Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AC2-066

Hillcrest 138 kV

March 2018

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

Hillcrest Solar 1, LLC ("Interconnection Customer") has proposed an uprate to prior queue project AB1-014 solar generation facility located on 4313 County Road B-C in Mount Orab, Brown County, Ohio. The increased capability associated with this queue request AC2-066 is achieved by adding more solar panels and supporting facilities to prior request AB1-014.

The following table shows the MW net contributions of each inverter to the Maximum Facility Output (MFO) at the Point of Interconnection:

	Queue No.	Total # of Inverters	MW/Inverter	Total MW
	AC2-066	38	1.97	75
	AB1-014	59	2.1	125
Total MFO MW				200

The following table shows the MW net contributions of each inverter to the total Capacity Interconnection Rights (CIR) at the Point of Interconnection:

	Queue No.	Total # of Inverters	MW/Inverter	Total MW
	AB2-066	38	0.75	28.5
	AB1-014	59	0.81	47.5
Total CIR MW				76.0

The proposed in-service date for the AC2-066 project is October 31, 2019. **This study does not imply a Duke Energy ("Transmission Owner") commitment to this in-service date.**

Point of Interconnection

This project will interconnect with the Duke Energy transmission system by direct injection into Hillcrest Substation 138 kV bus. Please refer to Appendix 2 for a one-line diagram of the system configuration.

Costs Summary and Transmission Owner Scope of Work

There are no additional network upgrades and hence no costs associated with this AC2-066 queue request. All costs for attachment facilities and network upgrades necessary to support the Hillcrest 138 kV project are contained in the AB1-014 study reports and agreements which are published on PJM website at the following links:

Document Type	**Link at PJM website**
System Impact Study Report	https://www.pjm.com/pub/planning/project-queues/impact_studies/ab1014_imp.pdf
Facilities Study Report	https://www.pjm.com/pub/planning/project-queues/facilities/ab1014_fac.pdf
Interconnection Service Agreement (ISA) **	https://www.pjm.com/pub/planning/project-queues/isa/ab1_014_isa.pdf
Interconnection Construction Service Agreement (ICSA)	https://www.pjm.com/pub/planning/project-queues/csa/ab1_014_csa.pdf

** Please Note: This ISA may be superseded in the future if the AC2-066 project receives an ISA.

Interconnection Customer Requirements

Interconnection Customer will be required to engineer, procure, and construct the connecting circuit from the Interconnection Customer's substation to the Point of Interconnection. This includes, but is not limited to, an underground circuit from the Interconnection Customer's substation, a structure near the Hillcrest 138 kV substation where the circuit will transition from underground to overhead, and a switch mounted on the structure.

In addition, Interconnection Customer will be responsible for meeting all criteria as specified in the applicable sections of the Duke Energy "Requirements for Connection of Facilities to the Duke Energy MIDWEST Transmission System" document, Version 6, effective January 31, 2014, which can be found under this link:

http://www.pjm.com/~/media/planning/plan-standards/deok/deok-facility-connection-requirements.ashx.

Revenue Metering and SCADA Requirements

PJM Requirements

The Interconnection Customer will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for IC's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

Duke Energy Requirements

The Interconnection Customer will be required to comply with all Duke Energy Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the "Requirements for Connection of Facilities to the Duke Energy MIDWEST Transmission System" document, Version 6, effective January 31, 2014.

Network Impacts

The Queue Project AC2-066 was evaluated as a 75.0 MW (Capacity 28.5 MW) injection into the Hillcrest 138 kV substation in the DEOK area. Project AC2-066 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC2-066 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2020

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

None

Short Circuit

None

Delivery of Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed, which will study all overload conditions associated with the overloaded element(s) identified.

None

Light Load Analysis - 2020

Not Required

System Reinforcements

Short Circuit

No new breakers to be over-duty.

Stability and Reactive Power Requirement

No mitigation required. Please refer to Appendix 3 for stability report (or dynamic simulation study report).

