Revised

Generation Interconnection

System Impact Study Report

for

Queue Project AE2-214

COLE 345 KV

120 MW Capacity / 200 MW Energy

November 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.

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2 General

Invenergy Solar Project Development, LLC has proposed a Solar generating facility located in Franklin County, Ohio. The installed facilities will have a total capability of 200 MW with 120 MW of this output being recognized by PJM as Capacity. The Point of Interconnection for the solar facilities will be AEP's Cole 345 kV substation.

The proposed in-service date for this project is December 31, 2021. This study does not imply AEP's commitment to this in-service date.

The objective of this System Impact Study is to determine budgetary cost estimates and approximate construction timelines for identified transmission facilities required to connect the proposed generating facilities to the AEP transmission system. These reinforcements include the Attachment Facilities, Local Upgrades, and Network Upgrades required for maintaining the reliability of the AEP transmission system.

Queue Number	**AE2-214**
Project Name	COLE 345 KV
Interconnection Customer	Invenergy Solar Project Development LLC
State	Ohio
County	Franklin
Transmission Owner	AEP
MFO	200
MWE	200
MWC	120
Fuel	Solar
Basecase Study Year	2022

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2.1 Point of Interconnection

AE2-214 will interconnect with the AEP transmission system at Cole 345 kV substation.

To accommodate the interconnection at the Cole 345 kV substation, the substation will have to be expanded requiring the installation of one (1) 345 kV circuit breaker (see Figure 1). Installation of associated protection and control equipment, 345 kV line risers, SCADA, and 345 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 AE2-214 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$1,600,000
Direct Connection Network Upgrade	$0
Non Direct Connection Network Upgrades	$3,200,000
Allocation for New System Upgrades	$0
Contribution for Previously Identified Upgrades	$0
Total Costs	$4,800,000

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.

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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
345 kV Revenue Metering	$350,000
Generator lead first span exiting the POI station, including the first structure outside the fence	$1,250,000
Total Attachment Facility Costs	$1,600,000

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
Total Direct Connection Facility Costs	$0

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
Expand the Cole 345 kV substation: Install one (1) additional 345 kV circuit breaker. Installation of associated protection and control equipment, 345 kV line risers and SCADA will also be required.	$2,500,000
Upgrade line protection and controls at the Beatty Road 345 kV substation	$350,000
Upgrade line protection and controls at the Hayden Road 345 kV substation	$350,000
Total Non-Direct Connection Facility Costs	$3,200,000

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7 Incremental Capacity Transfer Rights (ICTRs)

None

8 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 signing Agreement execution.

9 Interconnection Customer Requirements

It is understood that Invenergy Solar Project Development is responsible for all costs associated with this interconnection. The costs above are reimbursable to AEP. The cost of Invenergy Solar Project Development's generating plant and the costs for the line connecting the generating plant to the Cole 345 kV substation are not included in this report; these are assumed to be Invenergy Solar Project Development'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.

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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

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11 Network Impacts

The Queue Project AE2-214 was evaluated as a 200.0 MW (Capacity 120.0 MW) injection into the Cole 345 kV substation in the AEP area. Project AE2-214 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AE2-214 was studied with a commercial probability of 1.00. Potential network impacts were as follows:

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Summer Peak Load Flow

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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 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.

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17 Light Load Analysis

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

Not required

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18 System Reinforcements

None

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Affected Systems

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19 Affected Systems

19.1 LG&E

None

19.2 MISO

None.

