Generation Interconnection

System Impact Study Report

for

Queue Project AF2-075

BARTONSVILLE-MEADOW BROOK 138 KV III

30 MW Capacity / 50 MW Energy

Rev 0: February 2021

Rev 1: March 2022

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1 Introduction

This System Impact Study has been prepared in accordance with the PJM Open Access Transmission Tariff, 205, as well as the System Impact Study Agreement between the Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is APS.

2 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.

The Interconnection Customer seeking to interconnect a wind or solar generation facility shall maintain meteorological data facilities as well as provide that meteorological data which is required per Schedule H to the Interconnection Service Agreement and Section 8 of Manual 14D.

An Interconnection Customer 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.

Revision 1 – **March 2022**
This revision is being issued to incorporate the stability results for the project.

3 General

The Interconnection Customer (IC) has proposed an uprate to a planned Solar generating facility located in Frederick, Virginia. This project is an increase to the Interconnection Customer's AE2-230/AF1-291A project, which will share the same point of interconnection. The AF2-075 queue position is a 50 MW uprate (30 MW Capacity uprate) to the previous project. The total installed facilities will have a capability of 130 MW with 78 MW of this output being recognized by PJM as Capacity. The proposed in-service date for this uprate project is December 01, 2022. This study does not imply a TO commitment to this in-service date.

Queue Number	AF2-075
Project Name	BARTONSVILLE-MEADOW BROOK 138 KV III
State	Virginia
County	Frederick
Transmission Owner	APS
MFO	130
MWE	50
MWC	30
Fuel	Solar
Basecase Study Year	2023

Any new service customers who can feasibly be commercially operable prior to June 1st of the basecase study year are required to request interim deliverability analysis.

4 Point of Interconnection

AF2-075 will interconnect with the APS transmission system as an uprate to AE2-230 & AF1-291A which is tapping the Bartonville to Meadow Brook 138 kV line. The AF2-075 project will share the same property and point of interconnection as the AE2-230 and AF1-291A projects. Interconnection of the project at the POI will be accomplished by constructing a new 138 kV three (3) breaker ring bus substation and looping the Bartonville-Meadow Brook 138 kV line into the new Long Creek substation. The new substation will be located approximately 2.2 miles from Bartonville substation.

Attachment 1 shows a one-line diagram of the proposed primary Direct Connection facilities for the AE2-230/AF1-291A/AF2-075 generation project to connect to the FirstEnergy ("FE") Transmission System.

5 Cost Summary

The AF2-075 project will be responsible for the following costs:

Description	Total Cost
Total Physical Interconnection Costs	$35,400
Total System Network Upgrade Costs (Summer Peak)	$0
Total System Network Upgrade Costs (Light Load)	$0
Total System Network Upgrade Costs (TO Identified)	$0
Total Costs	**$35,400**

*As your project progresses through the study process and other projects modify their request or withdraw, then your cost allocation could change.

This cost excludes a Federal Income Tax Gross Up charges. This tax may or may not be charged based on whether this project meets the eligibility requirements of IRS Notice 88-129. If at a future date it is determined that the Federal Income Tax Gross charge is required, the Transmission Owner shall be reimbursed by the Interconnection Customer for such taxes.

Note 1: PJM Open Access Transmission Tariff (OATT) section 217.3A outline cost allocation rules. The rules are further clarified in PJM Manual 14A Attachment B. The allocation of costs for a network upgrade will start with the first Queue project to cause the need for the upgrade. Later queue projects will receive cost allocation contingent on their contribution to the violation and are allocated to the queues that have not closed less than 5 years following the execution of the first Interconnection Service Agreement which identifies the need for this upgrade.

Note 2: For customers with System Reinforcements listed: If your present cost allocation to a System Reinforcement indicates $0, then please be aware that as changes to the interconnection process occur, such as prior queued projects withdrawing from the queue, reducing in size, etc, the cost responsibilities can change and a cost allocation may be assigned to your project. In addition, although your present cost allocation to a System Reinforcement is presently $0, your project may need this system reinforcement completed to be deliverable to the PJM system. If your project comes into service prior to completion of the system reinforcement, an interim deliverability study for your project will be required.

