Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AA2-138

Hanging Rock (Cornu) 765 kV

April 2016

Preface

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

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

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

General

Dynegy proposes to increase the natural gas fired generation of its existing combined cycle plant of Power Block 2 section at Hanging Rock 765 kV by 45 MW (45 MWC) (see Figure 1). Currently Power Block 2 section is assigned CIRs of 625 MWs, and thus, the proposed increase will bring the total MFO of Power Block 2 section to 670 MW. Dynegy described that the increase will be accomplished by modifications introduced to the control systems, and turbines. There will be no change to the electrical or inertial characteristics of the plant equipment including the GSUs. The location of the generating facility of PJM Project AA2-138 is Ironton, OH (see Figure 2).

Note that the CIR and MFO values stated above reflect the as-yet-unexecuted AA1-013 Interconnection Service Agreements.

The requested in service date is May 1, 2019.

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

No additional attachment facilities are required to accommodate the increased generation at the existing Hanging Rock 765 kV combined cycle plant.

Local and Network Impacts

The impact of the proposed generating facility on the AEP Transmission 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 criterion were used to assess the impact of the proposed facility on the AEP System. PJM project # AA2-138 was studied as a 45 MW (45 MW Capacity) increase at Hanging Rock 765 kV Substation consistent with the interconnection application. PJM Queue #AA2-138 Project was evaluated for compliance with reliability criteria for summer peak conditions in 2019.

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1 https://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/GuideLines/2015_AEP_PJM_FERC_715_Final_Part_4.pdf

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

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

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

- No problem identified

Normal System (2019 Summer Conditions Full Output)

No problem identified

Single Contingency (2019 Summer Conditions Full Output)

- No problem identified

Multiple Contingency (2019 Summer Conditions Full Output)

- No problem identified

Contributions to Previously Identified Overloads (2019 Summer Conditions Full Output)

- No problem identified

Short Circuit Analysis

- No problem identified

Stability Analysis

- No problem identified – See Attachment 1- Dynamic Analysis at the end of this report.

Voltage Variations

- No problems identified

Additional Limitations of Concern

- No known additional limitations of concern.

Conclusion

Based upon the results of this System Impact Study, the increase of 45 MW (45 MW Capacity) of generation at Hanging Rock 765 kV Substation (PJM Project #AA2-138) will not require additional Network upgrades.

