Revised

Generation Interconnection

System Impact Study Report

for

Queue Project AE2-333

BEDINGTON 138 KV

60 MW Capacity / 100 MW Energy

February 2021

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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 **TCE Virginia Development, LLC**, the Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Allegheny Power Systems ("APS" in the Potomac Edison zone).

1 Revisions since February 2020 System Impact Study Report

The Stability Analysis section of this report has been updated to include the Executive Summary from the completed stability analysis.

The reactive power assessment for this project reveals that the project does not meet the 0.95 required lagging power factor at the high side of the main transformer. This project needs to have additional reactive power capabilities to fulfill the power factor requirement. The estimated required additional capacitive reactive power is 30.63 Mvar. The customer is responsible for this reactive power compensation. PJM will test the customer's proposed reactive solution in the Facilities Study phase to ensure the required power factor can be achieved.

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.

3 General

The Interconnection Customer (IC), has proposed a Solar generating facility located in Frederick, Maryland. The installed facilities will have a total capability of 100 MW with 60 MW of this output being recognized by PJM as Capacity. The proposed in-service date for this project is 12/01/2022. This study does not imply a TO commitment to this in-service date.

Queue Number	AE2-333
Project Name	BEDINGTON 138 KV
Interconnection Customer	TCE Virginia Development, LLC
State	Maryland
County	Frederick
Transmission Owner	APS – Potomac Edison
MFO	100
MWE	100
MWC	60
Fuel	Solar
Basecase Study Year	2022

3.1 Point of Interconnection

The interconnection of the AE2-333 project at the Primary POI will be accomplished by expanding Bedington 138 kV Substation by adding an additional breaker into the breaker-and-a-half scheme. The IC will be responsible for acquiring all easements, properties, and permits that may be required to construct the associated Attachment Facilities.

Attachment 1 shows a one-line diagram of the proposed primary Direct Connection facilities for the AE2-333 generation project to connect to the FirstEnergy ("FE") transmission system. Attachment 2 provides the proposed location for the point of interconnection. IC will be responsible for constructing all the facilities on its side of the POI, including the Attachment Facilities which connect the generator to the FE transmission system's Direct Connection facilities.

3.2 Cost Summary

The AE2-333 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$307,200
Direct Connection Network Upgrade	$0
Non Direct Connection Network Upgrades	$1,354,700
System Upgrades	$0
Total Costs	$1,661,900

The costs provided above exclude the Contribution in Aid of Construction ("CIAC") Federal Income Tax Gross Up charge. If, at a future date, it is determined that the CIAC Federal Income Tax Gross Up charge is required, the Transmission Owner shall be reimbursed by the Interconnection Customer for such taxes.

The required Attachment Facilities and Direct and Non-Direct Connection work for the interconnection of the AE2-345 generation project to the FE Transmission System is detailed in the following sections. The associated one-line with the generation project Attachment Facilities and the Primary Direct and Non-Direct Connection facilities are shown in Attachment 1.

Note: 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.

4 Transmission Owner Scope of Work

The interconnection of the project at the Primary POI will be accomplished by expanding Bedington 138 kV Substation by adding an additional breaker into the breaker-and-a-half scheme. The IC will be responsible for acquiring all easements, properties, and permits that may be required to construct the associated Attachment Facilities.

4.1 Attachment Facilities

The total preliminary cost estimate for the Attachment work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Total Cost
Attachment Facilities associated with new circuit breaker and other associated terminal equipment at Bedington Substation	$247,000
Review of customer drawings & nameplates at AE2-333	$60,200
Total Attachment Facility Costs	**$307,200**

5 Direct Connection Cost Estimate

The total preliminary cost estimate for the Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

Direct Connection Cost and Scope not required.