6 Transmission Owner Scope of Work

AF2-075 will interconnect with the APS transmission system as an uprate to AE2-230 & AF1-291A which is tapping the Bartonville to Meadow Brook 138 kV line. The AF2-075 project will share the same property and point of interconnection as the AE2-230 and AF1-291A projects. Interconnection of the project at the POI will be accomplished by constructing a new 138 kV three (3) breaker ring bus substation and looping the Bartonville-Meadow Brook 138 kV line into the new Long Creek substation. The new substation will be located approximately 2.2 miles from Bartonville substation.

The AF2-075 project would be responsible for relay setting reviews as shown in the table below. If the AE2-230 and AF1-291A projects withdraw from the interconnection queue, AF2-075 will have the responsibility for the interconnection switchyard.

The total physical interconnection costs is given in the table below:

Description	Total Cost
Review relay settings for generation increase at AE2-230/AF1-291A Generation. @ Long Creek (AE2-230_AF1-291A)	$35,400
Total Physical Interconnection Costs	$35,400

7 Schedule

Based on the scope of work for the interconnection facilities, it is expected to take a minimum of **4 months** after the signing of an Interconnection Construction Service Agreement and construction kickoff call to complete the installation. This schedule considers the AF2-075 upgrade project going into service after the new Long Creek 138 kV interconnection switchyard is in-service for AE2-230 and AF1-291A. This schedule assumes that all transmission system outages will be allowed when requested.

8 Transmission Owner Analysis

8.1 Power Flow Analysis

FE performed an analysis of its underlying transmission <100 kV system. The AE2-230/AF1-291A/AF2-075 project did not contribute to any overloads on the FE Transmission <100 kV System.

9 Interconnection Customer Requirements

9.1 System Protection

The IC must design its Customer Facilities in accordance with all applicable standards, including the standards in FE's "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx. Preliminary Protection requirements will be provided as part of the Facilities Study. Detailed Protection Requirements will be provided once the project enters the construction phase.

9.2 Compliance Issues and Interconnection Customer Requirements

The proposed Customer Facilities must be designed in accordance with FE's "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx. In particular, the IC is responsible for the following:

1. The purchase and installation of a fully rated 138 kV circuit breaker to protect the AE2-230/AF1-291A/AF2-075 generator lead line. A single circuit breaker must be used to protect this line; if the project has several GSU transformers, the individual GSU transformer breakers cannot be used to protect this line.

2. The purchase and installation of the minimum required FE generation interconnection relaying and control facilities. This includes over/under voltage protection, over/under frequency protection, and zero sequence voltage protection relays.

3. The purchase and installation of supervisory control and data acquisition ("SCADA") equipment to provide information in a compatible format to the FE Transmission System Control Center.

4. Compliance with the FE and PJM generator power factor and voltage control requirements.

5. The execution of a back-up service agreement to serve the customer load supplied from the AE2-230/AF1-291A/AF2-075 generation project metering point when the units are out-of-service. This assumes the intent of the IC is to net the generation with the load.

The IC will also be required to meet all PJM, ReliabilityFirst, and NERC reliability criteria and operating procedures for standards compliance. For example, the IC 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 with these requirements may result in a disconnection of service if the violation is found to compromise the reliability of the FE system.

9.3 Power Factor Requirements

The IC 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 FE transmission system.

10 Revenue Metering and SCADA Requirements

10.1 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 Section 8 of Attachment O.