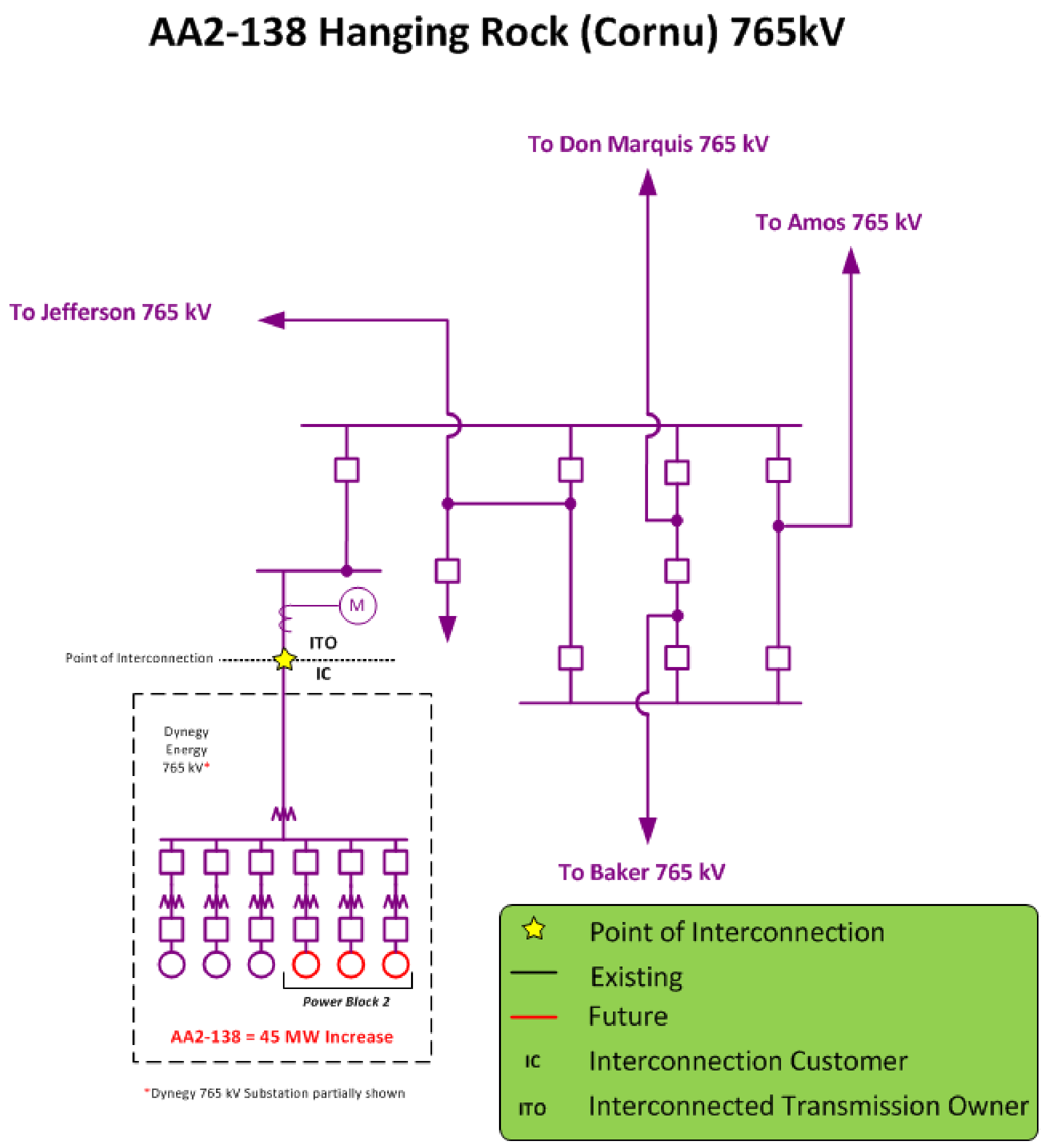

Figure 1 – Single Line Diagram

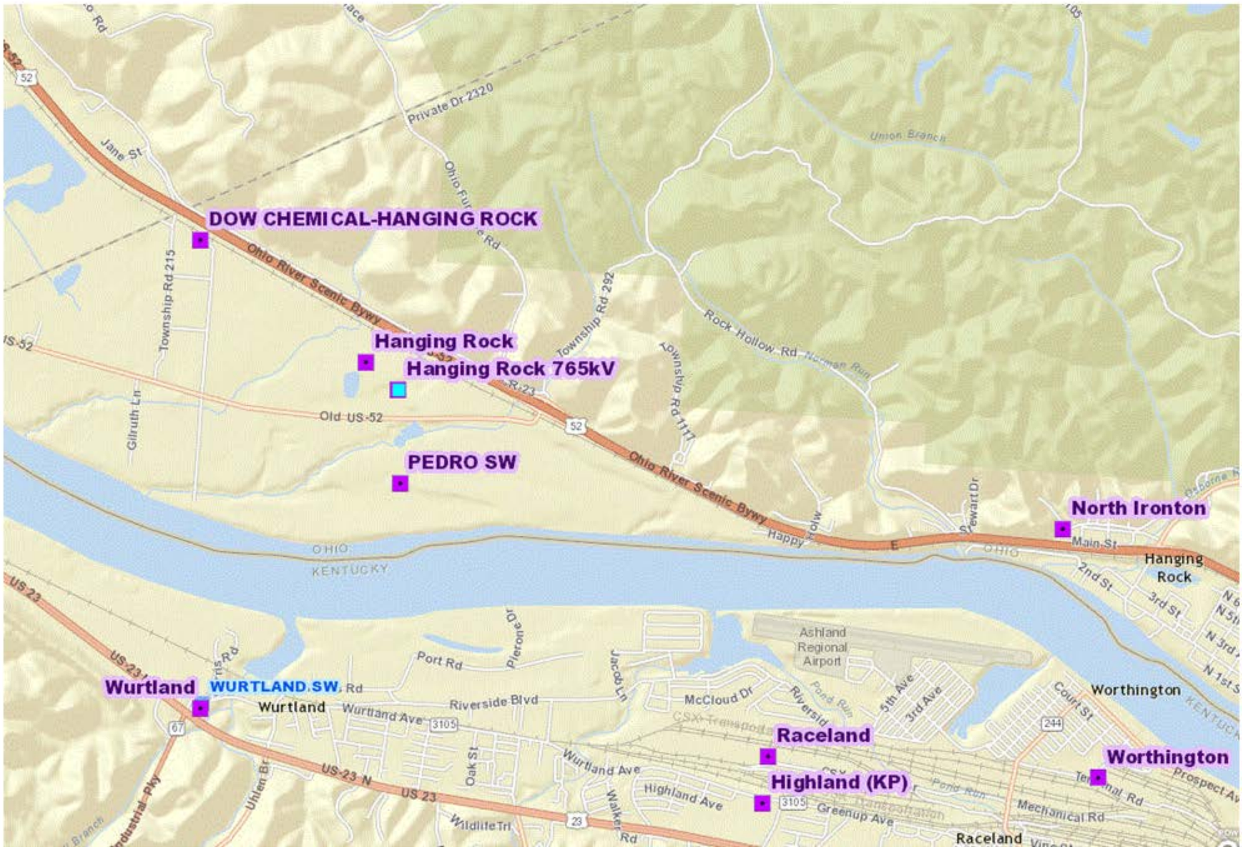

Figure 2 – Customer Point of Interconnection - Hanging Rock 765 kV Substation

Attachment 1 - Dynamic Analysis

Executive Summary

Generator Interconnection Request AA2-137 and AA2-138 are for a 45 MW uprate of the existing combined cycle power plant at Power Block I and Power Block II at the Hanging Rock Substation. Power Block I and Power Block II are both to be uprated to 670 MW Maximum Facility Output (MFO). The AA2-137 / AA2-138 combined cycle facilities consists of two combustion turbine generators and one steam turbine generator, with a Point of Interconnection (POI) at the Hanging Rock 765 kV bus in the American Electric Power (AEP) transmission system, Lawrence County, Ohio.

This report describes a dynamic simulation analysis of AA2-137 / AA2-138 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. AA2-137 / AA2-138 has been dispatched online at maximum power output.

AA2-137 / AA2-138 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 52 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

c) Single-phase faults with stuck breaker;

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.

All 52 fault contingencies tested on the 2019 light load case met the recovery criteria:

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

b) The AA2-137 / AA2-138 generators were able to ride through all faults (except for faults where protective action trips AA2-137 / AA2-138).

No mitigations were found to be required.

1. Introduction