6 Non-Direct Connection Cost Estimate

The total preliminary cost estimate for the Non-Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Total Cost
Direct injection into Bedington Substation to interconnect queue project AE2-333. Upgrade relaying as needed to accommodate the new AE2-333 generation queue project interconnection of 100 MW MFO. Add new circuit breaker and other associated terminal equipment at Bedington Substation	$1,238,000
Estimated SCADA work at Bedington Substation to support breaker and relay installations	$53,000
Project Management	$63,700
Total Non-Direct Connection Facility Costs	$1,354,700

7 Schedule

Based on the scope of work for the Attachment Facilities and the Direct and/or Non-Direct Connection facilities, it is expected to take a minimum of 15 months after the signing of an Interconnection Construction Service Agreement to complete the installation. This includes the requirement for the IC to make a preliminary payment that compensates FE for the first three months of the engineering design work that is related to the construction of the interconnection substation. This assumes 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 and network upgrades, and that all transmission system outages will be allowed when requested.

The schedule for the required Network Impact Reinforcements will be more clearly identified in future study phases. The estimate elapsed time to complete each of the required reinforcements is identified in the "System Reinforcements" section of the report.

8 Transmission Owner Analysis

8.1 Power Flow Analysis

FE performed an analysis of its underlying transmission <100 kV system. The AE2-333 project did not contribute to any overloads on the transmission <100 kV system.

8.2 Stability Analysis

If needed, PJM will complete a dynamic stability analysis as an addendum to the Impact Study. The results of this analysis will be reviewed by FE. Should stability concerns be identified in PJM's study, FE will develop appropriate system reinforcement(s) and include the estimated cost of any reinforcement(s).

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 AE2-333 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 AE2-333 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.

10.1.1 Meteorological Data Reporting Requirement

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

- Temperature (degrees Fahrenheit)
- Atmospheric pressure (hectopascals)
- Irradiance
- Forced outage data

10.2 FirstEnergy – APS Requirements

The IC will be required to comply with all FE revenue metering requirements for generation interconnection customers which can be found in FE's "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx.

11 Network Impacts

The Queue Project AE2-333 was evaluated as a 100.0 MW (Capacity 60.0 MW) injection at the Bedington 138 kV substation in the APS area. Project AE2-333 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AE2-333 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Load Flow

12 Generation Deliverability

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

None

13 Multiple Facility Contingency

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

None

14 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

15 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

16 System Reinforcements

None.

Affected Systems

17 Affected Systems

None.

Short Circuit

18 Short Circuit

The following Breakers are overduty:

None.

Stability

19 Stability Analysis and Reactive Power Requirement

Generator Interconnection Request AE2-333 is a 100 MW photovoltaic (PV) solar generation consisting of 35 x 2.9314 MW Power Electronics FS3000-CU PV inverters. The Maximum Facility Output (MFO) for the project is 100 MW.

The Point of Interconnection (POI) of AE2-333 connects directly to the Bedington 138 kV substation in Berkeley, West Virginia, in the APS transmission system.

The power flow scenario for the analysis was based on the RTEP 2022 summer peak case, modified to include applicable queue projects. AE2-333 has been dispatched online at maximum facility output, with approximately unity power factor at the high side of the station transformer.

AE2-333 were tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. For this study, 73 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
- Single-phase faults with a stuck breaker
- Single-phase faults with delayed clearing at remote end
- Single phase faults with loss of multiple-circuit towers

The 73 fault contingencies tested on the 2022 summer peak case met the recovery criteria:

- The AE2-333 generators were 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 voltage is within the range of 0.92 p.u. to 1.05 p.u. for buses other than 500 kV. The final voltages for 500 kV buses should be within 1.02 p.u. to 1.08 p.u.
- No transmission element trips, other than those either directly connected or designated to trip as a consequence of the fault.