19.3 TVA

None

19.4 Duke Energy Progress

None

19.5 NYISO

None

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Short Circuit

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20 Short Circuit

The following Breakers are over-duty

None

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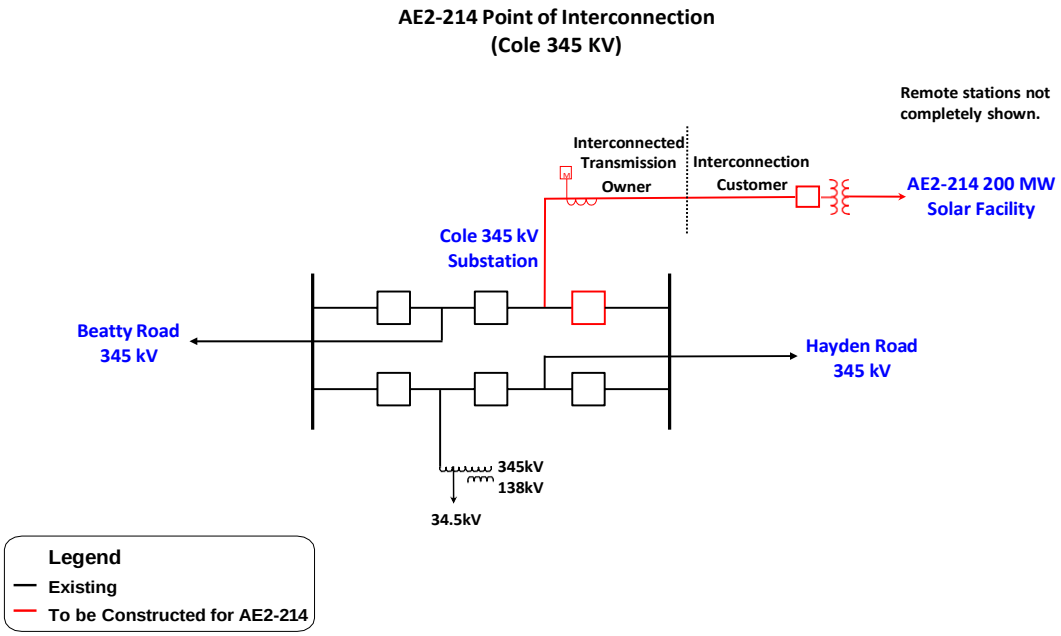
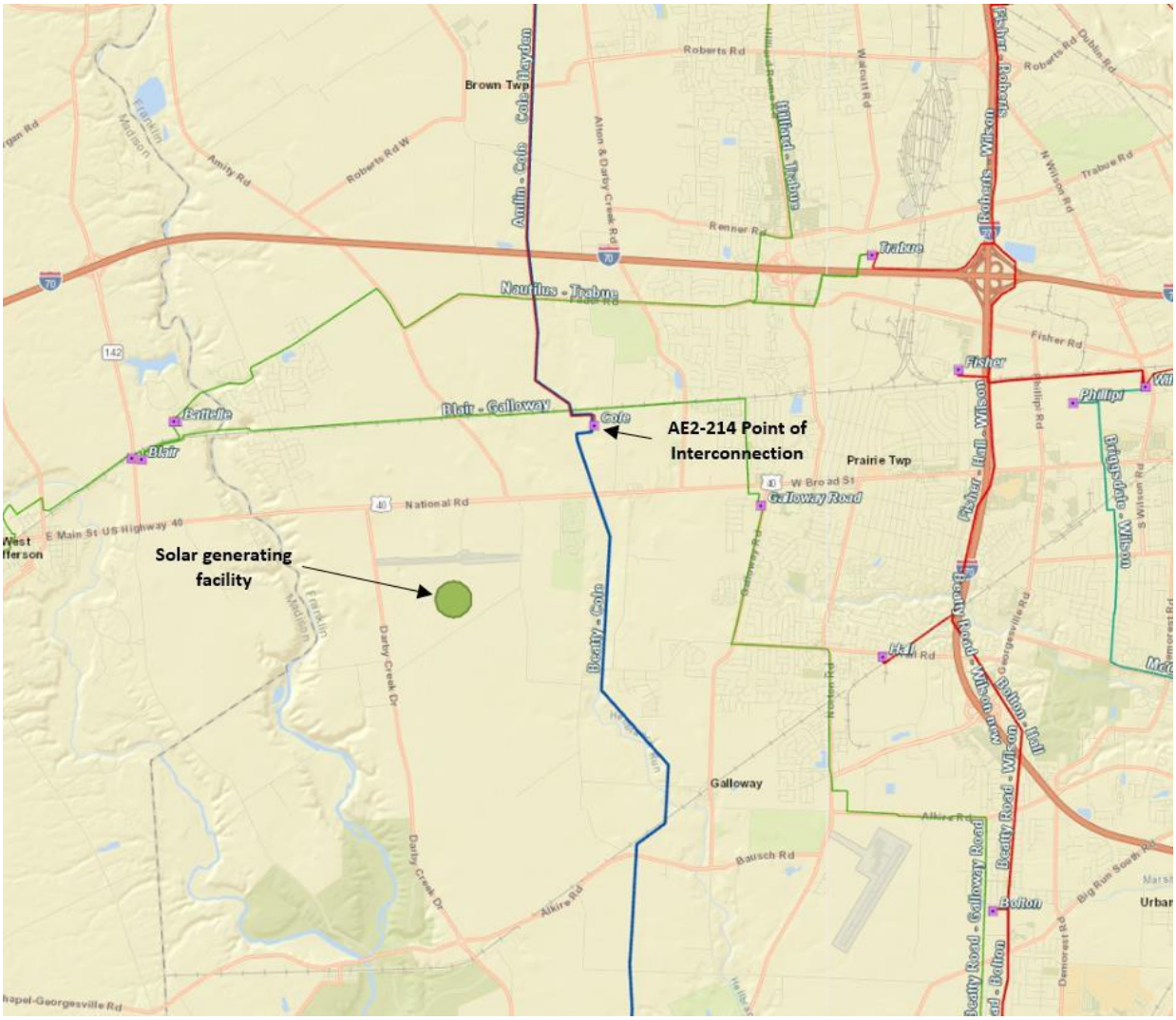
21 Figure 1: AE2-214 Point of Interconnection (Cole 345 kV)

Single-Line Diagram



22 Figure 2: AE2-214 Point of Interconnection (Cole 345 kV)



23 Appendix 1 – Stability Analysis

Executive Summary

Generator Interconnection Request AE2-214 is for a 200.0 MW Maximum Facility Output (MFO) solar generation plant. AE2-214 consists of 67 × 3.02 MW, TMEIC PVH-L3360GR solar PV inverters with a total capacity of 202.34 MW. The Point of Interconnection (POI) is at the existing Cole 345 kV station, in the American Electric Power (AEP) transmission system, Franklin County, Ohio.

This report describes a dynamic simulation analysis of AE2-214 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. AE2-214 has been dispatched online at maximum power output, with 1.0 p.u. voltage at the generator bus.

AE2-214 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. Steady-state condition and 52 contingencies were studied, each with a 20 second simulation time period. Studied faults included:

a) Steady-state operation (20 second run);

b) Three-phase faults with normal clearing time;

c) Single-phase faults with stuck breaker;

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;

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

No relevant bus[1] or high speed reclosing (HSR) schemes 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) AE2-214 was able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AE2-214 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.

AE2-214 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.

AE2-148 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.

[1] The bus faults 'AEP_P2-2_#3233_05HAYDEN 345_1', 'AEP_P2-2_#714_05HAYDEN 345_2', 'AEP_P2-2_#739_05BEATTY 345_N' and 'AEP_P2-2_#739_05BEATTY 345_S' have not been considered as the more onerous three-phase contingencies have been considered in P1 table.

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The reactive power capability of AE2-214 meets the 0.95 lagging and leading PF requirement at the high side of the main transformer.

No mitigations were found to be required.

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