Generator Interconnection Request AA2-137 and AA2-138 are for a 45 MW uprate of the existing combined cycle power plant at Power Block I and Power Block II at the Hanging Rock Substation. Power Block I and Power Block II are both to be uprated to 670 MW Maximum Facility Output (MFO). The AA2-137 / AA2-138 combined cycle facilities consists of two combustion turbine generators and one steam turbine generator, with a Point of Interconnection (POI) at the Hanging Rock 765 kV bus in the American Electric Power (AEP) transmission system, Lawrence County, Ohio.

This analysis is effectively a screening study to determine whether the addition of AA2-137 / AA2-138 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AA2-137 / AA2-138 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 AA2-137 and AA2-138 are for a 45 MW uprate of the existing combined cycle power plant at Power Block I and Power Block II at the Hanging Rock Substation. Power Block I and Power Block II are both to be uprated to 670 MW Maximum Facility Output (MFO). The AA2-137 / AA2-138 combined cycle facilities consists of two combustion turbine generators and one steam turbine generator, with a Point of Interconnection (POI) at the Hanging Rock 765 kV bus in the American Electric Power (AEP) transmission system, Lawrence County, Ohio.

Figure 1 shows the simplified one-line diagram of the AA2-137 / AA2-138 loadflow model. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AA2-137 / AA2-138 loadflow model.

The dynamic models for the AA2-137 / AA2-138 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 AA2-137 / AA2-138 project.
- Attachment 2 shows the one line diagram of the AEP network in the vicinity of AA2-137 / AA2-138.
- Attachment 3 provides a diagram of the PSS/E model in the vicinity of AA2-137 / AA2-138.
- Attachment 4 gives the AA2-137 / AA2-138 PSS/E loadflow and dynamic models of the AA2-137 / AA2-138 plant.

