Generation Interconnection

System Impact Study Report

for

Queue Project AE2-218

ELDEAN 138 KV

106 MW Capacity / 178 MW Energy

February 2020

1 Preface

The intent of the System Impact study is to determine a plan, with ballpark cost and construction time estimates, to connect the subject generation to the PJM network at a location specified by the Interconnection Customer. The Interconnection Customer may request the interconnection of generation as a capacity resource or as an energy-only resource. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system.

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 reinforcement costs may be shared with other projects, and the allocations tables are included in this report, if applicable.

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.

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.

2 General

The Interconnection Customer (IC) has proposed a Solar generating facility located in Miami County, Ohio. The installed facilities will have a total capability of 178 MW with 106 MW of this output being recognized by PJM as Capacity. The proposed in-service date for this project is December 31, 2021. **This study does not imply a TO commitment to this in-service date.**

Queue Number	AE2-218
Project Name	ELDEAN 138 KV
Interconnection Customer	Invenergy Solar Development North America LLC
State	Ohio
County	Miami
Transmission Owner	Dayton
MFO	178
MWE	178
MWC	106
Fuel	Solar
Basecase Study Year	2022

2.1 Point of Interconnection

The AE2-218 project will interconnect with the Dayton Power and Light Company transmission system at the Eldean Substation 138 kV bus. The physical Point of Interconnection (POI) will be the last takeoff structure leaving the Eldean 138 kV yard. Dayton will own the takeoff structure and all attachment hardware. The Interconnection Customer will own the conductor terminating onto the structure.

Under the AE1-218 project, the IC will construct a single 138 kV line up to the POI in the Eldean 138 kV yard.

See Attachment 1 for a one line of the physical interconnection point.

2.2 Cost Summary

The AE2-218 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$0
Direct Connection Network Upgrade	$900,000
Non Direct Connection Network Upgrades	$75,000
Total Costs	$975,000

In addition, the AE2-218 project may be responsible for a contribution to the following costs

Description	Total Cost
System Upgrades	$0

3 Attachment Facilities

There are no Attachment Facilities to be constructed by the Transmission Owner.

This report assumes that the Interconnection Customer will construct and own the attachment line from its generating facility into the proposed Point of Interconnection as depicted on the one-line diagram in Attachment 1. The IC will also be responsible for the fiber/OPGW that Dayton requires on the generator line for the communication assisted trip scheme.

The metering may be classified as an Attachment Facility in future study reports.

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**
None	$0
Total Attachment Facility Costs	**$0**

4 Direct Connection Cost Estimate

The substation direct connection cost estimate for the AE2-218 project is approximately $900,000. The substation direct connection work for this project includes the addition of a new 138 kV breaker to the Eldean Substation. The Eldean Substation is designed for a two bus, five breaker configuration. Thus, to create a reliable connection to the system, this project will require a single new breaker. The 138 kV generator lead line will be constructed by the developer and will be terminated onto the 138 kV takeoff structure leaving the Eldean Substation. The new 138 kV substation will be equipped with the necessary communication systems to facilitate remote supervisory control of the breaker and status monitoring. Dayton will install the physical structures, line relaying, communications, and interconnection metering to accommodate the interconnection of the AE2- 218 generator.

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
Install new 138 kV breaker at the Eldean Substation to interconnect the AE2-218 project. This will include the installation of all physical structures, P&C equipment, communications equipment, metering equipment, and associated facilities.	$900,000
Total Direct Connection Facility Costs	**$900,000**

5 Non-Direct Connection Cost Estimate

The substation non-direct connection cost estimate for the AE2-218 project is approximately $75,000. Protection settings changes at Eldean Substation will be required to facilitate the interconnection of the new generation.

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
Protection System upgrades at Eldean Substation	$75,000
Total Non-Direct Connection Facility Costs	**$75,000**

6 Schedule

Based on the extent of the Dayton primary Direct Connection and Non-Direct Connection upgrades required to support the AE2-218 generation project, it is expected to take a minimum of 18 months from the date of a fully executed Interconnection Construction Service Agreement to complete the installation subject to market conditions and vendor lead times. This includes the requirement for the Interconnection Customer to make a

preliminary payment to Dayton which funds the first three months of engineering design that is related to the construction of the Non-Direct Connection facilities. It assumes that there will be no environmental or permitting issues to implement the Non-Direct Connection upgrades for this project and that all system outages will be allowed when requested.

7 Transmission Owner Analysis

Power Flow Analysis

PJM performed a power flow analysis of the transmission system using a 2022 summer peak load flow model and the results were verified by Dayton. Additionally, Dayton performed an analysis of its underlying transmission <100 kV system. At the Primary POI, the [QUEUE] project does not create any issues on the Dayton transmission system.