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

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

None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

None

Light Load Load Flow Analysis Reinforcements

New System Reinforcements

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

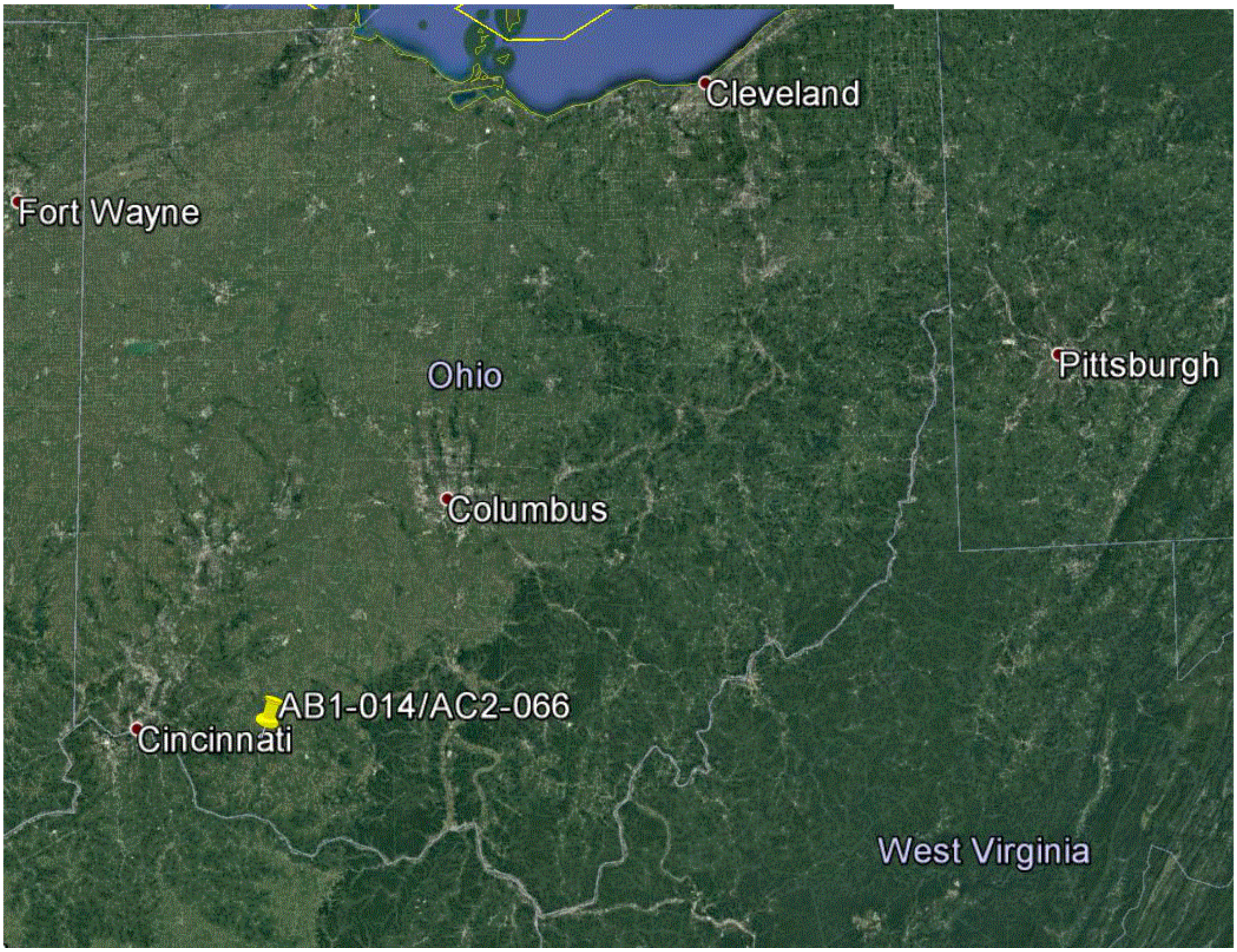
None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