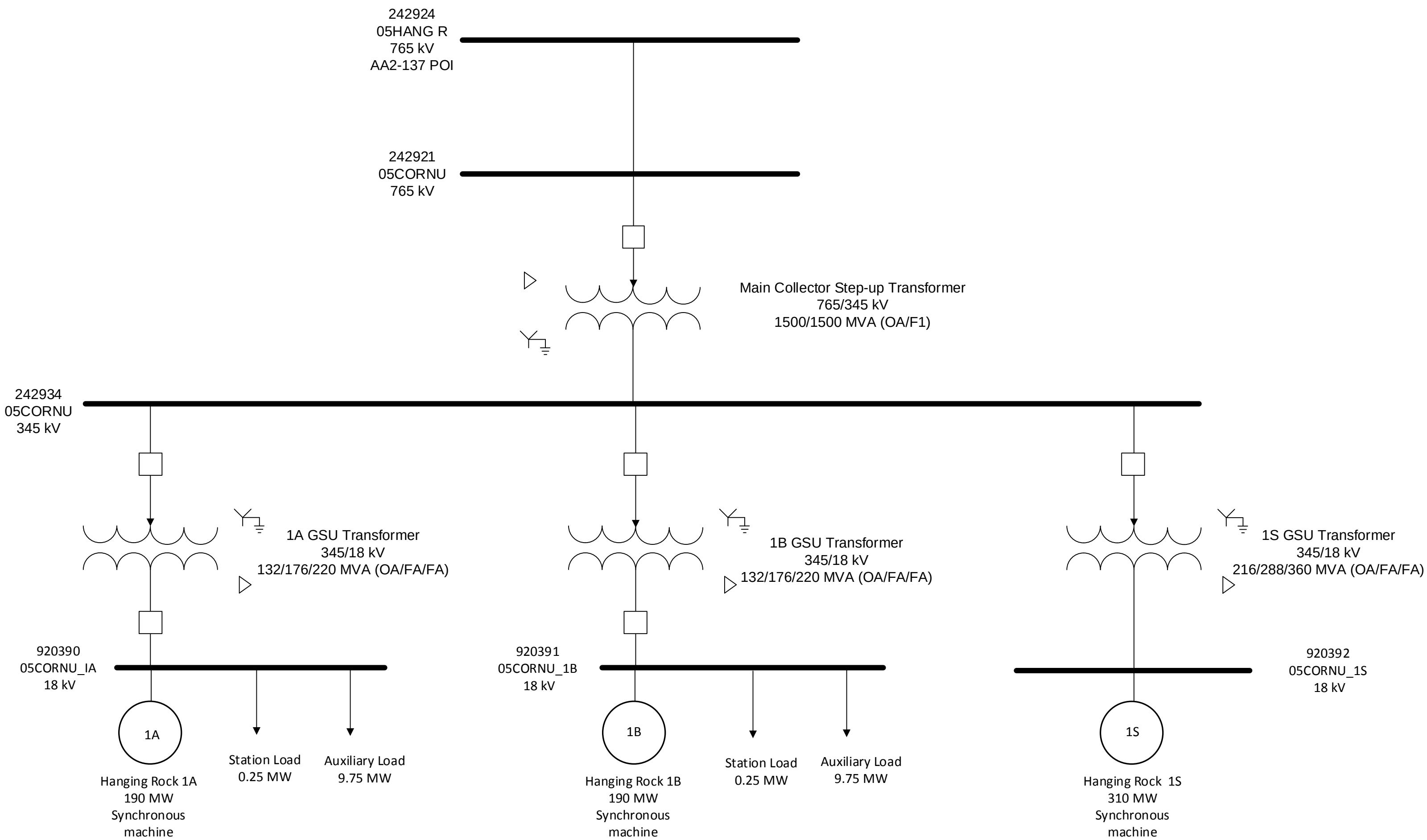

Figure 1: AA2-137 / AA2-138 Plant Model

Table 1: AA2-137 Plant Model

	Impact Study Data	Model
Combustion Turbine Generators	2 x 190 MW combustion turbine generators MVA base = 234 MVA Nominal power factor 0.85 Reactive power capability at max gross energy output: Lagging: 66 MVAr Leading -21 MVAr Unsaturated sub-transient reactance= 0.1958 pu @ MVA base	2 x 190 MW combustion turbine generators Pgen 190 MW Pmax 190 MW Pmin 0 MW Qgen -1.6 MVAr Qmax 66 MVAr Qmin -21 MVAr Mbase 234 MVA Zsource 0.0031 + j0.1958 pu @ MVA base
Steam Turbine Generator	1 x 310 MW steam turbine generator. MVA base = 373 MVA Nominal power factor 0.85 Reactive power capability at max gross energy output: Lagging: 139 MVAr Leading -68 MVAr Unsaturated sub-transient reactance = 0.2505 pu @ MVA base	1 x 310 MW steam turbine generator Pgen 310 MW Pmax 310 MW Pmin 0 MW Qgen -1.6 MVAr Qmax 139 MVAr Qmin -68 MVAr Mbase 373 MVA Zsource 0.0032 + j0.2505 pu @ MVA base

