Revised

Generation Interconnection

System Impact Study Report

for

Queue Project AE2-140

AXTON-DANVILLE 138 KV

120.66 MW Capacity / 201.1 MW Energy

October 2022

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1 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, a generator interconnection may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection, may also contribute to the need for the same network reinforcement. Cost allocation rules for network upgrades can be found in PJM Manual 14A, Attachment B. 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 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.

2 General

Lendlease Energy Development LLC has proposed a Solar generating facility located in Henry County, Virginia. The installed facilities will have a total capability of 201.1 MW with 120.66 MW of this output being recognized by PJM as Capacity.

The proposed in-service date for this project is 5/31/2022. This study does not imply a TO commitment to this in-service date.

Queue Number	AE2-140
Project Name	AXTON-DANVILLE 138 KV
Interconnection Customer	Lendlease Energy Development LLC
State	Virginia
County	Henry
Transmission Owner	AEP
MFO	201.1
MWE	201.1
MWC	120.66
Fuel	Solar
Basecase Study Year	2022

2.1 Point of Interconnection

AE2-140 will interconnect with the AEP transmission system via a new station cut into the Axton to Danville No.1 138kV circuit (see Figure 2).

To accommodate the interconnection on the Axton to Danville No.1 138kV Circuit, a new three (3) circuit breaker 138kV switching station physically configured in a breaker and half bus arrangement but operated as a ring-bus will be constructed (see Figure 1). Installation of associated protection and control equipment, 138 kV line risers, SCADA, and 138 kV revenue metering will also be required. AEP reserves the right to specify the final acceptable configuration considering design practices, future expansion, and compliance requirements.

2.2 Cost Summary

The AE2-140 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$ 250,000
Generator lead first span exiting the POI station, including the first structure outside the fence	$1,250,000
Direct Connection Network Upgrade	$ 6,000,000
Non Direct Connection Network Upgrades	$ 1,500,000
Total Costs	$ 9,000,000

In addition, the AE2-140 project may be responsible for a contribution to the following costs

Description	Total Cost
System Upgrades	$0

The estimates provided in this report are preliminary in nature, as they were determined without the benefit of detailed engineering studies. Final estimates will require an on-site review and coordination to determine final construction requirements. In addition, Stability analysis will be completed during the Facilities Study stage. It is possible that a need for additional upgrades could be identified by these studies.

3 Transmission Owner Scope of Work

4 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
138kV Revenue Metering	$250,000
Generator lead first span exiting the POI station, including the first structure outside the fence	$1,250,000
Total Attachment Facility Costs	$1,500,000

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.

Description	Total Cost
Construct a new three (3) circuit breaker 138 kV switching station physically configured in a breaker and half bus arrangement but operated as a ring-bus (See Figure 1). Installation of associated protection and control equipment, 138 kV line risers and SCADA will also be required.	$ 6,000,000
Total Direct Connection Facility Costs	$ 6,000,000

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
Axton – Danville No.1 138kV T-Line Cut In	$ 1,000,000
Upgrade line Protection & Controls at the Axton 138kV Substation	$ 250,000
Upgrade line Protection & Controls at the Danville 138kV Substation	$ 250,000
Total Non-Direct Connection Facility Costs	$ 1,500,000

7 Schedule

It is anticipated that the time between receipt of executed Agreements and Commercial Operation may range from 12 to 18 months if no line work is required. If line work is required, construction time would generally be between 24 to 36 months after Agreement execution.

8 Transmission Owner Analysis

Note that the City of Danville's 69kV system was not evaluated in the Feasibility Study. During the Impact Study, AEP may evaluate the City of Danville's 69kV system if impacts are anticipated. The City of Danville operates a 69 kV networked system fed from multiple AEP Delivery Points. Parallel-path flow through the Danville system is limited, but not prevented, by reverse-power relays.

9 Interconnection Customer Requirements

It is understood that Lendlease Energy Development LLC is responsible for all costs associated with this interconnection. The costs above are reimbursable to AEP. The cost of Lendlease Energy Development LLC's generating plant and the costs for the line connecting the generating plant to the Axton – Danville No.1 138kV Circuits are not included in this report; these are assumed to be Lendlease Energy Development LLC's responsibility.

The Generation Interconnection Agreement does not in or by itself establish a requirement for American Electric Power to provide power for consumption at the developer's facilities. A separate agreement may be reached with the local utility that provides service in the area to ensure that infrastructure is in place to meet this demand and proper metering equipment is installed. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

Requirement from the PJM Open Access Transmission Tariff:

1. An Interconnection Customer entering the New Services Queue on or after October 1, 2012 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.
2. The Interconnection Customer may be required to install and/or pay for metering as necessary to properly track real time output of the facility as well as installing metering which shall be used for billing purposes. See Section 8 of Appendix 2 to the Interconnection Service Agreement as well as Section 4 of PJM Manual 14D for additional information.

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 AEP Requirements

The Interconnection Customer will be required to comply with all AEP Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the "Requirements for Connection of New Facilities or Changes to Existing Facilities Connected to the AEP Transmission System" document located at the following link:

http://www.pjm.com/~/media/planning/plan-standards/private-aep/aep-interconnection-requirements.ashx

11 Network Impacts

The Queue Project AE2-140 was evaluated as a 201.1 MW (Capacity 120.7 MW) injection into a tap of the Axton Danville 138 kV line in the AEP area. Project AE2-140 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AE2-140 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 Steady-State Voltage Requirements

(Summary of the VAR requirements based upon the results of the steady-state voltage studies)

None.