10.2 Meteorological Data Reporting Requirements

The solar generation facility shall provide the Transmission Provider with site-specific meteorological data including:

- Back Panel temperature (Fahrenheit)
- Irradiance (Watts/meter2)
- Ambient air temperature (Fahrenheit) – (Accepted, not required)
- Wind speed (meters/second) – (Accepted, not required)
- Wind direction (decimal degrees from true north) – (Accepted, not required)

10.3 Interconnected Transmission Owner Requirements

The IC will be required to comply with all Interconnected Transmission Owner's revenue metering requirements for generation interconnection customers located at the following link:

http://www.pjm.com/planning/design-engineering/to-tech-standards/

11 Summer Peak Analysis

The Queue Project AF2-075 was evaluated as a 50.0 MW (Capacity 30.0 MW) injection as an uprate to AE2-230 & AF1-291A which is tapping the Bartonsville to Meadow Brook 138 kV line in the APS area. Project AF2-075 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AF2-075 was studied with a commercial probability of 100.0 %. Potential network impacts were as follows:

11.1 Generation Deliverability

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

None

11.2 Multiple Facility Contingency

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

None

11.3 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

11.4 Steady-State Voltage Requirements

To be determined in Facilities Study phase.

11.5 Potential Congestion due to Local Energy Deliverability

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.

Note: Only the most severely overloaded conditions are listed below. 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 shall study all overload conditions associated with the overloaded element(s) identified.

None

11.6 System Reinforcements

None

11.7 Flow Gate Details

The following indices contain additional information about each facility presented in the body of the report. For each index, a description of the flowgate and its contingency was included for convenience. The intent of the indices is to provide more details on which projects/generators have contributions to the flowgate in question. All New Service Queue Requests, through the end of the Queue under study, that are contributors to a flowgate will be listed in the indices. Please note that there may be contributors that are subsequently queued after the queue under study that are not listed in the indices. Although this information is not used "as is" for cost allocation purposes, it can be used to gage the impact of other projects/generators. It should be noted the project/generator MW contributions presented in the body of the report are Full MW Impact contributions which are also noted in the indices column named "Full MW Impact", whereas the loading percentages reported in the body of the report, take into consideration the PJM Generator Deliverability Test rules such as commercial probability of each project as well as the ramping impact of "Adder" contributions. The MW Impact found and used in the analysis is shown in the indices column named "Gendeliv MW Impact".

None

11.8 Queue Dependencies

The Queue Projects below are listed in one or more indices for the overloads identified in your report. These projects contribute to the loading of the overloaded facilities identified in your report. The percent overload of a facility and cost allocation you may have towards a particular reinforcement could vary depending on the action of these earlier projects. The status of each project at the time of the analysis is presented in the table. This list may change as earlier projects withdraw or modify their requests.

None

11.9 Contingency Descriptions

None

12 Light Load Analysis

The Queue Project AF2-075 was evaluated as a 50.0 MW injection as an uprate to AE2-230 & AF1-291A which is tapping the Bartonsville to Meadow Brook 138 kV line in the APS area. Project AF2-075 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AF2-075 was studied with a commercial probability of 100.0 %. Potential network impacts were as follows:

12.1 Light Load Deliverability

(Single or N-1 contingencies)

None

12.2 Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies)

None

12.3 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

12.4 Potential Congestion due to Local Energy Deliverability

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.

Note: Only the most severely overloaded conditions are listed below. 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 shall study all overload conditions associated with the overloaded element(s) identified.

None

12.5 System Reinforcements

None

12.6 Flow Gate Details

The following indices contain additional information about each facility presented in the body of the report. For each index, a description of the flowgate and its contingency was included for convenience. The intent of the indices is to provide more details on which projects/generators have contributions to the flowgate in question. All New Service Queue Requests, through the end of the Queue under study, that are contributors to a flowgate will be listed in the indices. Please note that there may be contributors that are subsequently queued after the queue under study that are not listed in the indices. Although this information is not used "as is" for cost allocation purposes, it can be used to gage the impact of other projects/generators. It should be noted the project/generator MW contributions presented in the body of the report are Full MW Impact contributions which are also noted in the indices column named "Full MW Impact", whereas the loading percentages reported in the body of the report, take into consideration the PJM Generator Deliverability Test rules such as commercial probability of each project as well as the ramping impact of "Adder" contributions. The MW Impact found and used in the analysis is shown in the indices column named "Gendeliv MW Impact".