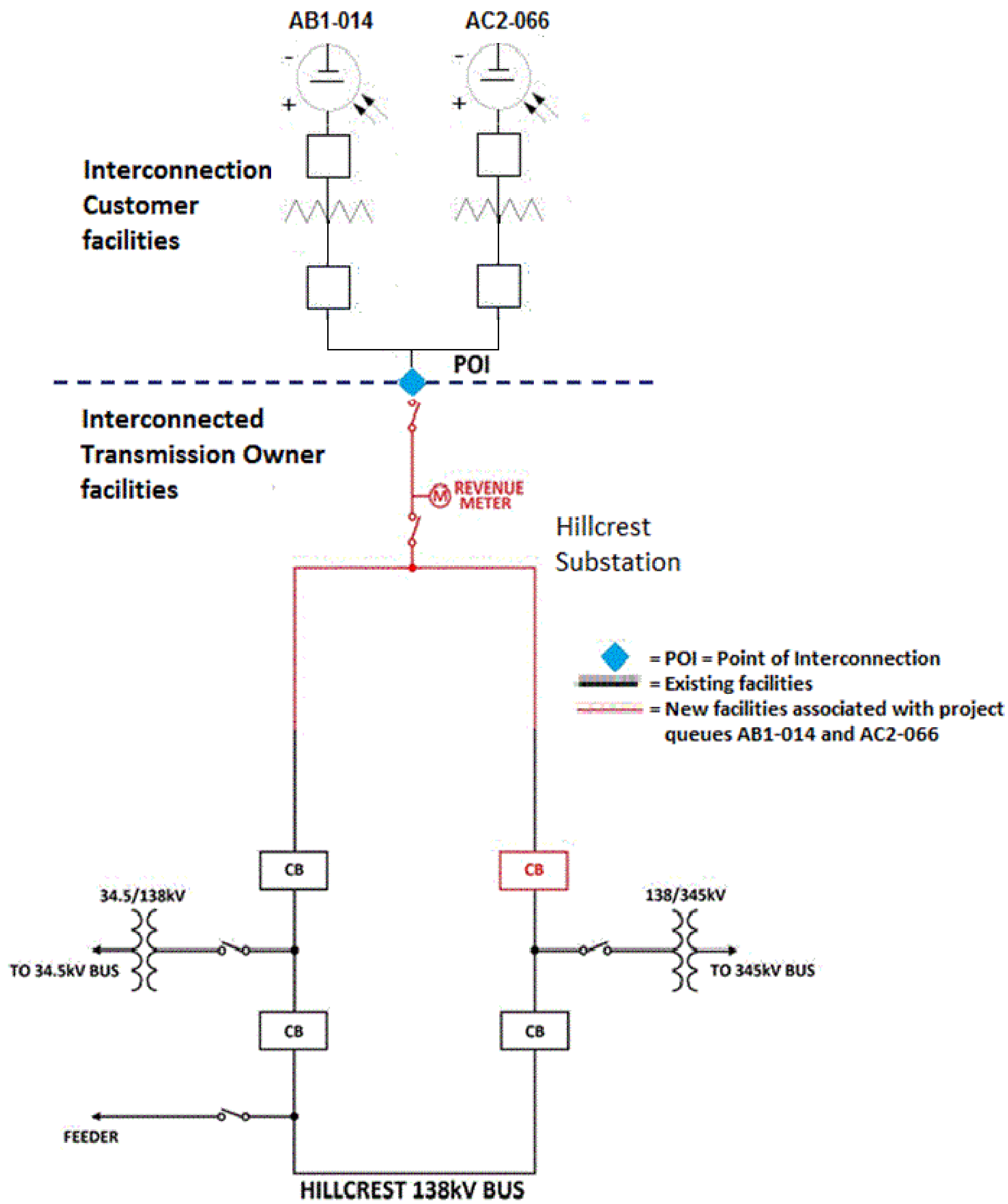
None

Appendix 1
Facility Location
PJM Queue Position: AC2-066



Appendix 2

Interconnection One-Line Diagram
PJM Queue Position: AC2-066



Appendix 3

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Executive Summary

Generator Interconnection Request AC2-066 is for an increase in energy injection capability of solar photovoltaic generating facility interconnection request AB1-014. The uprate increases the Maximum Facility Output (MFO) of the plant from 125 MW to 200 MW. AC2-066 consist of 38 x SMA Sunny Central 2200-US 2.0 MW inverters. AC2-066 has a Point of Interconnection (POI) at Hillcrest 138 kV substation in the Duke Energy transmission system, Brown County, Ohio.

This report describes a dynamic simulation analysis of AC2-066 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 summer peak case, modified to include applicable queue projects. AC2-066 has been dispatched online at maximum power output, with unity power factor and 1.0 pu voltage at the generator bus.

AC2-066 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 39 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;
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 faults with loss of multiple-circuit bus contingency

No relevant Bus or High Speed Reclosing (HSR) contingencies were identified.

For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.

For the remaining fault contingencies tested on the 2020 summer peak case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3%.
a) The AC2-066 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

No mitigations were found to be required.

Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Introduction

