Generation Interconnection Combined Feasibility and System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD1-060

Mercersburg - Milnor 34.5 kV

April 2018

Preface

The intent of the Combined Feasibility and 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, if any, is included in the System Impact Study.

The Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. Interconnection Customer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs associated with them will be addressed when seeking an Interconnection Agreement as outlined below. Interconnection Customer will also be responsible for providing and installing metering equipment in compliance with applicable PJM and Transmission Owner standards.

General

Orion Solar Northeast, LLC ("Interconnection Customer") has proposed a new solar generation facility of 15 MW Maximum Facility Output in the West Penn Power zone ("Transmission Owner"). PJM recognizes 5.7 MW as Capacity Interconnection Rights. The facility is located in Franklin County, Pennsylvania, GPS coordinates: 39.8091290, -77.8128840. The proposed in-service date for this project is September 1, 2021. **This study does not imply a West Penn Power commitment to this in-service date.**

Please Note: Interconnection Customer informed PJM that AD1-060 is a qualifying facility (QF) as defined by the FERC at this link: https://www.ferc.gov/industries/electric/gen-info/qual-fac/what-is.asp; Hence, the Agreement associated with this project will be an Interconnection Service Agreement (ISA).

Point of Interconnection ("POI")

Customer Interconnection facilities will interconnect with West Penn Power subtransmission system by tapping the Mercersburg – Milnor 34.5 kV line at a point located approximately 5.6 miles from Mercersburg substation and 5.4 miles from Milnor substation. Please refer to Appendix 2 for one-line diagram of system configuration.

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Costs Summary and Transmission Owner Scope of Work

West Penn Power facilities and network upgrades required to support AD1-060 project are:

(a) Attachment Facilities: $0.0

(b) Direct Connection Network Upgrades:

PJM Network Upgrade Number: N5575.
Construct AD1-060 line tap, Install 2 34.5 kV line switches, Install single 34.5 kV tap switch, and provide revenue metering package.....**$62,500**

(c) Non-Direct Connection Network Upgrades:

PJM Network Upgrade Number: N5576.
Adjust remote end relay settings at Milnor and Mercersburg Substations.....**$12,700**

(d) Direct Connection Local Upgrades: $0.0

(e) Non-Direct Connection Local Upgrades: $0.0

(f) Option to Build Upgrades: $0.0

Estimated Total Costs (a) to (f): ***$75,200***

NOTE: Contribution in Aid of Construction (CIAC) Federal Income Tax Gross Up charge will be charge if this project does not meet the eligibility requirements of IRS Notice 88-129.

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Interconnection Customer Requirements

In addition to the West Penn Power facilities, Interconnection Customer is responsible for meeting all criteria as specified in the applicable sections of the FirstEnergy "Requirements for Transmission Connected Facilities" document, effective 10-3-2016, which can be found under this link: http://www.pjm.com/~/media/planning/plan-standards/private-fe/fcr-facilities-connection-requirements.ashx, including:

1. Interconnection Customer is required to install generation lead line facilities from the AD1-060 generation site to the Point of Interconnection as shown in the single line diagram in Appendix 2.
2. The purchase and installation of a fully rated circuit breaker on the high side of the AD1-060 step-up transformer.
3. The purchase and installation of a lockable switch at the point of interconnection. This switch must be accessible by First Energy.
4. The purchase and installation of the minimum required FirstEnergy generation interconnection relaying and control facilities. This includes over/under voltage protection, over/under frequency protection, and zero sequence voltage protection relays.
5. The purchase and installation of a 34.5 kV interconnection metering instrument transformer. West Penn Power will provide the ratio and accuracy specifications based on the customer load and generation levels.
6. The purchase and installation of a revenue class meter for each unit to measure the power delivered in compliance with the FirstEnergy standards.
7. The purchase and installation of supervisory control and data acquisition (SCADA) equipment to provide information in a compatible format to the FirstEnergy Transmission System Control Center. The RTU, the communications channel and all related equipment will be furnished and maintained by the Interconnection Customer. The RTU must communicate with the FirstEnergy EMS via DNP 3.0 protocol.
8. The establishment of dedicated communication circuits for SCADA report to the FirstEnergy Transmission System Control Center.
9. A compliance with the FirstEnergy and PJM generator power factor and voltage control requirements.
10. The execution of a back-up service agreement to serve the customer load supplied from the Mercersburg – Milnor 34.5 kV Line when the units are out-of-service.
11. The proposed interconnection facilities must be designed in accordance with the FirstEnergy "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx
12. Interconnection Customer must meet all PJM, ReliabilityFirst and NERC reliability criteria and operating procedures for standards compliance. For example, Hecate Energy LLC will need to properly locate and report the over and under voltage and over and under frequency system protection elements for its units as well as the submission of the generator model and protection data required to satisfy the PJM and ReliabilityFirst audits. Failure to comply

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with these requirements may result in a disconnection of service if the violation is found to compromise the reliability of the FirstEnergy system.