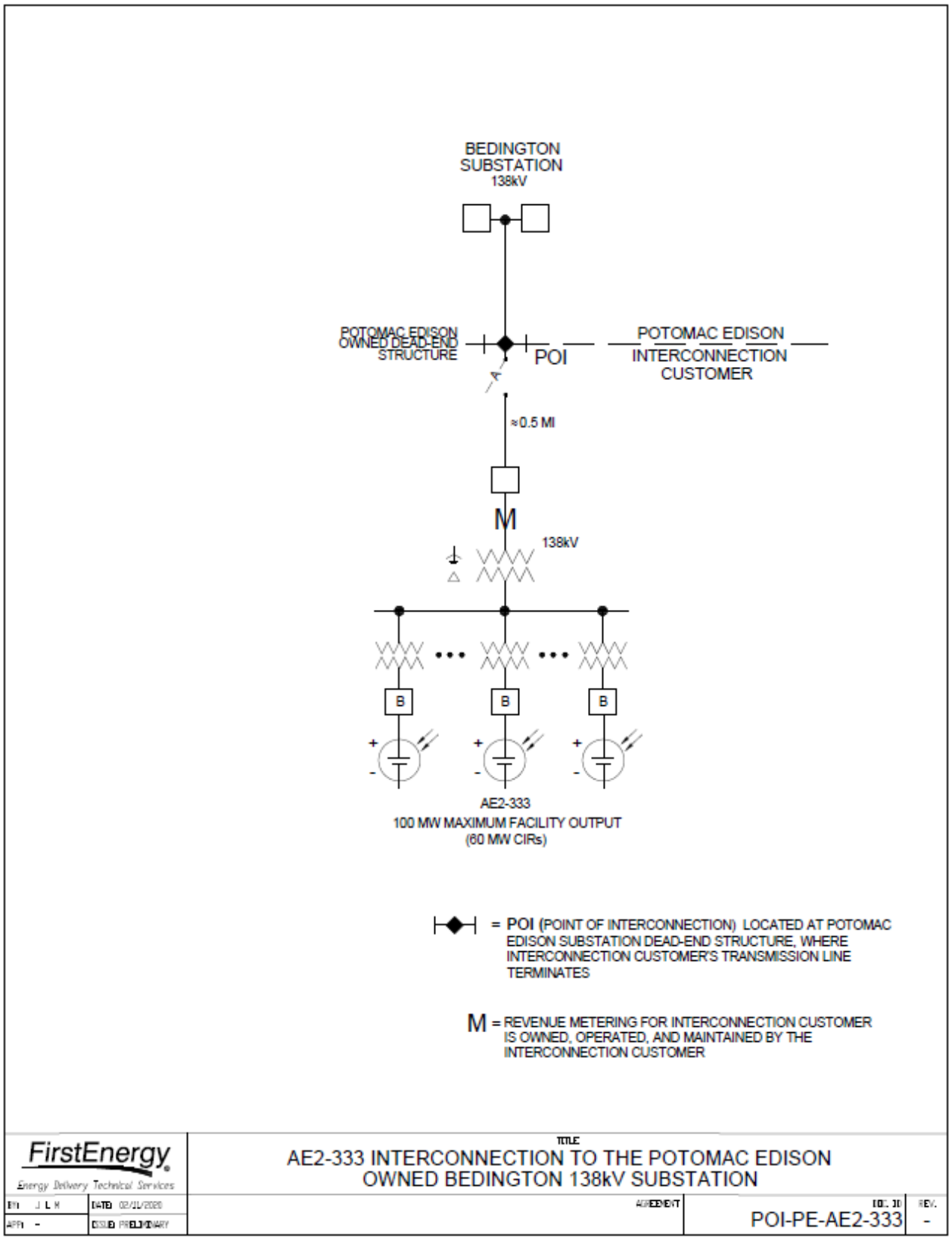
Based on the Impact Study Data provided, AE2-333 project did not meet the 0.95 lagging power factor requirement. An additional 30.63 Mvar would be required for the plant to meet the 0.95 lagging power factor requirement. The plant did meet the 0.95 leading power factor requirement.

Light Load

20 Light Load Analysis

Light Load analysis not required for solar projects.

21 Attachment One: One Line Diagram



22 Attachment Two: Project Location