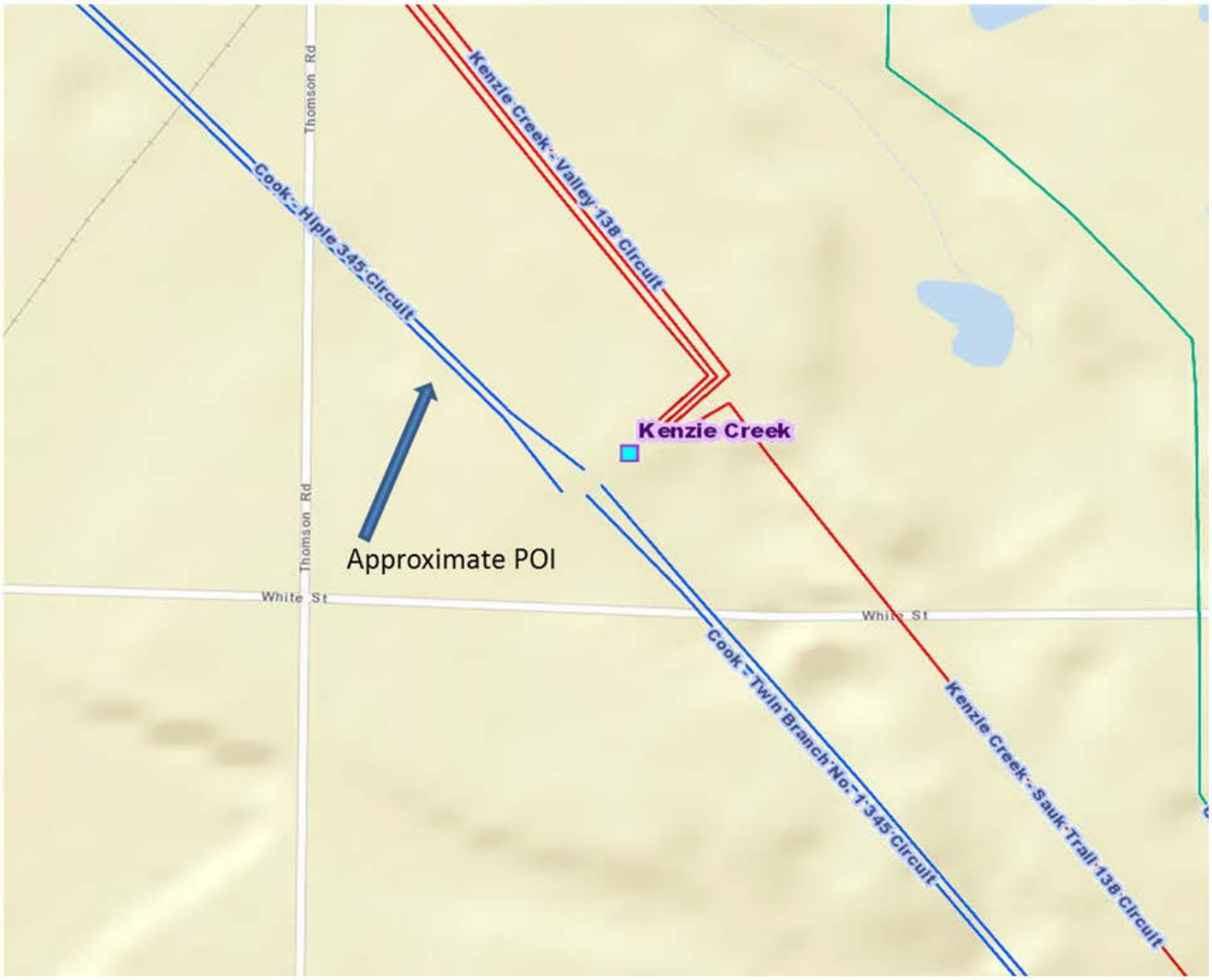

Figure 2 – Approximate Point of Interconnection (POI)

Network Impacts – PJM Analysis

The Queue Project AA2-116 was evaluated as a 994.0 MW (Capacity 994.0 MW) injection into a double tap of the Cook – Kenzie Creek 345 kV line and the Cook – East Elkhart 345 kV line in the AEP area. Project AA2-116 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AA2-116 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)

None

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

None

Steady-State Voltage Requirements
(Results of the steady-state voltage studies should be inserted here)

None

Short Circuit
(Summary of impacted circuit breakers)

Preliminary Short Circuit results based on newly built substation facilities were provided by AEP. The results will be confirmed by PJM during the Facilities Study phase.