Generator Interconnection Request AC2-066 is for an increase in energy injection capability of solar photovoltaic generating facility interconnection request AB1-014. The uprate increases the Maximum Facility Output (MFO) of the plant from 125 MW to 200 MW. AC2-066 consist of 38 x SMA Sunny Central 2200-US 2.0 MW inverters. AC2-066 has a Point of Interconnection (POI) at Hillcrest 138 kV substation in the Duke Energy transmission system, Brown County, Ohio.

This analysis is effectively a screening study to determine whether the addition of AC2-066 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AC2-066 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.

Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Description of Project

Generator Interconnection Request AC2-066 is for an increase in energy injection capability of solar photovoltaic generating facility interconnection request AB1-014. The uprate increases the Maximum Facility Output (MFO) of the plant from 125 MW to 200 MW. AC2-066 consist of 38 x SMA Sunny Central 2200-US 2.0 MW inverters. AC2-066 has a Point of Interconnection (POI) at Hillcrest 138 kV substation in the Duke Energy transmission system, Brown County, Ohio.

Figure 1 shows the simplified one-line diagram of the AC2-066 loadflow model. Table 1 summarizes the uprate changes between AC2-066 and AB1-014. Table 2 lists the parameters given in the impact study data and the corresponding parameters of the AC2-066 loadflow model.

The dynamic model for the AC2-066 plant is based on the SMASC_C126 PSS/E user defined model supplied by PJM, as indicated by the developer in the System Impact Study Data Form.