Combustion Turbine Generator GSU Transformers	2 x 345/18 kV YNd Rating = 132/176/220 MVA (OA/FA/FA) Transformer base = 132 MVA Impedance CTG 1A = j 0.0908 pu @ MVA base CTG 1B = j 0.0909 pu @ MVA base Number of taps = 5 Tap step size = 2.5%	2 x 345/18 kV Rating = 132/176/220 MVA Transformer base = 132 MVA Impedance CTG 1A = j 0.0908 pu @ MVA base CTG 1B = j 0.0909 pu @ MVA base Number of taps = 5 Tap step size = 2.5%

Table 2: AA2-137 Plant Model (continued)

Steam Turbine Generator GSU Transformer	1 x 345/18 kV YNd Rating = 216/288/360 MVA (OA/FA/FA) Transformer base = 216 MVA Impedance = j 0.0925 pu @ MVA base Number of taps = 5 Tap step size = 2.5%	1 x 345/18 kV Rating = 216/288/360 MVA Transformer base = 216 MVA Impedance = j 0.0925 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Collector step-up transformer	Information not complete*	1 x 765/345 kV YNd Rating = 1500/1500 MVA Transformer base = 100 MVA Impedance = 0.00007 + j00872 @ system Mbase Number of taps = 33 Tap step size = 0.625%
Auxiliary Load	19.5 MW	9.75 MW at each CT generator bus
Station Load	0.5 MW	0.25 MW at each CT generator bus

*See Section 2 "AA2-137-1-0 Dynamic Model Report"

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 AA2-137 / AA2-138.

b) Addition of AA2-137 / AA2-138 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AA2-137 / AA2-138.

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

The AA2-137 / AA2-138 initial conditions are listed in Table 2, indicating maximum power output, leading power factor and 0.95 pu voltage at each generator terminal.

Table 3: AA2-137 / AA2-138 machine initial conditions

Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
920390	AA2-137 CT1	1A	190 MW	-18 MVAr	0.9500 pu	1.006 pu
920391	AA2-137 CT2	1B	190 MW	-18 Mvar	0.9500 pu	
920392	AA2-137 ST	1S	310 MW	-26 Mvar	0.9500 pu	
920400	AA2-138 CT1	2A	190 MW	-18 MVAr	0.9500 pu	
920401	AA2-138 CT2	2B	190 MW	-18 Mvar	0.9500 pu	
920402	AA2-138 ST	2S	310 MW	-26 Mvar	0.9500 pu	

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AA2-137 / AA2-138 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AA2-137 / AA2-138 is given in Attachment 5.

[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

Tables 4 to 6 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 10 second simulation time interval. The studied contingencies include:

a) Steady state operation (20 second simulation);

b) Three phase faults with normal clearing time;

c) Single-phase faults with stuck breaker;

No single-phase faults with delayed (Zone 2) clearing were required to be studied for the 765 kV circuits with dual communications installed.
No additional relevant bus or tower contingencies were identified for this study.

The contingencies listed above were applied to:

- AA2-137 / AA2-138 Hanging Rock 765 kV POI
- Jefferson 765 kV
- Don Marquis 765 kV
- John Amos 765 kV
- Baker 765 kV
- North Proctorville 765 kV

The three phase faults with normal clearing time were performed under network intact conditions.
Clearing times listed in Tables 5 to 6 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 AA2-137 / AA2-138, 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 AA2-137 / AA2-138 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 AA2-137 / AA2-138, 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:

c) The system with AA2-137 / AA2-138 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

d) AA2-137 / AA2-138 is able to ride through faults (except for faults where protective action trips AA2-137 / AA2 – 138).

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Table 4 through Table 6.

All 51 fault contingencies tested on the 2019 light load case met the recovery criteria:

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

b) AA2-137 / AA2-138 generator was able to ride through all faults (except for faults where protective action trips AA2-137 / AA2-138).

No mitigations were found to be required.