17 Stability and Reactive Power Requirements for Low Voltage Ride Through

(Summary of the VAR requirements based upon the results of the dynamic studies)

See Appendix 1.

18 Light Load Analysis

Light Load Studies (applicable to wind, coal, nuclear, and pumped storage projects).

Not required

Affected Systems

19 Affected Systems

19.1 LG&E

None

19.2 MISO

None

19.3 TVA

None

19.4 Duke Energy Progress

Duke Energy Progress Impacts to be determined during later study phases (as applicable).

Short Circuit

20 Short Circuit

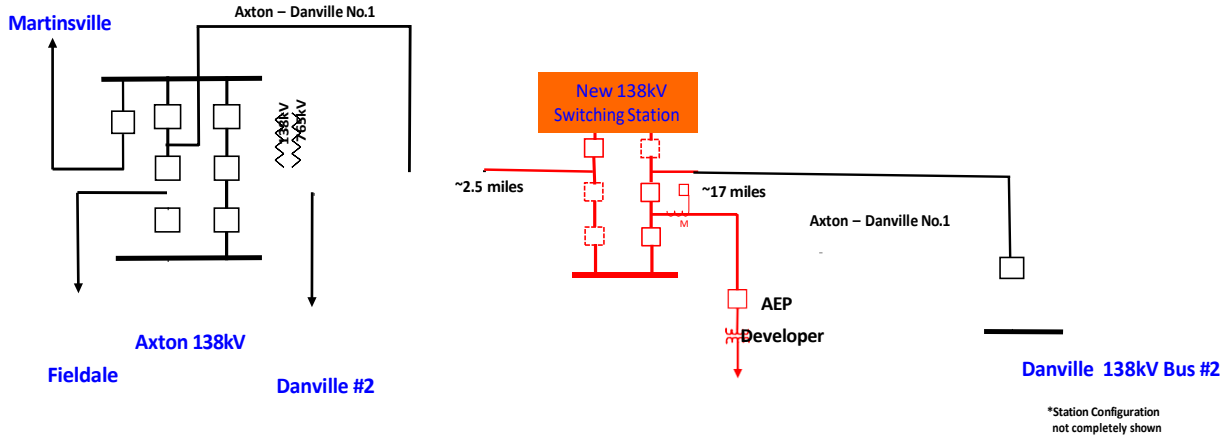
The following Breakers are overduty

None

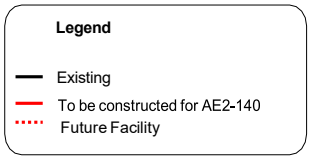
21 Figure 1: AE2-140 Point of Interconnection One Line Diagram

(Axton – Danville No.1 138kV circuit)

AE2-140 Primary Point of Interconnection
Axton – Danville 138kV Substation



AE2-140 201.1 MW
Solar facility



22 Figure 2: Point of Interconnection (Axton – Danville No.1 138kV Circuit)

23 Appendix 1 – Stability Study Report Results

Executive Summary

Generator Interconnection Request AE2-140 is for a 201.1 MW Maximum Facility Output (MFO) solar generation plant. AE2-140 consists of 76 × 2.683421 MW, Power Electronics FS2800 solar PV inverters with a total capacity of 203.94 MW. The Point of Interconnection (POI) is at a tap on Axton – Danville 138 kV circuit 1 in the American Electric Power (AEP) transmission system, Henry county, Virginia.

This report describes a dynamic simulation analysis of AE2-140 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2022 peak load case, modified to include applicable queue projects. AE2-140 has been dispatched online at maximum power output, with 1.0 p.u. voltage at the generator bus.

AE2-140 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. Steady-state condition and 51 contingencies were studied, each with a 20 second simulation time period. Studied faults included:

a) Steady state operation (20 second);

b) Three phase faults with normal clearing time;

c) Single phase bus faults with normal clearing time;

d) Single phase faults with stuck breaker;

e) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from the fault due to primary communications/relay failure;

f) Three-phase faults with loss of multiple-circuit tower line.

No relevant high-speed reclosing (HSR) contingencies were identified for this study.

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.

P6 contingencies will be tested during the facility study phase if required.

For all of the fault contingencies tested on the 2022 peak load case:

a) AE2-140 was able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AE2-140 included is transiently stable and post-contingency oscillations were positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recovered to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element tripped, other than those either directly connected or designed to trip as a consequence of that fault.

AE2-140 was tripped in contingency P5.01 due to action of under-voltage relay, i.e., VTGDCAT ‘94143506’. The tripping was resolved by using fault impedance from short circuit case for the contingency.

AE2-140 exhibited slow reactive power recovery for several contingencies. This issue did not cause instability in the system and the model can be tuned to have faster reactive power recovery upon request.

AE1-100 exhibited slow reactive power recovery for several contingencies. This issue did not cause instability in the system and the model can be tuned to have faster reactive power recovery upon request.

The reactive power capability of AE2-140 meets the 0.95 lagging and leading PF requirement at the high side of the main transformer.

No mitigations were found to be required.