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO Impacts:

MISO Impacts to be determined during the Facilities Study phase (as applicable).

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

OVEC Impacts to be determined during the Facilities Study phase (as applicable).

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

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

Not required

Stability and Reactive Power Requirement

Generator Interconnection Request AA2-116 is for a 2x1 combined cycle facility with a Maximum Facility Output (MFO) of 994 MW. AA2-116 consists of two combustion

turbine generators and a single steam turbine generator with a Point of Interconnection (POI) at a new substation that cuts into D.C Cook – Kenzie Creek – Twin Branch and Cook – East Elkhart – Hiple 345 kV circuits in the American Electric Power (AEP) transmission system, in Cass County, Michigan.

This report describes a dynamic simulation analysis of AA2-116 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. AA2-116 units have been dispatched online at maximum power output and leading power factor at the generator bus.

AA2-116 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 85 contingencies were studied, each with a 20 second simulation time period. Studied faults included:

a) Steady state operation (20 second simulation)

b) Three phase faults with normal clearing time

c) Multi-circuit tower single-phase faults with normal clearing time;

d) Single-phase bus faults with normal clearing time;

e) Single-phase faults with stuck breaker;

f) 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.

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.

Insufficiently damped power oscillations on local synchronous machines were observed in 42 of the 85 contingencies. Similarly low damping was observed with AA2-116 offline.

Contingencies 3N.12 and 3N.22 were tested on the RTEP 2019 Summer Peak case and were found to be transiently stable, with acceptable damping levels. Therefore it was concluded that the insufficient damping observed in the RTEP 2019 Light Load Case was not attributable to the addition of AA2-116. Further RTEP Light Load Case studies may be required.

1. Introduction

Generator Interconnection Request AA2-116 is for a 2x1 combined cycle facility with a Maximum Facility Output (MFO) of 994 MW. AA2-116 consists of two combustion turbine generators and a single steam turbine generator with a Point of Interconnection (POI) at a new substation that cuts into D.C Cook – Kenzie Creek – Twin Branch and Cook – East Elkhart – Hiple 345 kV circuits in the American Electric Power (AEP) transmission system, in Cass County, Michigan.

This analysis is effectively a screening study to determine whether the addition of AA2-116 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AA2-116 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

AA2-116 consists of two 352.03 MW combustion turbine generators and a single 312.5 MW steam turbine generator. Each of the combustion turbine generators will be connected to the POI via a 345/25 kV generator step-up (GSU) transformer with a rating of 520 MVA; the steam turbine generator will be connected to the POI via a 345/23.5 kV GSU transformer with a rating of 520 MVA. The AA2-116 POI will be a new substation that cuts into D.C. Cook – Kenzie Creek – Twin Branch and D.C. Cook – East Elkhart – Hiple 345 kV circuits, as shown in Figure 1.

Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AA2-116 loadflow model.

The dynamic models for the AA2-116 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 AA2-116 project.
- Attachment 2 shows the one line diagram of the AEP network in the vicinity of AA2-116.
- Attachment 3A and 3B provides a diagram of the PSS/E model in the vicinity of AA2-116 for the 2019 Light Load and Summer Peak cases.
- Attachment 4 gives the AA2-116 PSS/E loadflow and dynamic models of the AA2-116 plant.