13. System Protection Requirements: Interconnection Customer must design it's facilities in accordance with all applicable standards, including the standards in FirstEnergy's "Requirements for Transmission Connected Facilities" document which can be found at above stated link. A detailed protection specification will be provided once the project enters the construction phase. Remote end relay settings at Milnor, Mercersburg, and Route 16 will need to be reviewed, and revised if necessary, to ensure coordination with the Interconnection Customer's relaying on the customer breaker protecting the tap line at the point of interconnection. Also, anti-islanding equipment will not be required at any FirstEnergy substation, provided the Interconnection Customer's inverters are UL 1741 certified to provide a means to automatically cease exporting power within 2 seconds of disconnection from the FirstEnergy network. If this condition is not met, anti-islanding equipment will be required at the Interconnection Customer's expense.
14. Reactive Power Requirements: Interconnection Customer shall design its non-synchronous Customer Facility with the ability to maintain a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs) measured at the high-side of the facility substation transformer(s) connected to the FirstEnergy transmission system.
15. Right of Way (ROW) Requirements: Interconnection Customer is responsible for obtaining their own Right of Way for their facilities. Using existing ROW of installed FirstEnergy facilities is not permitted. For example: Interconnection Customer is not allowed to build over existing FirstEnergy distribution/subtransmission/transmission lines to get from the generation site to the Point of Interconnection.

The above requirements are in addition to any metering required by PJM.

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 Interconnection Customer's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

FirstEnergy Requirements

The Interconnection Customer will be required to comply with all FirstEnergy Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the "FirstEnergy Requirements for Transmission Connected Facilities" document located at the following links:

http://www.firstenergycorp.com/feconnect
http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx

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Schedule

Based on the scope of the attachment facilities, direct and non-direct system upgrades, it is expected to take twelve (12) months from the date of a fully executed Interconnection Construction Service Agreement and the occurrence a Construction Kick off Meeting to complete the installation. This includes a full payment for the work that is related to this interconnection project. It also assumes that the Interconnection Customer will provide the property for the Project direct connection facilities and all right-of-way, permits, easements, etc. that will be needed. A further assumption is that there will be no environmental issues with any of the new properties associated with this project, that there will be no delays in acquiring the necessary permits for implementing the defined direct connection facilities and that transmission system outages will be possible when requested.

Network Impacts

The Queue Project AD1-060 was evaluated as a 15.0 MW (Capacity 5.7 MW) injection at the Route 16 34.5kV substation in the APS area. Project AD1-060 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD1-060 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2021

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

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Short Circuit

None, no newly over-dutied breakers were identified.

Short Circuit Data 34.5 kV at proposed new delivery point			
100 MVA Base in P.U.		**Symmetric A-phase Current in Amperes**	
Z1	Z0	3 Phase to Gnd. Fault	Phase to Gnd. Fault
0.0566+ j0.2682	0.0598 + j0.5624	6,104	4,445

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 - 2021

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

System Reinforcements

Short Circuit

None

Stability and Reactive Power Requirement

None

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)

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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