Table 1: Uprate change in MW

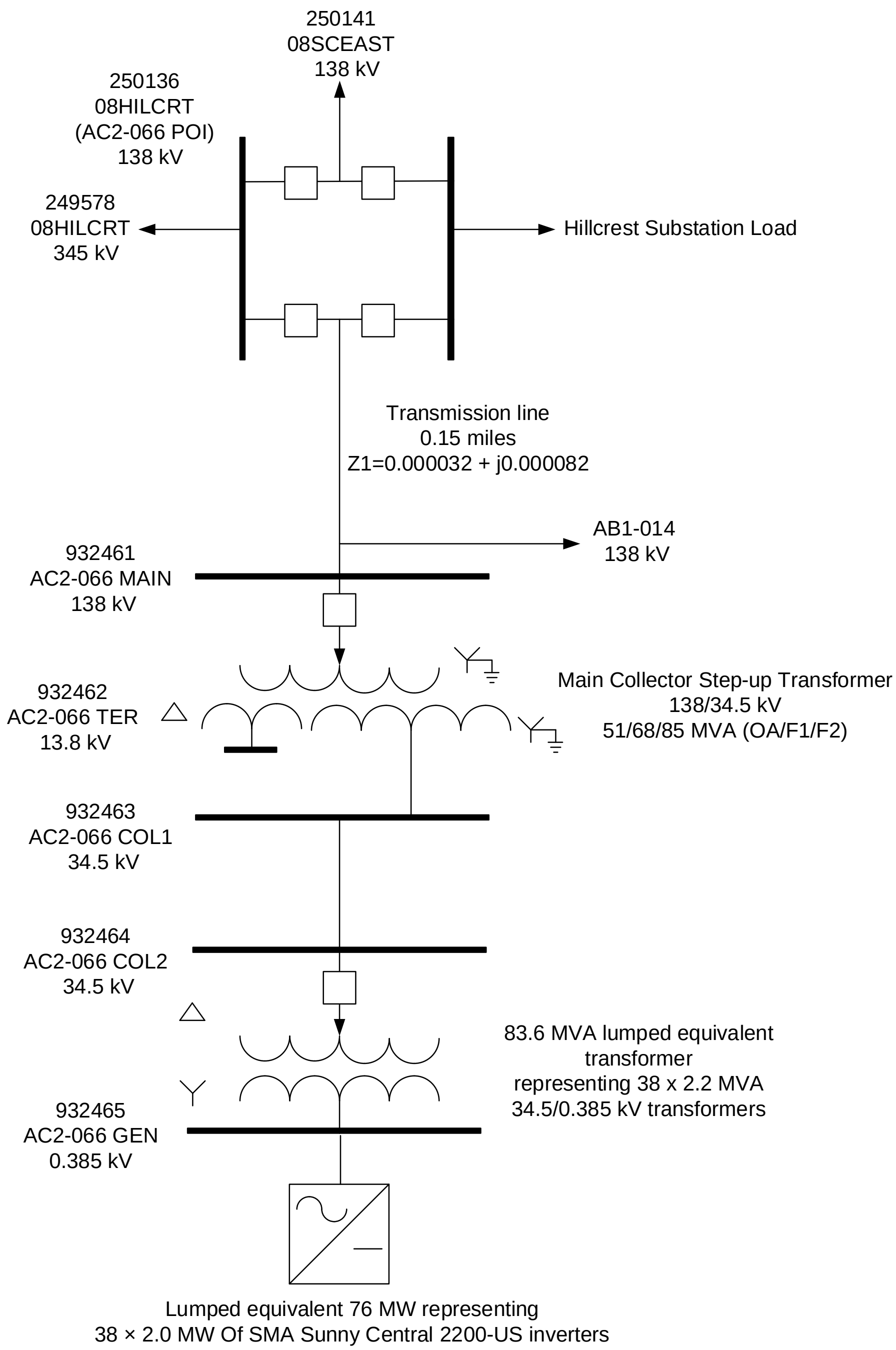
Queue project	Gross Output / MW	Increased Generation Due to
AB1-014	125	Original
AC2-066	75	Adding 38 more SMA Sunny Central 2200-US 2.0 MW inverters.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Project Description (Continued)

Figure 1: AC2-066 Plant Model



Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Project Description (Continued)

Table 1: AC2-066 Plant Model

	Impact Study Data	**Model**
Inverters	38 x SMA Sunny Central 2200-US 2.0 MW inverters MVA base = 2.2 MVA Vt = 0.385 kV Unsaturated sub-transient reactance = N/A	Lumped equivalent representing 38 x Sunny Central 2200-US 2.0 MW inverters Pgen 76.0 MW Pmax 76.0 MW Pmin 0 MW Qmax 25.0 MVAr Qmin -25.0 MVAr Mbase 83.6 MVA Zsorce[1] j10000 pu @ Mbase
GSU Transformers	38 x 34.5/0.385 kV two winding transformers Rating = 2.2 MVA (OA) Transformer base = 2.2 MVA Impedances @ MVA base High to Low = 0.007132 + j0.057056 pu Number of taps = N/A Tap step size = N/A	Lumped equivalent representing 38 x 34.5/0.385 kV 2.2 MVA transformers Rating = 83.6 MVA (OA) Transformer base = 83.6 MVA Impedances @ MVA base High to Low = 0.007132 + j0.057056 pu Number of taps = 5 Tap step size = 2.5 %