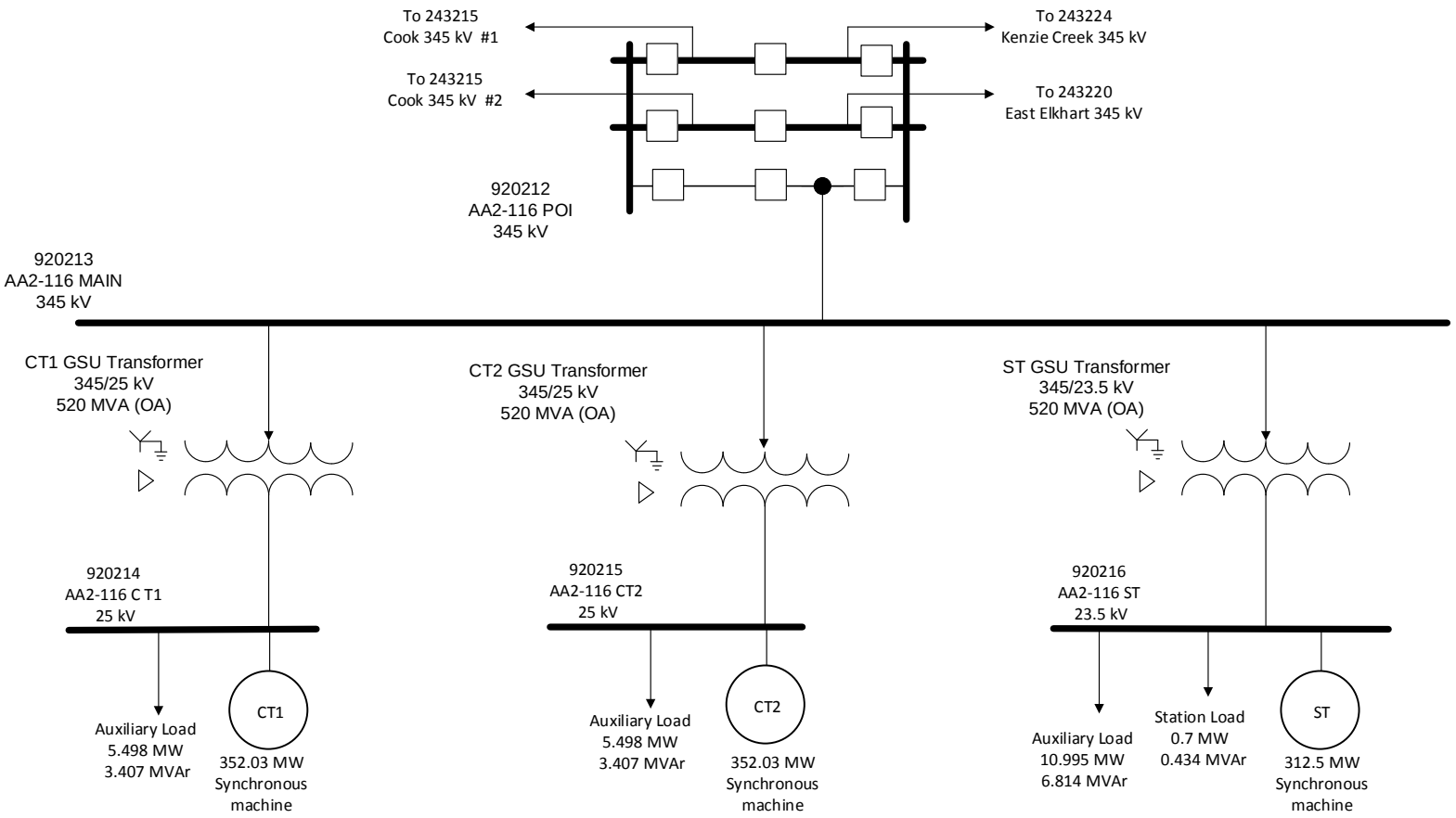

Figure 1: AA2-116 Plant Model

Table 1: AA2-116 Plant Model

	Impact Study Data	Model
Combustion Turbines – CT1, CT2	MVA base = 437.6 MVA Vt = 25 kV Unsaturated sub-transient reactance = 0.24 pu @ MVA base	2 x 352.03 MW generators Pgen 352 MW Pmax 352 MW Pmin 0 MW Qgen -29.5 MVAr Qmax 218.17 MVAr Qmin -115.71 MVAr Mbase 437.6 MVA Zsorce j0.24 pu @ Mbase
Steam Turbine – ST	MVA base = 460 MVA Vt = 23.5 kV Unsaturated sub-transient reactance = 0.135 pu @ MVA base	1 x 312.5 MW generator Pgen 312.5 MW Pmax 312.5 MW Pmin 0 MW Qgen -28.3 MVAr Qmax 193.67 MVAr Qmin -102.71 MVAr Mbase 460 MVA Zsorce j0.135 pu @ Mbase
GSU transformers – CT1, CT2	2 x 345/25 kV transformers Rating = 520 MVA (ONAN) Transformer base = 520 MVA Impedance = 0.00208 + j0.10275 pu @ MVA base Number of taps = 5 Tap step size = N/A	2 x 345/25 kV transformers Rating = 520 MVA Transformer base = 520 MVA Impedance = 0.00208 + j0.10275 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
GSU transformer – ST	345/23.5 kV transformer Rating = 520 MVA (ONAN) Transformer base = 520 MVA Impedance = 0.00208 + j0.10275 pu @ MVA base Number of taps = 5 Tap step size = N/A	345/23.5 kV transformer Rating = 520 MVA Transformer base = 520 MVA Impedance = 0.00208 + j0.10275 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load – CT1, CT2	10.995 MW + 6.814 MVAr	5.497 MW + 3.407 MVAr at each CT