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Appendix 1

Facility Location
PJM Queue Position: AD1-060

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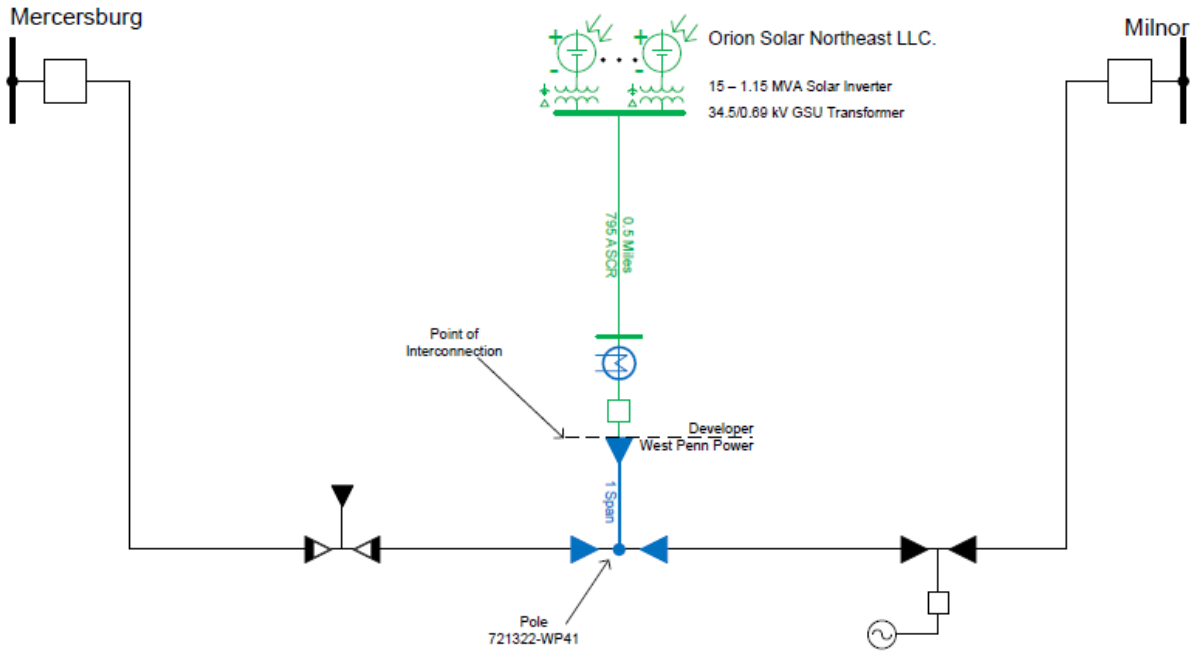
Appendix 2

Interconnection One-Line Diagram
PJM Queue Position: AD1-060



AD1-060 Direct Connect:

- Install 34.5 kV Line Tap at Pole 721322-WP41
- Install 2 Manual 34.5 kV Line Switches
- Install 1 Span of 336 AAC 34.5 kV Conductor
- Install Manual 34.5 kV Tap Switch
- Provide 34.5 kV Meter Package

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Appendix 3

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

Executive Summary

Generator Interconnection Request AD1-020 project is for a 100 MW Maximum Facility Output (MFO) solar and energy storage powered generating facility with a Point of Interconnection (POI) on Hunterstown – Lincoln 115kV line in the MAIT system, Adams County, PA.
This report describes a dynamic simulation analysis of AD1-020 as part of the overall system impact study.
The load flow scenario for the analysis was based on the RTEP 2021 summer peak case, modified to include applicable queue projects. AD1-020 has been dispatched online at maximum power output, with approximately unity power factor at the POI.
The AD1-020 queue project was tested for compliance with NERC, PJM and other applicable criteria. The range of contingencies evaluated was limited to that necessary to assess compliance and each was limited to a 20-second simulation time period.

Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Operating of a line section w/o a fault, Single-line-to-ground (slg) on Bus Section and Breaker. (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis. In this study, P2 contingencies are not applicable.

Other applicable criteria tested include:

1. Transmission Owner (TO) specific criteria
2. Other criteria

The system was tested for a system intact condition and the fault types listed above. Specific fault descriptions and breaker clearing times used for this study are provided in the result table. Relevent High Speed Reclosing (HSR) contingencies were identified in the P1 contingency list table.
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 fault contingencies tested on the 2021 summer peak case:

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

b) The AD1-020 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.

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

1. Introduction

Generator Interconnection Request AD1-020 project is for a 100 MW Maximum Facility Output (MFO) solar and energy storage powered generating facility with a Point of Interconnection (POI) on Hunterstown – Lincoln 115kV line in the MAIT system, Adams County, PA.
This analysis is effectively a screening study to determine whether the addition of AD1-020 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.
In this report the AD1-020 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.

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

2. Description of the Project

Generator Interconnection Request AD1-020 project is for a 100 MW Maximum Facility Output (MFO) solar and energy storage powered generating facility with a Point of Interconnection (POI) on Hunterstown – Lincoln 115kV line in the MAIT system, Adams County, PA.
Figure 1 shows the simplified one-line diagram of the AD1-020 loadflow model. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AD1-020 loadflow model.
The dynamic models for AD1-020 plant are based on the SMASCS, SMASC_135, and SMAPPC_111 PSS/E version 33 user models supplied by the developer.