Table 4: Steady State Operation

Fault ID	Duration	AA2-137 / AA2-138 No Mitigation
SS01	Steady state 20 sec	Stable

Table 5: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-137 / AA2-138 No Mitigation
3N.01	Fault at AA2-137 / AA2-138 765 kV POI on AA2-137 / AA2-138 circuit (trips AA2-137 / AA2-138).	4.5	Stable
3N.02	Fault at Hanging Rock 765 kV on Jefferson circuit.	4.5	Stable
3N.03	Fault at Hanging Rock 765 kV on Don Marquis circuit.	4.5	Stable
3N.04	Fault at Hanging Rock 765 kV on North Proctorville—John Amos circuit.	4.5	Stable
3N.05	Fault at Hanging Rock 765 kV on Baker circuit.	4.5	Stable
3N.06	Fault at Jefferson 765 kV on Hanging Rock circuit.	4.5	Stable
3N.07	Fault at Jefferson 765 kV on Rockport circuit.	4.5	Stable
3N.08	Fault at Jefferson 765 kV on Greentown circuit.	4.5	Stable
3N.09	Fault at Jefferson 765 kV on Jefferson 765/345 kV 7500 MVA Transformer T-2.	4.5	Stable
3N.10	Fault at Don Marquis 765 kV on Hanging Rock circuit.	4.5	Stable
3N.11	Fault at Don Marquis 345 kV on 765/345 kV 10000 MVA Transformer T-1	4.5	Stable
3N.12	Fault at Don Marquis 345 kV on 345/138 kV 1450 MVA Transformer T-2.	4.5	Stable
3N.13	Fault at Don Marquis 345 kV on Bixby circuit.	4.5	Stable
3N.14	Fault at Don Marquis 345 kV on Killen circuit.	4.5	Stable
3N.15	Fault at North Proctorville 765 kV on Hanging Rock—North Proctorville—John Amos circuit.	4.5	Stable
3N.16	Fault at North Proctorville 765 kV on Proctorville 765/138 kV 600 MVA Transformer T-1.	4.5	Stable
3N.17	Fault at John Amos 765 kV on Hanging Rock circuit.	4.5	Stable
3N.18	Fault at John Amos 765 kV on Culloden circuit.	4.5	Stable
3N.19	Fault at John Amos 765 kV on Mountaineer circuit.	4.5	Stable
3N.20	Fault at John Amos 765 kV on John Amos 765/345 kV 1500 MVA Transformer T-5.	4.5	Stable
3N.21	Fault at Baker 765 kV on Hanging Rock circuit.	4.5	Stable
3N.22	Fault at Baker 765 kV on Broadford circuit.	4.5	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-137 / AA2-138 No Mitigation
3N.23	Fault at Baker 765 kV on Culloden circuit.	4.5	Stable
3N.24	Fault at Baker 765 kV on Baker 765/345 kV 1500 MVA Transformer T-100.	4.5	Stable
3N.25	Fault at Jefferson 765 kV on Sullivan circuit.	4.5	Stable