Auxiliary load – ST	10.995 MW + 6.814 MVAr	10.995 MW + 6.814 MVAr
Station load	0.7 MW + 0.434 MVAr	0.7 MW + 0.434 MVAr (offline)
Transmission line	Impedance = 0.00006 + j 0.00096 pu; 0.01784 pu charging	Impedance = 0.00006 + j 0.00096 pu; 0.01784 pu charging

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 AA2-116.

b) Addition of AA2-116 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AA2-116.

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

The AA2-116 initial conditions are listed in Table 2, indicating maximum power output and leading power factor with 0.95 pu voltage at the generator buses.

Table 2: AA2-116 machine initial conditions

Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
920214	AA2-116 CT1	1	352 MW	-29.5 MVAr	0.950 pu	1.007 pu
920215	AA2-116 CT2	1	352 MW	-29.5 MVAr	0.950 pu	
920216	AA2-116 ST	1	312 MW	-28.3 MVAr	0.950 pu	

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AA2-116 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AA2-116 is given in Attachment 5A and Attachment 5B.

[3] 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

Table 3 to Table 9 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 include:

a) Steady state operation (20 second simulation);

b) Three phase faults with normal clearing time;

c) Multi-circuit tower single-phase faults with normal clearing time;

d) Single-phase bus faults with normal clearing time;

e) Single-phase faults with stuck breaker;

f) 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.

The contingencies listed above were applied to:

- AA2-116 345 kV POI
- Cook 345 kV
- Cook 765 kV
- Twin Branch 345 kV
- Hiple 345 kV

Clearing times listed in Table 4 to Table 8 are as per Revision 17 of "*2015 Revised Clearing times for each PJM company*" spreadsheet.
Attachment 2 contains the one-line diagrams of the AEP network in the vicinity of AA2-116, showing where faults were 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 AA2-116 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

5. Evaluation Criteria

This study is focused on AA2-116, 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 AA2-116 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

b) AA2-116 generators are able to ride through all faults (except for faults where protective action trips AA2-116).

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Table 3 through Table 9.
All fault contingencies tested on the 2019 light load case met the second recovery criterion:

b) AA2-116 generator was able to ride through all faults (except for faults where protective action trips AA2-116).

However, insufficiently damped (less than 3%) power oscillations were observed in 42 of the 85 contingencies on local synchronous machines. Similarly low damping was observed with AA2-116 offline.

Contingencies 3N.12 and 3N.22 were tested on the RTEP 2019 Summer Peak case and were found to be transiently stable, with acceptable damping levels. Therefore it was concluded that the insufficient damping observed in the RTEP 2019 Light Load Case was not attributable to the addition of AA2-116. Further RTEP Light Load Case studies may be required.

Table 3: Steady State Operation

Fault ID	Duration	AA2-116 No Mitigation
SS01	Steady state 20 sec	Stable

Table 4: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
3N.01	Fault at AA2-116 345 kV POI on AA2-116 circuit (trips AA2-116).	4.5	Insufficient damping (trips AA2-116)
3N.02	Fault at AA2-116 345 kV POI on D.C. Cook circuit 1.	4.5	Insufficient damping
3N.03	Fault at AA2-116 345 kV POI on East Elkhart – Hiple circuit.	4.5	Insufficient damping
3N.04	Fault at AA2-116 345 kV POI on Kenzie Creek – Twin Branch circuit.	4.5	Insufficient damping
3N.05	Fault at D.C. Cook 345 kV on 765/345 kV Transformer T-4.	4.5	Insufficient damping
3N.06	Fault at D.C. Cook 345 kV on D.C. Cook Unit 1.	4.5	Insufficient damping
3N.07	Fault at D.C. Cook 345 kV on AA2-116 POI circuit 1.	4.5	Insufficient damping
3N.08	Fault at D.C. Cook 345 kV on Jackson Road – Twin Branch circuit.	4.5	Insufficient damping
3N.09	Fault at D.C. Cook 345 kV on Olive circuit.	4.5	Insufficient damping
3N.10	Fault at D.C. Cook 345 kV on T94 circuit.	4.5	Insufficient damping
3N.11	Fault at D.C. Cook 345 kV on Benton Harbor circuit.	4.5	Insufficient damping
3N.12	Fault at D.C. Cook 765 kV on 765/345 kV Transformer T-4.	4.5	Insufficient damping
3N.13	Fault at D.C. Cook 765 kV on D.C. Cook Unit 2.	4.5	Insufficient damping
3N.14	Fault at D.C. Cook 765 kV on Dumont circuit.	4.5	Stable
3N.15	Fault at Hiple 345 kV on 345/138 kV Transformer T-1.	4.5	Stable
3N.16	Fault at Hiple 345 kV on 345/138 kV Transformer T-2.	4.5	Stable
3N.17	Fault at Hiple 345 kV on Collingwood circuit.	4.5	Stable
3N.18	Fault at Hiple 345 kV on East Elkhart – AA2-116 POI circuit.	4.5	Stable
3N.19	Fault at Twin Branch 345 kV on 345/138 kV Transformer T-7.	4.5	Insufficient damping
3N.20	Fault at Twin Branch 345 kV on Argenta circuit.	4.5	Insufficient damping
3N.21	Fault at Twin Branch 345 kV on Dumont circuit 1.	4.5	Insufficient damping
3N.22	Fault at Twin Branch 345 kV on Jackson Road – D.C. Cook circuit.	4.5	Insufficient damping