Short Circuit Analysis

PJM performed a short circuit analysis and the results were verified by Dayton. The connection of [QUEUE] project to the system does not result in any newly overdutied circuit breakers on the Dayton transmission system.

Stability Analysis

PJM performed the dynamic stability analysis and the results were reviewed by Dayton. There were no stability concerns identified in PJM's study.

8 Interconnection Customer Requirements

8.1 PJM Requirements

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.

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.

8.2 Dayton Interconnection Requirements

System Protection

The IC must design its Customer Facilities in accordance with all applicable standards, including the standards in Dayton's "Requirements for the Connection of Facilities to the Dayton Power & Light company Transmission System" document located at: https://www.pjm.com/planning/design-engineering/to-tech-standards/private-dayton.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.

Compliance Issues and Interconnection Customer Requirements

The Dayton Power and Light Company (DP&L) has prepared this Facilities Connection Requirements document to ensure compliance with North American Electric Reliability Council (NERC) Reliability Standards and applicable Regional Reliability Organization, sub regional, Power Pool, and individual Transmission Owner planning criteria and facility connection requirements in compliance to NERC Standard FAC-001-2. These connection requirements apply to all generation facilities, transmission facilities, and end-users connecting to the DP&L transmission system. Detailed information outlining DP&L interconnection requirements can be reviewed utilizing the following link:

https://www.pjm.com/~/media/planning/plan-standards/private-dayton/dayton-facilities-connection-requirements.ashx

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 Dayton transmission system.

9 Revenue Metering and SCADA Requirements

9.1 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.

9.2 Dayton Requirements

The Interconnection Customer will be required to comply with all Dayton Revenue Metering Requirements for Generation Interconnection Customers as outlined in the link below. The Revenue Metering Requirements may be found within the Dayton Power & Light Co. "Requirements for the Connection of Facilities to the Dayton Power & Light Co. Transmission System" document located at the following link:

http://www.pjm.com/~/media/planning/plan-standards/private-dayton/dayton-facilities-connection-requirements.ashx

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

10 Network Impacts

The Queue Project AE2-218 was evaluated as a 178.0 MW (Capacity 106.0 MW) injection into the Eldean 138 kV substation in the Dayton area. Project AE2-218 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AE2-218 was studied with a commercial probability of 1.00. Potential network impacts were as follows:

Summer Peak Load Flow

11 Generation Deliverability

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

None

12 Multiple Facility Contingency

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

None

13 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

14 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

15 System Reinforcements

None required

16 Flow Gate Details

The following appendices contain additional information about each flowgate presented in the body of the report. For each appendix, a description of the flowgate and its contingency was included for convenience. However, the intent of the appendix section is to provide more information on which projects/generators have contributions to the flowgate in question. Although this information is not used "as is" for cost allocation purposes, it can be used to gage other generators impact. It should be noted the generator contributions presented in the appendices sections are full contributions, whereas in the body of the report, those contributions take into consideration the commercial probability of each project.

Not applicable

Affected Systems

17 Affected Systems

17.1 LG&E

None

17.2 MISO

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

17.3 TVA

None

17.4 Duke Energy Progress

None

17.5 NYISO

None

Short Circuit

18 Short Circuit

The following Breakers are over duty

None.

19 Stability and Reactive Capability Analysis

Generator Interconnection Request AE2-218 is for a 178 MW Maximum Facility Output (MFO) solar generating facility, which consists of 59 TMEIC PVH-L3360GR solar inverters. The AE2-218 solar generating facility will be located in Miami County, Ohio.

The AE2-218 solar generating facility will connect directly to the existing Eldean 138 kV bus in the Dayton Power & Light Company (DAY or DP&L) transmission system. The Point of Interconnection (POI) will be the last takeoff structure leaving the Eldean 138 kV yard.

This report describes a dynamic simulation analysis of AE2-218 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. AE2-218 has been dispatched online at maximum power output, with unity power factor and approximately 1.00 pu voltage at the generator terminals.

AE2-218 was tested for compliance with NERC, PJM, Transmission Owner, and other applicable criteria. 143 contingencies were studied, each with a 20 second simulation time period (with 1.0 second initial run prior to any events). The studied faults include:

a) Steady state operation (Category P0);

b) Three phase faults with normal clearing time on the intact network (Category P1);

c) Single phase to ground faults with delayed clearing due to a stuck breaker (Category P4);

d) 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 (Category P5);

e) Single phase to ground faults with normal clearing for common structure (Category P7).

For all 143 fault contingencies tested on the 2022 peak load case:

a) AE2-218 was able to ride through the faults (except for faults where protective action trips a generator(s)).

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

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.

Please also note that the project AE2-218 meets the 0.95 leading and lagging reactive power requirement at the high side of the facility main transformer.

Attachment 1 – One Line