[1] Obtained from “SMASC_C126_PSSE.pdf”

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Project Description (Continued)

Table 2: AC2-066 Plant Model (Continued)

Collector Transformer	1 x 138/34.5/13.8 kV three winding transformer Rating = 51/68/85 MVA (OA/F1/F2) Transformer Base = 51 MVA Impedances @ MVA base High to Low = 0.003102 + j0.089947 pu High to Tertiary = 0.004960 + j0.143920 pu Low to Tertiary = 0.001550 + j0.044970 pu Number of taps = N/A Tap step size = N/A	1 x 138/34.5/13.8 kV three winding transformer Rating = 51/68/85 MVA (OA/F1/F2) Transformer base = 51 MVA Impedances @ MVA base High to Low = 0.003102 + j0.089947 pu High to Tertiary = 0.004960 + j0.143920 pu Low to Tertiary = 0.001550 + j0.044970 pu Number of taps = 5 Tap step size = 2.5 %
Auxiliary Load	0.0 MW + 0.0 MVAR	Not modeled
Station Load	0.0 MW + 0.0 MVAR	Not modeled
Transmission Line	Length = 0.15 miles Voltage = 138 kV MVA base = 100 Impedance = 0.000032 + j0.000082 Susceptance = 0.000020	Length = 0.15 miles Voltage = 138 kV MVA base = 100 Impedance = 0.000032 + j0.000082 Susceptance = 0.000020

Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.

The load flow scenario and fault cases for this study are based on PJM's Regional Transmission Planning Process[2].

The selected load flow scenario is the RTEP 2020 summer peak case with the following modifications:

a) Addition of all applicable queue projects prior to AC2-066.

b) Addition of AC2-066 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AC2-066.

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

The AC2-066 initial conditions are listed in Table 3, indicating maximum power output, with AC2-066 at unity power factor at the generator bus.

Table 3: AC2-066 machine initial conditions

Bus	Name	Unit	PGEN (MW)	QGEN (MVAR)	ETERM (p.u.)	POI Voltage (p.u.)
930061	AB1-014-GEN 0.3850	1	126	0	0.96	0.97
932465	AC2-066 GEN 0.3850	1	76	13	1.00	0.97

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AC2-066 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AC2-066 is given in Attachment 5.

[2] Manual 14B: PJM Region Transmission Planning Process, Rev 33, May 5 2016, Attachment G : PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Fault Cases

Tables 3 to 8 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;

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 faults with loss of multiple-circuit bus contingency

No relevant Bus or High Speed Reclosing (HSR) contingencies were identified.

Buses at which the faults listed above will be applied are

- Hillcrest 138 kV (AC2-066 138 kV POI)
- Eastwood 138 kV
- Hillcrest 345 kV
- Foster 345 kV

The three phase faults with normal clearing time were performed under network intact conditions.

Additional delayed (Zone 2) clearing at remote and faults will be applied on lines from Ford 138 kV, Brown 138 kV and Stuart 345 kV towards the queue project.

Clearing times listed in Tables 3 to 8 are as per Revision 18 of "*2016 Revised Clearing times for each PJM company"* spreadsheet.

Attachment 2 contains the one-line diagrams of the DEOK network in the vicinity of AC2-066, 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 AC2-066 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Evaluation Criteria

This study is focused on AC2-066, 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 AC2-066 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

b) The AC2-066 is able to ride through faults (except for faults where protective action trips AC2-066).

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.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Table 3 through Table 8.

For the remaining fault contingencies tested on the 2020 summer peak case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3%.
b) The AC2-066 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 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.

No mitigations were found to be required.

Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Table 4: Steady State Operation

Fault ID	Duration	AC2-066 No Mitigation
SS.01	Steady state 20 sec	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Table 5: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AC2-066 No Mitigation
3N.01	Fault at Hillcrest 138 kV (AC2-066 POI) on AC2-066 circuit (trips AC2-066, AB1-014).	4	Stable
3N.02	Fault at Hillcrest 138 kV on Hillcrest 345/138kV Transformer 21.	4	Stable
3N.03	Fault at Hillcrest 138 kV on Hillcrest 138/34.5kV Transformer 1.	4	Stable
3N.04	Fault at Hillcrest 138 kV on SCP East – EastWood circuit 8887.	4	Stable
3N.05	Fault at Eastwood 138 kV on Ford Circuit 8481.	4	Stable
3N.06	Fault at Eastwood 138 kV on Brown Circuit 5884.	4	Stable
3N.07	Fault at Eastwood 138 kV on Eastwood 138/33kV Transformer 2.	4	Stable
3N.08	Fault at Hillcrest 345 kV on Foster Circuit 34569.	3	Stable
3N.09	Fault at Hillcrest 345 kV on Stuart Circuit 4511.	3	Stable
3N.10	Fault at Hillcrest 345 kV on Hillcrest 345/138kV Transformer 21.	3	Stable
3N.11	Fault at Ford 138 kV on Eastwood Circuit 8481.	4	Stable
3N.12	Fault at Ford 138 kV on Cedarville Circuit 2986.	4	Stable
3N.13	Fault at Brown 138 kV on Stuart Circuit 5886.	4	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Table 6: Single-phase Faults With Stuck Breaker

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AC2-066 No Mitigation
1B.01	Fault at Hillcrest 138 kV (AC2-066 POI) on AC2-066 circuit. Breaker stuck to AC2-066. (Trips AC2-066, AB1-014). Fault cleared without additional losses	4 / 17	Stable
1B.02	Fault at Hillcrest 138 kV on AC2-066 circuit. Breaker CB803 stuck. Fault cleared with loss of Hillcrest 138/34.5kV Transformer 1. (trips AC2-066, AB1-014).	4 / 17	Stable
1B.03	Fault at Hillcrest 138 kV on AC2-066 circuit. Breaker AC2-066 stuck. Fault cleared with loss of Hillcrest 345/138kV 21 Transformer. (Trips AC2-066, AB1-014).	4 / 17	Stable
1B.04	Fault at Hillcrest 138 kV on Hillcrest load at Hillcrest. Breaker CB805 stuck. Fault cleared with loss of SCP East – Eastwood 8887 and Eastwood – Ford Circuit 8481.	4 / 17	Stable
1B.05	Fault at Hillcrest 138 kV on SCP East – Eastwood Circuit 8887. Breaker CB817 stuck. Fault cleared with loss of SCP East – Eastwood 8887 and Eastwood – Ford Circuit 8481, Hillcrest 345/138 kV transformer 21. (trips AB1-014, AC2-066)	4 / 17	Stable
1B.06	Fault at Hillcrest 138 kV on Hillcrest 345/138 kV 21 transformer. Breaker CB817 stuck. Fault cleared with loss of SCP East – Eastwood 8887, Eastwood – Ford Circuit 8481 and Hillcrest 345/138 kV transformer 21. (trips AB1-014, AC2-066)	4 / 17	Stable
1B.07	Fault at Eastwood 138kV on SCP East – Eastwood Circuit 8887. Breaker CB859 stuck. Fault cleared with loss Ford circuit 8481.	4 / 17	Stable
1B.08	Fault at Eastwood 138kV on SCP East – Eastwood Circuit 8887. Breaker CB860 stuck. Fault cleared with loss Eastwood transformer 2.	4 / 17	Stable
1B.09	Fault at Eastwood 138kV on Ford circuit 8481. Breaker 859 stuck. Fault cleared with loss of SCP East – Hillcrest circuit 8887. CB 860, 805, 817, 920, 936	4 / 17	Stable
1B.10	Fault at Eastwood 138kV on Brown circuit 5884. Breaker CB 861 stuck. Fault cleared with loss of Eastwood transformer 2.	4 / 17	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Table 7: Single-phase Faults With Stuck Breaker (Continued)