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
3N.23	Fault at Twin Branch 345 kV on Kenzie Creek – AA2-116 circuit.	4.5	Insufficient damping
3N.24	Fault at Twin Branch 345 kV on Meridian Sta. circuit.	4.5	Insufficient damping

Table 5: Single-phase Faults With Loss of Multiple-Circuit Tower

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1T.01	Fault at AA2-116 POI 345 kV on East Elkhart – Hiple circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2. • AA2-116 POI – Kenzie Creek – Twin Branch circuit. • Kenzie Creek 345/138 kV Transformer T-62. CONTINGENCY '8033_B'	4.5	Stable
1T.02	Fault at AA2-116 POI 345 kV on East Elkhart – Hiple circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2. • Robison Park – Weed Lake circuit. CONTINGENCY '8028_B'	4.5	Stable
1T.03	Fault at AA2-116 POI 345 kV on East Elkhart – Hiple circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2. • Twin Branch – Argenta circuit. CONTINGENCY '8030_B'	4.5	Stable
1T.04	Fault at AA2-116 POI 345 kV on East Elkhart – Hiple circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2. • AA2-116 – Kenzie Creek – Twin Branch circuit. • Kenzie Creek 345/138 kV Transformer T-62. CONTINGENCY '8032_B'	4.5	Stable
1T.05	Fault at D.C. Cook 345 kV on Benton Harbor circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • D.C. Cook – Benton Harbor circuit. • D.C. Cook – T94 circuit. CONTINGENCY '7027'	4.5	Insufficient damping
1T.06	Fault at D.C. Cook 345 kV on T94 circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • D.C. Cook – T94 circuit. • Benton – T94 circuit. CONTINGENCY '7030'	4.5	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1T.07	Fault at AA2-116 POI 345 kV on D.C. Cook circuit 1 resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 – D.C. Cook circuit 2. • AA2-116 – Kenzie Creek – Twin Branch circuit. • Kenzie Creek 345/138 kV Transformer T-62. CONTINGENCY '8032_A'	4.5	Stable
1T.08	Fault at AA2-116 POI 345 kV on D.C. Cook circuit 1 resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 – D.C. Cook circuit 2. • Robison Park – Weed Lake circuit. CONTINGENCY '8028_A'	4.5	Stable
1T.09	Fault at AA2-116 POI 345 kV on D.C. Cook circuit 1 resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 – D.C. Cook circuit 2. • Twin Branch – Argenta circuit. CONTINGENCY '8030_A'	4.5	Insufficient damping
1T.10	Fault at AA2-116 POI 345 kV on D.C. Cook circuit 1 resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 – D.C. Cook circuit 1. • AA2-116 – D.C. Cook circuit 2. CONTINGENCY '8033_A'	4.5	Insufficient damping
1T.11	Fault at D.C. Cook 345 kV on Olive circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • D.C. Cook – Olive circuit. • D.C. Cook – Jackson Road – Twin Branch circuit. • Jackson Road 345/138 kV Transformer T-3. CONTINGENCY '6560'	4.5	Stable
1T.12	Fault at D.C. Cook on Jackson Road – Twin Branch ciruit resulting in multi-tower failure. Fault cleared with loss of: • D.C. Cook – Jackson Road – Twin Branch circuit. • Jackson Road 345/138 kV Transformer T-3. • Dumont – Sorenson circuit. CONTINGENCY '439'	4.5	Stable
1T.13	Fault at Twin Branch on Jackson Road – D.C. Cook circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • Twin Branch – Jackson Road – D.C. Cook circuit. • Jackson Road 345/138 kV Transformer T-3. • Dumont – Sorenson circuit. CONTINGENCY '447'	4.5	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1T.14	Fault at Twin Branch 345 kV on Dumont circuit 1 resulting in multi-circuit tower failure. Fault cleared with loss of: • Twin Branch – Dumont circuit 1. • Twin Branch – Dumont circuit 2. CONTINGENCY '450'	4.5	Stable
1T.15	Fault at AA2-116 POI 345 kV on East Elkhart – Hiple circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2. • Robison Park – Weed Lake circuit. CONTINGENCY '8029'	4.5	Stable
1T.16	Fault at Twin Branch 345 kV on Jackson Road – D.C. Cook circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • Twin Branch – Jackson – D.C. Cook circuit. • Jackson Road 345/138 kV Transformer T-3. • Meridian Sta. – Sorenson circuit. CONTINGENCY '453'	4.5	Stable
1T.17	Fault at AA2-116 POI 345 kV on Kenzie Creek – Twin Branch circuit resulting in multi-circuit tower failure. Fault cleared with loss of: • AA2-116 POI – Kenzie Creek – Twin Branch circuit. • Kenzie Creek 345/138 kV Transformer T-62. • Twin Branch – Argenta circuit. CONTINGENCY '6589'	4.5	Stable