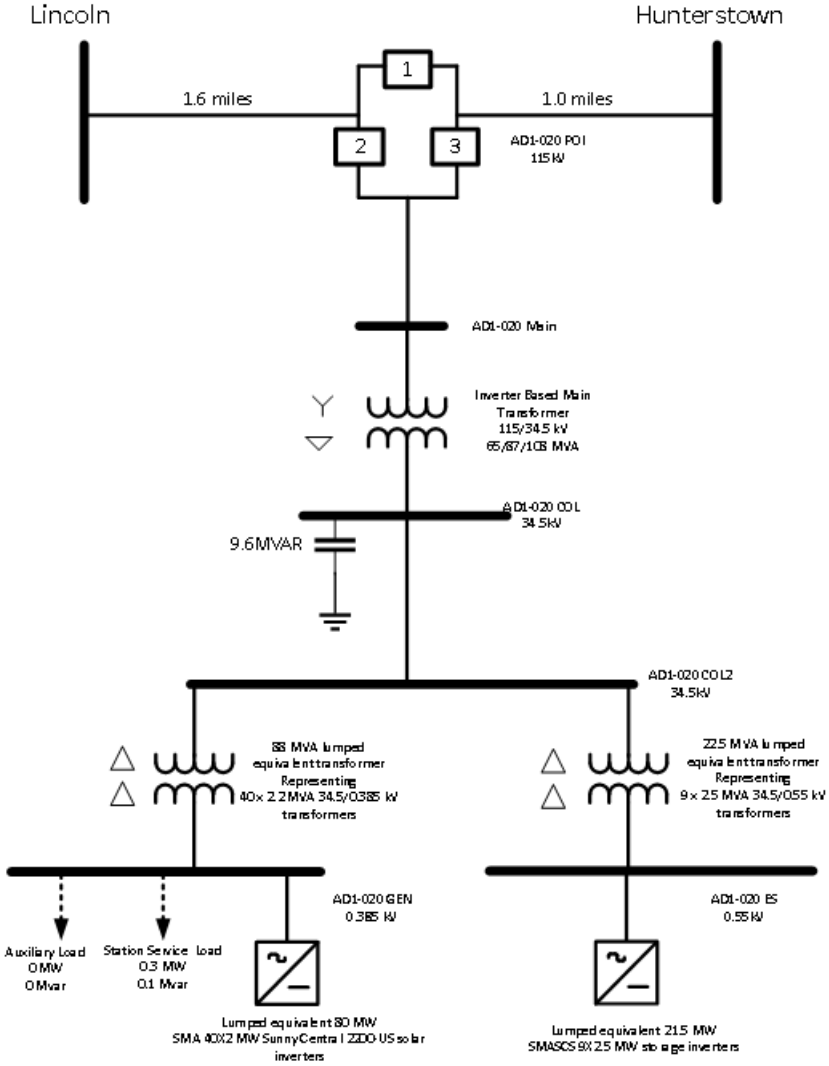

Figure 1: AD1-020 Plant Model

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

Table 1: AD1-020 Plant Model

	Impact Study Data	Model
Inverter Type	40 × 2.0 MW SMASC SC2200 MVA base = 2.2 MVA Vt = 0.385 kV Unsaturated sub-transient reactance = j10000.0 pu @ MVA base 9 × 2.5 MW SMASCS MVA base = 2.5 MVA Vt = 0.55 kV Unsaturated sub-transient reactance = j10000.0 pu @ MVA base	Lumped equivalent representing 40 x 2.0 MW SMA units Pgen 80 MW Pmax 80 MW Pmin 0 MW Qmax 35 MVAr Qmin -35 MVAr Mbase 88 MVA Zsorce j10000.0 pu @ Mbase Lumped equivalent representing 9 x 2.5 MW SMA units Pgen 21.5 MW Pmax 21.5 MW Pmin 0 MW Qmax 5 MVAr Qmin -5 MVAr Mbase 22.5 MVA Zsorce j10000.0 pu @ Mbase
GSU transformer(s)	40 x 34.5/0.385 kV two winding transformers Rating = 2.2 MVA Transformer base = 2.2 MVA Impedance = 0.0068 + j0.0546pu @ MVA base Number of taps = N/A Tap step size = N/A 9 x 34.5/0.55 kV two winding transformers Rating = 2.5 MVA Transformer base = 2.5 MVA Impedance = 0.0068 + j0.0546pu @ MVA base Number of taps = N/A Tap step size = N/A	Lumped equivalent representing 40 x 34.5/0.385 kV two winding transformers Transformer base = 88 MVA Rating = 88 MVA Impedance = 0.0068 + j0.0546pu @ MVA base Number of taps = 5 Tap step size = 2.5% Lumped equivalent representing 9 x 34.5/0.55 kV two winding transformers Transformer base = 22.5 MVA Rating = 22.5 MVA Impedance = 0.0068 + j0.0546pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Main collector step-up transformer	1 x 115/34.5 kV two winding transformer Rating = 65/87/108 MVA Transformer base = 35 MVA Impedances High-Low = 0.003075+ j0.079941 pu High-Tert = 0.004920+ j0.127910 pu Low-Tert = 0.001540+ j0.039970 pu All impedances pu @ MVA Base Number of taps = N/A Tap step size = N/A	1 x 115/34.5/13.8 KV Three winding transformer Rating = 35/47/58 MVA Transformer base = 35 MVA Impedances High-Low = 0.003075+ j0.079941 pu High-Tert = 0.004920+ j0.127910 pu Low-Tert = 0.001540+ j0.039970 pu All impedances pu @ MVA Base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	0.0 MW, 0.0 MVAr	0.0 MW, 0.0 MVAr
Station load	0.3 MW, 0.1 MVAr	0.3 MW, 0.1 MVAr
Collector system losses	Not provided	Not modelled
Attachment line	Not provided	Not modelled