Table 6: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-137 / AA2-138 No Mitigation
1B.01	Fault at Hanging Rock 765 kV on Jefferson circuit. Hanging Rock "D1" breaker stuck. Fault cleared with the loss of AA2-137 / AA2-138 circuit.	4.5 / 12	Stable
1B.02	Fault at Hanging Rock 765 kV on Don Marquis circuit. Hanging Rock "B1" breaker stuck. Fault cleared with the loss of AA2-137 / AA2-138.	4.5 / 12	Stable
1B.03	Fault at Hanging Rock 765 kV on Don Marquis circuit. Hanging Rock "B" breaker stuck. Fault cleared with the loss of Baker circuit.	4.5 / 12	Stable
1B.04	Fault at Hanging Rock 765 kV on North Proctorville—John Amos circuit. Hanging Rock "C1" breaker stuck. Fault cleared with the loss of AA2-137 / AA2-138.	4.5 / 12	Stable
1B.05	Fault at Hanging Rock 765 kV on Baker circuit. Hanging Rock "B" breaker stuck. Fault cleared with loss of Don Marquis circuit.	4.5 / 12	Stable
1B.06	Fault at Jefferson 765 kV on Greentown circuit. Jefferson "A" breaker stuck. Fault cleared with loss of Hanging Rock circuit.	4.5 / 12	Stable
1B.07	Fault at Jefferson 765 kV on Rockport circuit. Jefferson "B" breaker stuck. Fault cleared with loss of 765/345 kV 7500 MVA Transformer T-2.	4.5 / 12	Stable
1B.08	Fault at Jefferson 765 kV on Sullivan circuit. Jefferson "D" breaker stuck. Fault cleared with loss of 765/345 kV 7500 MVA Transformer T-2.	4.5 / 12	Stable
1B.09	Fault at Don Marquis 345 kV on 765/345 kV 10000 MVA Transformer T-1. Don Marquis "E1" breaker stuck. Fault cleared with loss of 345/138 kV 1450 MVA Transformer T-2.	4.5 / 15	Stable
1B.10	Fault at Don Marquis 345 kV on Bixby 345 kV circuit. Don Marquis "D1" breaker stuck. Fault cleared with loss of 345/138 kV 1450 MVA Transformer T-2.	4.5 / 15	Stable
1B.11	Fault at Don Marquis 345 kV on Bixby 345 kV circuit. Don Marquis "D" breaker stuck. Fault cleared with loss of Killen circuit.	4.5 / 15	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-137 / AA2-138 No Mitigation
1B.12	Fault at John Amos 765 kV on Mountaineer circuit. John Amos “U1” breaker stuck. Fault cleared with loss of John Amos 765/138 kV 750 MVA Transformer T-6.	4.5 / 12	Stable
1B.13	Fault at John Amos 765 kV on Mountaineer circuit. John Amos “U” breaker stuck. Fault cleared with loss of Hanging Rock circuit.	4.5 / 12	Stable
1B.14	Fault at John Amos 765 kV on Culloden circuit. John Amos “S” breaker stuck. Fault cleared with loss of 800 MW G1.	4.5 / 12	Stable
1B.15	Fault at John Amos 765 kV on Culloden circuit. John Amos “S2” breaker stuck. Fault cleared with loss of John Amos 765/345 kV 1500 MVA Transformer T-5.	4.5 / 12	Stable
1B.16	Fault at John Amos 765 kV on 765/345 kV Transformer T-5. John Amos “S2” breaker stuck. Fault cleared with loss of Culloden circuit.	4.5 / 12	Stable
1B.17	Fault at John Amos 765 kV on 765/345 kV Transformer T-5. John Amos “T2” breaker stuck. Fault cleared with loss of 1300 MW generation.	4.5 / 12	Stable
1B.18	Fault at John Amos 765 kV on 765/345 kV Transformer T-5. John Amos “U2” breaker stuck. Fault cleared with loss of Hanging Rock circuit.	4.5 / 12	Stable
1B.19	Fault at Baker 765 kV on Culloden circuit. Baker “Q” breaker stuck. Fault cleared with loss of Hanging Rock circuit.	4.5 / 12	Stable
1B.20	Fault at Baker 765 kV on Culloden circuit. Baker “P1” breaker stuck. Fault cleared with loss of Broadford circuit.	4.5 / 12	Stable
1B.21	Fault at Baker 765 kV on Broadford circuit. Baker “P1” breaker stuck. Fault cleared with loss of Culloden circuit.	4.5 / 12	Stable
1B.22	Fault at Baker 765 kV on 765/345 kV 1500 MVA Transformer T-100. Baker “P2” stuck. Fault cleared with loss of Broadford circuit.	4.5 / 12	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AA2-137 / AA2-138 No Mitigation
1B.23	Fault at Baker 765 kV on 765/345 kV 1500 MVA Transformer T-100. Baker “Q2” stuck. Fault cleared with loss of Hanging Rock circuit.	4.5 / 12	Stable
1B.24	Fault at Don Marquis 345 kV on Killen 345 kV circuit. Don Marquis “D2” breaker stuck. Fault cleared with loss of 345/138 kV 1450 MVA Transformer T-3.	4.5 / 15	Stable
1B.25	Fault at Don Marquis 345 kV on Kyger Creek 345 kV circuit. Don Marquis “B1” breaker stuck. Fault cleared with loss of 345/138 kV 1450 MVA Transformer T-2.	4.5 / 15	Stable
1B.26	Fault at Jefferson 765 kV on 765/345 kV 7500 MVA Transformer T-2 circuit. Fault cleared with loss of Hanging Rock circuit.	4.5 / 12	Stable

Attachment 1. Impact Study Data

Attachment 2. AEP One Line Diagram

Attachment 3. PSS/E Model One Line Diagram

Attachment 4. AA2-137 / AA2-138 PSS/E Dynamic Model

Attachment 5. AA2-137 / AA2-138 PSS/E Case Dispatch

Attachment 6. Plots from Dynamic Simulations