Table 6: Single-phase Bus Fault With Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	AA2-116 No Mitigation
1S.01	Fault on D.C. Cook 765 kV Bus 1. Fault cleared with loss of Dumont 765 kV circuit. CONTINGENCY '358_C1_05COOK 765-1'	4.5	Stable

Table 7: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1B.01	Fault at AA2-116 POI 345 kV on D.C. Cook circuit 1. Breaker stuck. Fault cleared with loss of: • AA2-116 POI – D.C. Cook circuit 1. • AA2-116 POI – Kenzie Creek – Twin Branch circuit. • Kenzie Creek 345/138 kV Transformer T-62	4.5 / 15	Insufficient damping
1B.02	Fault at AA2-116 POI 345 kV on D.C. Cook circuit 2. Breaker stuck. Fault cleared with loss of: • AA2-116 POI – D.C. Cook circuit 2. • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2.	4.5 / 15	Insufficient damping
1B.03	Fault at AA2-116 POI 345 kV on East Elkhart – Hiple circuit. Breaker stuck. Fault cleared with loss of: • AA2-116 POI – East Elkhart – Hiple circuit. • East Elkhart 345/138 kV Transformer T-2. • AA2-116 POI - D.C. Cook circuit 2.	4.5 / 15	Insufficient damping
1B.04	Fault at AA2-116 POI 345 kV on Kenzie Creek – Twin Branch circuit. Breaker stuck. Fault cleared with the loss of: • AA2-116 POI – Kenzie Creek – Twin Branch circuit. • Kenzie Creek 345/138 kV Transformer T-62. • AA2-116 POI – D.C. Cook circuit 1.	4.5 / 15	Insufficient damping
1B.05	Fault at AA2-116 POI 345 kV on AA2-116 circuit. Breaker stuck. Fault cleared without additional losses.	4.5 / 15	Insufficient damping (trips AA2-116)
1B.06	Fault at D.C. Cook 345 kV on 345 kV Transformer T-5. Breaker K1 stuck. Fault cleared with loss of: • D.C. Cook 345 kV Transformer T-5. • D.C. Cook 765/345 kV Transformer T-4.	4.5 / 15	Insufficient damping
1B.07	Fault at D.C. Cook 345 kV on 345 kV Transformer T-5. Breaker 01 stuck. Fault cleared with loss of: • D.C. Cook 345 kV Transformer T-5. • D.C. Cook Unit 1.	4.5 / 15	Insufficient damping
1B.08	Fault at D.C. Cook 345 kV on 765/345 kV Transformer T-4. Breaker K stuck. Fault cleared with loss of: • D.C. Cook 765/345 kV Transformer T-4. • D.C. Cook - AA2-116 circuit 1.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1B.09	Fault at D.C. Cook 345 kV on AA2-116 POI circuit 1. Breaker K stuck. Fault cleared with loss of: • D.C. Cook – AA2-116 POI circuit 1. • D.C. Cook 765/345 Transformer T-4.	4.5 / 15	Insufficient damping
1B.10	Fault at D.C. Cook 345 kV on AA2-116 POI circuit 2. Breaker L1 stuck. Fault cleared with loss of: • D.C. Cook – AA2-116 POI circuit 2. • D.C. Cook 345 kV Transformer T-5.	4.5 / 15	Insufficient damping
1B.11	Fault at D.C. Cook 345 kV on Benton Harbor circuit. Breaker N stuck. Fault cleared with loss of: • D.C. Cook – Benton Harbor circuit. • D.C. Cook – T94 circuit.	4.5 / 15	Insufficient damping
1B.12	Fault at D.C. Cook 345 kV on Jackson Road – Twin Branch circuit. Breaker M stuck. Fault cleared with loss of: • D.C. Cook – Jackson Road – Twin Branch circuit. • Jackson Road 345/138 kV Transformer T-3. • D.C. Cook – Olive circuit.	4.5 / 15	Insufficient damping
1B.13	Fault at D.C. Cook 345 kV on Olive circuit. Breker M stuck. Fault cleared with loss of: • D.C. Cook – Olive circuit. • D.C. Cook – Jackson Road – Twin Branch circuit. • Jackson Road 345/138 kV Transformer T-3.	4.5 / 15	Insufficient damping
1B.14	Fault at D.C. Cook 345 kV on T94 circuit. Breaker N stuck. Fault cleared with loss of: • D.C. Cook – T94 circuit. • D.C. Cook – Benton Harbour circuit.	4.5 / 15	Insufficient damping
1B.15	Fault at D.C. Cook 345 kV on D.C. Cook Unit 1. Breaker 01 stuck. Fault cleared with loss of: • D.C. Cook Unit 1. • D.C. Cook 345 kV Transformer T-5.	4.5 / 15	Insufficient damping
1B.16	Fault at D.C. Cook 765 kV on 765/345 kV Transformer T-4. Breaker A1 stuck. Fault cleared with loss of: • D.C. Cook 765/345 kV Transformer T-4. • D.C. Cook Unit 2.	4.5 / 12	Insufficient damping
1B.17	Fault at D.C. Cook 765 kV on D.C. Cook Unit 2. Breaker A1 stuck. Fault cleared with loss of: • D.C. Cook Unit 2. • D.C. Cook 765/345 kV Transformer T-4.	4.5 / 12	Insufficient damping