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

3. 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[1].

The selected load flow scenario is the RTEP 2021 summer peak case with the following modifications:

a) Addition of all applicable queue projects prior to AD1-020.

b) Addition of AD1-020 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AD1-020.

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

The AD1-020 initial conditions are listed in Table 2, indicating maximum power output with regulating to unity power factor at the POI bus.

Table 2: AD1-020 machine initial conditions

Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
933974	AD1-020 GEN 0.3800	1	80.0	4.3	1.04	1.02
933975	AD1-020 ES 0.5500	1	21.5	4.3	1.04	1.02

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AD1-020 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AD1-020 is given in Attachment 3.

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

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

4. Fault Cases

Tables 3 listed the contingencies and results that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 20 second simulation time interval.

Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Operating of a line section w/o a fault, Single-line-to-ground (slg) on Bus Section and Breaker. (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis. In this study, P2 contingencies are not applicable.

Other applicable criteria tested include:

1. Transmission Owner (TO) specific criteria
2. Other criteria

The system was tested for a system intact condition and the fault types listed above. High Speed Reclosing (HSR) contingencies in the vinicity area were studied and the HSR time is also included in the P1 fault list.

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

5. Evaluation Criteria

This study is focused on AD1-020, 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 AD1-020 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%

b) The AD1-020 is able to ride through faults (except for faults where protective action trips AD1-020).

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.

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 4, with results summarized in Table 3.

Frequency protection in the model is disabled due to the deficiency of PSSE frequency calculation for inverter based generation facilities.

For the studied fault contingencies tested on the 2021 summer peak case:

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

b) The AD1-020 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.

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Appendix 3 (Continued)
Dynamic Simulation Analysis (Stability Study)
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7. System Reinforcement Requirements

None.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

Table 3 (P0): Steady State Operation

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

Table 4 (P1): Three-Phase Faults with Normal Clearning

Fault ID	Fault description	Clearing Time Normal & HSR (Cycles)	Results
P1.00	3PG @ AC2-053 Main – Germantown 115kV line with normal clearing, trip the generator	7	Stable
P1.01	3PG @ Germantown – Straban – Lincoln 115kV line with normal clearing	7	Stable
P1.02	3PG @ Germantown 115/138kV TF with normal clearing loss of Germantown – TaneyTown – Carrol 138kV line	7	Stable
P1.03	3PG @ Hunterstown – Oxford – North Hanover 115kV line with normal clearing	7/43	Stable
P1.04	3PG @ Hunterstown – Hamilton 115kV line with normal clearing	7/25	Stable
P1.05	3PG @ Hunterstown – Texas E Tap – Gardners 115kV with normal clearing	7	Stable
P1.06	3PG @ Hunterstown – AD1-020 POI 115kV line with normal clearing	7/25	Stable
P1.07	3PG @ Hunterstown 115/230kV T4 with normal clearing	7	Stable
P1.08	3PG @ Hunterstown 115/230kV TF with normal clearing	7	Stable
P1.09	3PG @ Hunterstown – Jackson 230kV line with normal clearing	5	Stable
P1.10	3PG @ Hunterstown 230/500kV T1 with normal clearing	5	Stable
P1.11	3PG @ Lincoln – Straban – Germantown 115kV line with normal clearing	7/43	Stable
P1.12	3PG @ Lincoln – AD1-020 POI 115kV line with normal clearing	7/25	Stable
P1.13	3PG @ Lincoln – Lincoln Tap – Orrtanna – Hunterstown 115kV with normal clearing loss of Orrtanna unit	7	Stable
P1.14	3PG @ Carrol – Taneytown – Germantown 138kV with normal clearing loss of Germantown 138/115kV TF	12	Stable
P1.15	3PG @ Carrol 138/230kV TF with normal clearing	12	Stable
P1.16	3PG @ Carrol – Catoctin 138kV line with normal clearing	12	Stable
P1.17	3PG @ Carrol – Lehigh 138kV line with normal clearing	12	Stable
P1.18	3PG @ Carrol 138/34.5kV TF #1, normal clear loss of Carrol – Taneytown – Germantown 138kV line and Germantown 138/115kV TF, Carrol – Catoctin 138kV line	12	Stable
P1.19	3PG @ Carrol 138/34.5kV TF #3, normal clear loss of Carrol 138/230kV TF and Carrol – Lehigh 138kV line, Carrol 138kV capacitor	12	Stable
P1.20	3PG @ AD1-020 POI – Lincoln 115kV line with normal clearing	7/25	Stable
P1.21	3PG @ AD1-020 POI – Hunterstown 115kV line with normal clearing	7/25	Stable
P1.22	3PG @ AD1-020 POI – AD1-020 Main 115kV line with normal clearing, loss of AD1-020	7	Stable