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AC2-066 No Mitigation
1B.11	Fault at Eastwood 138kV on Eastwood Transformer 2. Breaker CB 861 stuck. Fault cleared with loss of Eastwood – Brown circuit 5884. CB860, 842	4 / 17	Stable
1B.12	Fault at Hillcrest 345kV on Hillcrest 345/138 kV 21 transformer. Breaker 1425 stuck. Fault cleared with loss of Foster circuit 34569.	3 / 10	Stable
1B.13	Fault at Hillcrest 345kV on Stuart circuit 4511. Breaker 1423 stuck. Fault cleared with loss of Hillcrest 345/138 kV 21 transformer.	3 / 10	Stable
1B.14	Fault at Hillcrest 345kV on Foster circuit 34569. Breaker 1425 stuck. Fault cleared with loss of Hillcrest 345/138 kV 21 transformer.	3 / 10	Stable
1B.15	Fault at Ford 138kV on Eastwood circuit 8481. Breaker CB 920 stuck. Fault cleared with loss of Cedarville circuit 2986.	4 / 17	Stable
1B.16	Fault at Ford 138kV on Cedarville circuit 2986. Breaker CB 920 stuck. Fault cleared with loss of Eastwood circuit 8481.	4 / 17	Stable
1B.17	Fault at Brown 138kV on Eastwood circuit 5884. Breaker CB 842 stuck. Fault cleared with loss of Brown load.	4 / 17	Stable
1B.18	Fault at Brown 138kV on Stuart circuit 5886. Breaker CB 839 stuck. Fault cleared with loss of Brown load.	4 / 17	Stable

Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Table 8: Single-phase Faults With Delayed (Zone 2) Clearing at line end closest to AC2-066 POI

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AC2-066 No Mitigation
1D.01	Fault at 80% of 138 kV line from Hillcrest to SCP East – Eastwood 8887. Delay at Hillcrest.	4 / 33	Stable
1D.02	Fault at 80% of 138 kV line from Eastwood to Ford circuit 8481. Delay at Eastwood	4 / 33	Stable
1D.03	Fault at 80% of 138 kV line from Eastwood to Brown 5884. Delay at Eastwood.	4 / 33	Stable
1D.04	Fault at 80% of 138 kV line from Ford to Cedarville circuit 2986. Delay at Ford.	4 / 33	Stable
1D.05	Fault at 80% of 138 kV line from Brown to Stuart 5884. Delay at Brown.	4 / 33	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AC2-066

Table 9: Single phase Faults With Loss of Multiple-Circuit Tower Line

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AC2-066 No Mitigation)
1T.01	Fault at Foster 345kV on Foster circuit 34569 resulting in tower failure. Fault cleared with loss of Foster – Bath 345 kV circuit 34598. CONTINGENCY 'C5 34569FOSTERHILLCREST34598FOSTERBATH'	3 / 3	Stable
1T.02	Fault at Foster 345kV on Foster circuit 34569 resulting in tower failure. Fault cleared with loss of Foster – Sugar Creek 345 kV circuit 4524. CONTINGENCY 'C5 34569FOSTERHILLCREST4524FOSTRSUGRCRK'	3 / 3	Stable

Table 8: Single phase Faults With Loss of Multiple-Circuit Bus Contingencies

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	AC2-066 No Mitigation
1S.01	Bus fault at Brown 138kV. Fault cleared with loss of Brown 138/69/34.5 kV Transformer T1, Brown – Stuart 138 kV circuit 5886 and Brown – Eastwood 138 kV circuit 5884. CONTINGENCY 'C1 BROWN'	4 / 4	Stable