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1B.18	Fault at D.C. Cook 765 kV on Dumont circuit. Breaker B stuck. Fault cleared with loss of: • D.C. Cook – Dumont circuit. • D.C. Cook 765/345 kV Transformer T-4. • D.C. Cook Unit 2.	4.5 / 12	Stable
1B.19	Fault at Hiple 345 kV on 345/138 kV Transformer T-1. Breaker 26 stuck. Fault cleared with loss of: • Hiple 345/138 kV Transformer T-1. • Hiple – Collingwood circuit.	4.5 / 15	Insufficient damping
1B.20	Fault at Hiple 345 kV on 345/138 kV Transformer T-2. Breaker 25 stuck. Fault cleared with loss of: • Hiple 345/138 kV Transformer T-2. • Hiple – East Elkhart – AA2-116 POI. • East Elkhart 345/138 kV Transformer T-2.	4.5 / 15	Insufficient damping
1B.21	Fault at Hiple 345 kV on Collingwood 345 kV circuit. Breaker 25-26 stuck. Fault cleared with loss of: • Hiple – Collingwood circuit. • Hiple – East Elkhart – AA2-116 POI circuit. • East Elkhart 345/138 kV Transformer T-2.	4.5 / 15	Stable
1B.22	Fault at Hiple 345 kV on East Elkhart – AA2-116 POI circuit. Breaker 25-26 stuck. Fault cleared with loss of: • Hiple – East Elkhart – AA2-116 circuit. • East Elkhart 345/138 kV Transformer T2. • Hiple – Collingwood circuit.	4.5 / 15	Stable
1B.23	Fault at Twin Branch 345 kV on Kenzie Creek – AA2-116 POI circuit. Breaker LM stuck. Fault cleared with loss of: • Twin Branch – Kenzie Creek – AA2-116 circuit. • Kenzie Creek 345/138 kV Transformer T-62. • Twin Branch – Dumont circuit 1.	4.5 / 15	Insufficient damping
1B.24	Fault at Twin Branch 345 kV on Argenta circuit. Breaker KM stuck. Fault cleared with loss of: • Twin Branch – Argenta circuit. • Twin Branch – Dumont circuit 2.	4.5 / 15	Stable
1B.25	Fault at Twin Branch 345 kV on Dumont circuit 1. Breaker LM stuck. Fault cleared with loss of: • Twin Branch – Dumont circuit 1. • Twin Branch – Kenzie Creek – AA2-116 circuit. • Kenzie Creek 345/138 kV Transformer T-62.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1B.26	Fault at Twin Branch 345 kV on Dumont circuit 2. Breaker KM stuck. Fault cleared with loss of: • Twin Branch – Dumont circuit 2. • Twin Branch – Argenta circuit.	4.5 / 15	Stable
1B.27	Fault at Twin Branch 345 kV on Jackson Road – D.C. Cook circuit. Breaker JM stuck. Fault cleared with loss of: • Twin Branch – Jackson Road – D.C. Cook circuit. • Jackson Road 345/138 kV Transformer T-3. • Twin Branch – Meridian Sta. circuit.	4.5 / 15	Stable
1B.28	Fault at Twin Branch 345 kV on Meridan circuit. Breaker JM stuck. Fault cleared with loss of: • Twin Branch – Meridian Sta. circuit. • Twin Branch – Jackson Road – D.C. Cook circuit. • Jackson Road 345/138 kV Transformer T-3.	4.5 / 15	Insufficient damping
1B.29	Fault at Twin Branch 345 kV on 345/138 kV Transformer T-7. Breaker H2 stuck. Fault cleared without additional losses.	4.5 / 15	Stable