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
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Table 4 (P4): Single Line to Ground Fault w. Stuck Breaker (SB) Faults at Backup Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P4.01	SLG at Hunterstown – Hamilton 115kV line, SB @ Hunterstown 115kV, loss of Hunterstown – AD1-020 115kV line, Hunterstown units, Hunterstown 230/115kV Tx4	7/20	Stable
P4.02	SLG at Hunterstown – Oxford – North Hanover 115kV line, SB @ Hunterstown 115kV, loss of Hunterstown – Texas E Tap – Gardners 115kV line, Hunterstown – Orrtanna – Lincoln 115kV line, Hunterstown 230/115kV Tx 5	7/20	Stable
P4.03	SLG at Hunterstown 230/115kV Tx4, SB @ Hunterstown 115kV, loss of Hunterstown – AD1-020 115kV line, Hunterstown – Hamilton 115kV line, Hunterstown units	7/20	Stable
P4.04	SLG at Hunterstown – Texas E Tap – Gardners 115kV line, SB @ Hunterstown 115kV, loss of, Hunterstown – Orrtanna – Lincoln 115kV line, Hunterstown – Oxford – North Hanover 115kV line, Hunterstown 230/115kV Tx 5	7/20	Stable
P4.05	SLG at Hunterstown – AD1-020 115kV line, SB @ Hunterstown 115kV, loss of Hunterstown – Hamilton 115kV line, Hunterstown units, Hunterstown 230/115kV Tx4	7/20	Stable
P4.06	SLG at Hunterstown – Orrtanna – Lincoln 115kV line, SB @ Hunterstown 115kV, loss of Hunterstown – Texas E Tap – Gardners 115kV line, Hunterstown – Oxford – North Hanover 115 kV line, Hunterstown 230/115kV Tx 5	7/20	Stable
P4.07	SLG at Hunterstown 230/115kV Tx 5, SB @ Hunterstown 115kV, loss of Hunterstown – Texas E Tap – Gardners 115kV line, Hunterstown – Oxford – North Hanover 115 kV line, Hunterstown – Orrtanna – Lincoln 115kV line	7/20	Stable
P4.08	SLG at Huneterstown 230/115kV Tx 5, SB @ Hunterstown 230kV, loss of two Hunterstown 230kV capacitors	7/16	Stable
P4.09	SLG at Huneterstown 230/115kV TF, SB @ Hunterstown 230kV, loss of Hunterstown – Jackson 230kV line	7/16	Stable
P4.10	SLG at Hunterstown – Jackson 230kV line, SB @Hunterstown 230kV, loss of Hunterstown 500/230 T1	5/16	Stable
P4.11	SLG at Huneterstown 230/115kV T4, SB 1@ Hunterstown 230kV, loss of Hunterstown 500/230 T1	7/16	Stable
P4.12	SLG at Huneterstown 230/115kV T4, SB 2@ Hunterstown 230kV, loss of two Hunterstown 230kV capacitors	7/16	Stable