None

12.7 Contingency Descriptions

None

13 Short Circuit Analysis

The following Breakers are overdutied:

None

13.1 System Reinforcements - Short Circuit

None

14 Stability and Reactive Power

Generator Interconnection Request AF2-075 is for an increase in energy injection capability of the AE2-230 and AF1-291A queue projects. The AF2-075 uprate increased the Maximum Facility Output (MFO) of the plant from 80 MW to 130 MW. AF2-075 has a Point of Interconnection (POI) connecting to the transmission line between Bartonville and Meadow Brook 138 kV in Frederick, Virginia, in the First Energy (FE) transmission system.

The power flow scenario for the analysis was based on the RTEP 2023 summer peak case, modified to include applicable queue projects. AF2-075 has been dispatched online at maximum facility output, with approximately unity power factor at the high side of the station transformer.

AF2-075 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. For this study, 103 contingencies were simulated, each with a 20 second simulation time period. Studied faults included:

- Steady-state operation (20 second simulation)
- Three-phase faults with normal clearing time
- Single-phase bus faults with normal clearing time
- Single-phase faults with a stuck breaker with delayed clearing time
- Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at remote line end because of primary communications/relaying failure
- Single-phase faults with loss of multiple circuits caused by a common tower contingency

The 103 fault contingencies tested on the 2023 summer peak case met the recovery criteria:

- The AF2-075 generator was able to ride through the faults except for faults where protective actions trip one or more generator(s).
- All generators maintained synchronism and any post-contingency oscillations are positively damped with a damping margin of at least 3%.
- All bus voltages recover to 0.7 p.u. within 2.5 seconds and the final voltages are within the steady-state voltage ranges below per FE's transmission planning criteria.
  - 500 kV Facilities: 0.97 to 1.1 p.u.
  - 345, 230, 138, and 69 kV Facilities: 0.92 to 1.05 p.u.
- No transmission element trips, other than those either directly connected or designated to trip as a consequence of the fault.

Prior to the AF2-075 uprate, a real power recovery issue at AE2-230 was observed caused by low voltages at Bartonsville 138 kV bus following an outage of the Meadow Brook to AE2-230 Tap 138 kV circuit 1. To resolve this, the Bartonsville 138 kV capacitor bank Vlo setting was increased from 0.96 p.u. to 0.98 p.u..

During the AF2-075 dynamic analysis, it was observed that the uprate resolved the real power recovery issue at AE2-230 without the need to change the Bartonsville 138 kV capacitor bank Vlo value.

The AF2-075 queue project meets both the 0.95 lagging and 0.95 leading power factor requirements.

Table 1: Power Factor Assessment for the AF2-075 Queue Project

Generator	MFO (MW)	Required Power Factor Range		Maximum Lagging (Mvar)	Minimum Leading (Mvar)
		Lagging	Leading		
AE2-230	70.00	0.95	0.95	23.01	23.01
AF1-291A	10.00	0.95	0.95	3.29	3.29
AF2-075	50.00	0.95	0.95	16.43	16.43
Total Reactive Power Required				42.73	-42.73
Reactive Power from Generator				**Qmax**	**Qmin**
				46.58	-46.58
Customer Planned Compensation				15.2	0
Reactive Power Losses				-18.04	-18.04
Total Available Reactive Power at High Side of Main Transformer				43.73	-64.62
Deficiency in Reactive Power				Meet	Meet

A power factor assessment was performed for the AF2-075 project evaluating if the plants meets PJM's power factor requirement for a non-synchronous generator. PJM requires a non-synchronous generator to provide 0.95 lagging power factor and 0.95 leading power factor measured at the high side of the station transformer for the initial interconnection and the uprates. The reactive capability curve, provided in Figure 2, was used to determine the reactive power for the AF2-075 plant. Table 2 summarizes the results for the power factor assessment for the AF2-075 queue project.

The AF2-075 queue project meets both the 0.95 lagging and 0.95 leading power factor requirements.

15 Affected Systems

15.1 NYISO

NYISO Impacts to be determined during later study phases (as applicable).

16 Attachment 1: One Line Diagram