Table 8: Single-phase Faults With Delayed (Zone 2) Clearing at line end closest to AA2-116 POI

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
1D.01	Fault at 80% of 345 kV line 1 from AA2-116 POI to Cook. Delayed clearing at AA2-116 POI 345 kV.	4.5 / 60	Stable
1D.02	Fault at 80% of 345 kV line from AA2-116 POI to East Elkhart – Hiple. Delayed clearing at AA2-116 POI 345 kV.	4.5 / 60	Stable
1D.03	Fault at 80% of 345 kV line from AA2-116 POI to Kenzie Creek – Twin Branch. Delayed clearing at AA2-116 POI 345 kV.	4.5 / 60	Stable
1D.04	Fault at 80% of 345 kV line from D.C. Cook to Benton Harbor. Delayed clearing at D.C. Cook 345 kV.	4.5 / 60	Stable
1D.05	Fault at 80% of 345 kV line from D.C. Cook to Jackson Road – Twin Branch. Delayed clearing at D.C. Cook 345 kV.	4.5 / 60	Stable
1D.06	Fault at 80% of 345 kV line from D.C. Cook to Olive. Delayed clearing at D.C. Cook 345 kV.	4.5 / 60	Stable
1D.07	Fault at 80% of 345 kV line from D.C. Cook to T94 POI. Delayed clearing at D.C. Cook 345 kV.	4.5 / 60	Stable
1D.08	Fault at 80% of 765 kV line from D.C. Cook to Dumont. Delayed clearing at D.C. Cook 765 kV.	4.5 / 4.5	Stable
1D.09	Fault at 80% of 345 kV line from Hiple to Collingwood. Delayed clearing at Hiple 345 kV.	4.5 / 60	Stable
1D.10	Fault at 80% of 345 kV line from Twin Branch to Argenta. Delayed clearing at Twin Branch 345 kV.	4.5 / 60	Stable
1D.11	Fault at 80% of 345 kV line 1 from Twin Branch to Dumont. Delayed clearing at Twin Branch 345 kV.	4.5 / 60	Stable
1D.12	Fault at 80% of 345 kV line from Twin Branch to Jackson Road – Cook. Delayed clearing at Twin Branch 345 kV.	4.5 / 60	Stable
1D.13	Fault at 80% of 345 kV line from Twin Branch to Meridian Sta. Delayed clearing at Twin Branch 345 kV.	4.5 / 60	Stable

Table 9: Three-phase Faults With Normal Clearing, 2019 Summer Peak Case

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-116 No Mitigation
3N.12	Fault at D.C. Cook 765 kV on 765/345 kV Transformer T-4.	4.5	Stable
3N.22	Fault at Twin Branch 345 kV on Jackson Road – D.C. Cook circuit.	4.5	Stable

==========

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.