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Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P4.13	SLG at Lincoln – Straban – Germantown 115kV line, SB @ Lincoln 115kV, loss of Lincoln 115kV bus	7/20	Stable
P4.14	SLG at Lincoln – Orrtanna – Hunterstown 115kV line, SB @ Lincoln 115kV, loss of Lincoln 115kV bus	7/20	Stable
P4.15	SLG at Lincoln – AD1-020 115kV line, SB @ Lincoln 115kV, loss of Lincoln 115kV bus	7/20	Stable
P4.16	SLG at Hunterstown 115kV bus #4, normal clear loss of Hunterstown – Hamilton 115kV line, Hunterstown – AD1-020 115kV line, Hunterstown units, Hunterstown 230/115kV Tx4, SB @ Hunterstown 115kV bus tie, delayed clear loss of Hunterstown 115kV bus	7/20	Stable
P4.17	SLG at Hunterstown 115kV bus #8, normal clear loss of Hunterstown – Oxford – North Hanover 115kV line, Hunterstown – Texas E Tap – Gardners 115kV line, Hunterstown – Orrtanna – Lincoln 115kV line, Hunterstown 230/115kV Tx F. SB @ Hunterstown 115kV bus tie, delayed clear loss of Hunterstown 115kV bus	7/20	Stable
P4.18	SLG at Germantown 115kV bus, delayed clear loss of AC2-053	7/20	Stable
P4.19	SLG at Carrol 138/34.5kV TF #1, normal clear loss of Carrol – Taneytown – Germantown 138kV line and Germantown 138/115kV TF, Carrol – Catoctin 138kV line, SB @ Carrol 138kV, delayed clear loss of Carrol 138kV bus	12/20	Stable
P4.20	SLG at Carrol 138/34.5kV TF #3, normal clear loss of Carrol 138/230kV TF and Carrol – Lehigh 138kV line, Carrol 138kV capacitor, SB @ Carrol 138kV, delayed clear loss of Carrol 138kV bus	12/20	Stable
P4.21	SLG at AD1-020 POI 115kV, normal clear loss of AD1-020 – Hunterstown 115kV, SB @ AD1-020 POI 115kV, delayed clear loss of AD1-020 – Lincoln 115kV, AD1-020	7/20	Stable

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

Table 5 (P5): Single Line to Ground Faults with Delayed Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P5.01	SLG fault at 80% Germantown – Straban – Lincoln 115 kV line, Germantown 115kV relay failed and delayed clearing	7/80	Stable
P5.02	SLG fault at 80% Lincoln – Straban – Germantown 115 kV line, Lincoln 115kV relay failed and delayed clearing	7/80	Stable
P5.03	SLG fault at 80% Germantown – Taneystown – Carrol 138 kV line, Germantown 138kV relay failed and delayed clearing	7/80	Stable
P5.04	SLG fault at 80% Carrol – Taneystown – Germantown 138 kV line, Carrol 138kV relay failed and delayed clearing	7/80	Stable
P5.05	SLG fault at 80% AD1-020 – Lincoln 115kV line, AD1-020 relay failed and delayed clearing	7/80	Stable
P5.06	SLG fault at 80% Lincoln – AD1-020 115kV line, AD1-020 relay failed and delayed clearing	7/80	Stable
P5.07	SLG fault at 80% AD1-020 – Hunterstown 115kV line, AD1-020 relay failed and delayed clearing	7/80	Stable
P5.08	SLG fault at 80% Hunterstown – AD1-020 115kV line, AD1-020 relay failed and delayed clearing	7/80	Stable

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

Table 6: Single-Phase Faults with Delayed (Zone2) Clearing at line end closest to AD1-060 POI

None.

Table 7: Single Line to Ground Faults with Common Structure Failure

Fault ID	Fault description	Clearing Time (Cycles)	Results
P7.01	SLG fault at Hunterstown – Hamilton 115 kV line, Common Structure failure loss of Hunterstown - Jackson 230kV line	7	Stable

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Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-060

PSS/E Dynamic Model

///Solar farm

```
933974 'USRMDL' 1 'SMAPPC111' 4 0 54 35 10 50 933973 933972 1 1
                933974 0 0 0 0 0 0 0 0 0
                0 0 0 0 0 0 0 0 0 0
                0 0 0 0 0 0 0 0 0 0
                0 0 0 0 0 0 0 0 0 0
                0 0 0 0 0 0 0 0 0 0
                1 0.5 2.0 0.04 0.0 0.0 10.0 0.04 0.0
                0.0 1.0 0.0 4.0 0.0268
                0.1 2.0 0.04 0.0 1.0 0.2 0.2
                0.8 0.70 0.70 1.20 1.20 60 1.0
                0.0 0.5 0.04 0.0 0.123 100.0 100.0/
/               CtlMod KP_PF KI_PF PFXdcrTm PFDB KP_Vol KI_Vol VolXdcrTm VolDB
/               PFNomTot VolNomTot QNomTotH VolDroop HybCtlTun
/               KP_P KI_P PXdcrTm PDB PNomTot QCommTm PCommTm
/               PFLim FRTThrVolNomMin Reserved FRTThrVolNomMax Reserved FRTHldTm Reserved
/               KP_Q KI_Q QXdcrTm QDB QNomTot PRefTot QRefTot
933974 'USRMDL' 1 'SMASC135' 1 1 0 82 20 200
                1.0 1.0 0.0 0.8 1.0 0.0 1.0 0.0 0.35
                1.0 0.0 5.0 0.5 2.0
                0.0 0.9 0.5 1.0 0.9 0.9
                1.0 0.2 0.05 0.4
                1.0 1.0 2.0 2.0 2.0 2.0 0.1 0.1 0.1 0.1 0.1 0.1
                0.01 0.0 20.0 0.01 0.2 0.0 0.0 0.0 0.125 0.1
                1.2 10.0 1.18 9.5 1.15 9.0 0.88 12.0 0.6 10.0 0.5 9.0
                65.0 0.1 64.0 1.0 61.5 3.0 59.3 5.0 57.0 3.0 50.0 0.1
                30.0 1.0 50.0 3.0 0.0 1.0 5.0 0.3 0 0 1.0 0.0/
/               PPrim PWNom QVArNom PFLIM PFPF PFPFExt QVArMod QoDEna QoDQMax
/               VArCtlVol_Volref VArCtlVol_VolDB VArCtlVol_VArGra VArCtlVol_VArMax
VArCtlVol_VArTm
/               PFPFExtStr PFPFStr PFWStr PFPFExtStop PFPFStop PFWStop
/               WCtlHzMod PHzStr PHzStop PWGra
/               WGra VArGra FRTMod FRTArGraNom FRTArGraNomHi FRTArGraNomLo FRTDbVolNomMax Reserved
FRTDbVolNomMin Reserved FRTWRcvrTmF FRTWRcvrTmP
/               VArCmdFltTm FRTPreErrVEna FRTPreErrTm FRTSwOffTm FRTAmpQGra FRTSpkMtgLo FRTSpkMtgHi VCtllCharEna
VCtlllCharTm VCtlCorTm
/               VCtlMax VCtlMaxTm VCtlhhLim VCtlhhLimTm VCtlhLim VCtlhLimTm VCtllLim VCtllLimTm VCtlllLim VCtlllLimTm
VCtlMin VCtlMinTm
/               HzCtlMax HzCtlMaxTm HzCtlhhLim HzCtlhhLimTm HzCtlhLim HzCtlhLimTm HzCtllLim HzCtllLimTm HzCtlllLim
HzCtlllLimTm HzCtlMin HzCtlMinTm
/               KPLL1 PLLFlag KPPLL2 KIPLL2 HzFltTm PLLFlag2 KPPLL3 KIPLL3 Reserved Reserved GenTrpFlag PPrioEna
```

///Energy storage SMASCS

```
/ SMA SUNNY CENTRAL STORAGE 2200 SERIRES BATTERY INVERTER MODEL
933975 'USRMDL' 1  'SMASCS'  1 1 0 117 18 100
      2200, 314, 2200, 1905, 4737, 0.001, 1, 0, 0, 1
      1, 0, 1, 0.2, 1, 1, 0, 0.5, 0.5, 1000
      1000, 1, 0.98, 0, 1.02, 2, 0, 0, 15, 15
      0, 0, 0.5, 1, 1, 0.9, 1.1, 1, 0.5, 2
      2, 2, 1, 0, 0, 2, 2, 2, 1, 2
      2, 60, 1, 60, 3000, 52.5, 1000, 55, 10000, 55
      10000, 55, 10000, 55, 10000, 55, 10000, 49, 1000, 45
      10000, 45, 10000, 45, 10000, 45, 10000, 45, 10000, 0.002
      1.15, 10000, 1.3, 10000, 2, 10000, 2, 10000, 2, 10000
      0.8, 10000, 0.45, 10000, 0, 10000, 0, 10000, 0, 10000
      5, 10000, 50.05, 49.95, 1.05, 0.95, 1, 0.1, 50, 3
      1.2, 0.8, 10, 1, 1.2, 0.8, 50/
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