Revised Generation Interconnection Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD1-043

Makahoy 138 kV

April 2021

Revised May 2022

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.

General

Free Sky Energy Leasing, LLC proposes to install PJM Project #AD1-043, a 120.0 MW (45.6 MW Capacity) solar generating facility in Madison County, Indiana. The point of interconnection is to AEP's Makahoy 138kV Substation (see Figure 1).

The requested in service date is September 30, 2020.

Attachment Facilities

Point of Interconnection (Makahoy 138 kV Substation)

To accommodate the interconnection at the Makahoy 138kV Substation, the Makahoy substation will have to be expanded requiring the installation of one (1) additional 138 kV circuit breaker (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.

Non-Direct Connection Facilities:

- Expand the Makahoy 138kV Substation: Install one (1) additional 138 kV circuit breaker (see Figure 1). Installation of associated protection and control equipment, 138 kV line risers and SCADA will also be required.
    - **Estimated Station Cost: $1,250,000**

Attachment Facilities:

The total preliminary cost estimate for Non-Direct Connection work is given in the following tables below:

For AEP building Direct Connection cost estimates:

Description	Estimated Cost
138 kV Revenue Metering	$250,000
Total	**$250,000**

Table 1

Interconnection Customer Requirements

It is understood that Free Sky Energy Leasing is responsible for all costs associated with this interconnection. The costs above are reimbursable to AEP. The cost of the Free Sky Energy Leasing generating plant and the costs for the line connecting the generating plant to the Makahoy 138 kV substation are not included in this report; these are assumed to be the responsibility of Free Sky Energy Leasing.

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.

Revenue Metering and SCADA Requirements

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 Sections 24.1 and 24.2.

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

Network Impacts

The Queue Project AD1-043 was evaluated as a 120.0 MW (Capacity 45.6 MW) injection into the South Elwood Tap 138 kV substation in the AEP area. Project AD1-043 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD1-043 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2021

Generator Deliverability

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

None

Multiple Facility Contingency

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

None

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

Steady-State Voltage Requirements

(Results of the steady-state voltage studies should be inserted here)

To be determined

Short Circuit

(Summary of impacted circuit breakers)
New circuit breakers found to be over-duty:

None

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

See Attachment 3

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO Impacts:

No Preliminary MISO Impacts were identified by MISO. Final MISO Impacts to be determined during Facilities Study phase.

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

None

Delivery of Energy Portion of Interconnection Request

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.

1. (AEP - AEP) The 05STRWTN-05ALEXAN 138 kV line (from bus 246988 to bus 247116 ckt 1) loads from 80.3% to 113.3% (AC power flow) of its emergency rating (150 MVA) for the single line contingency outage of 'AEP_P1-2_#6964'. This project contributes approximately 49.14 MW to the thermal violation.

CONTINGENCY 'AEP_P1-2_#6964'
OPEN BRANCH FROM BUS 246763 TO BUS 246988 CKT 1 / 246763 05PIPECK 138 246988 05STRWTN 138 1
END

2. (AEP - AEP) The 05ALEXAN-05JONES 138 kV line (from bus 247116 to bus 246913 ckt 1) loads from 68.37% to 101.31% (AC power flow) of its emergency rating (150 MVA) for the single line contingency outage of 'AEP_P1-2_#6964'. This project contributes approximately 49.14 MW to the thermal violation.

CONTINGENCY 'AEP_P1-2_#6964'
OPEN BRANCH FROM BUS 246763 TO BUS 246988 CKT 1 / 246763 05PIPECK 138 246988 05STRWTN 138 1
END

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)

None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)
(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

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 be between 24 to 36 months after signing an interconnection agreement.

Conclusion

Based upon the results of this System Impact Study, the construction of the 120.0 MW (45.6 MW Capacity) solar generating facility of Free Sky Energy Leasing (PJM Project #AD1-043) will require the following additional interconnection charges. This plan of service will interconnect the proposed generating facility in a manner that will provide operational reliability and flexibility to both the AEP system and the Free Sky Energy Leasing generating facility.

Cost Breakdown for Point of Interconnection (Makahoy 138 kV)		
	Expansion of Makahoy 138kV substation and installation of associated protection and control equipment	$1,250,000
	138 kV Revenue Metering	$250,000
	New System Reinforcements *Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)*	$0
	Contribution to Previously Identified System Reinforcements	$0

	(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, identified for earlier generation or transmission interconnection projects in the PJM Queue)	
	Total Estimated Cost for Project AD1-043	**$1,500,000**

The estimates 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.

Figure 1: Point of Interconnection (Makahoy 138kV Substation)

Single Line Diagram

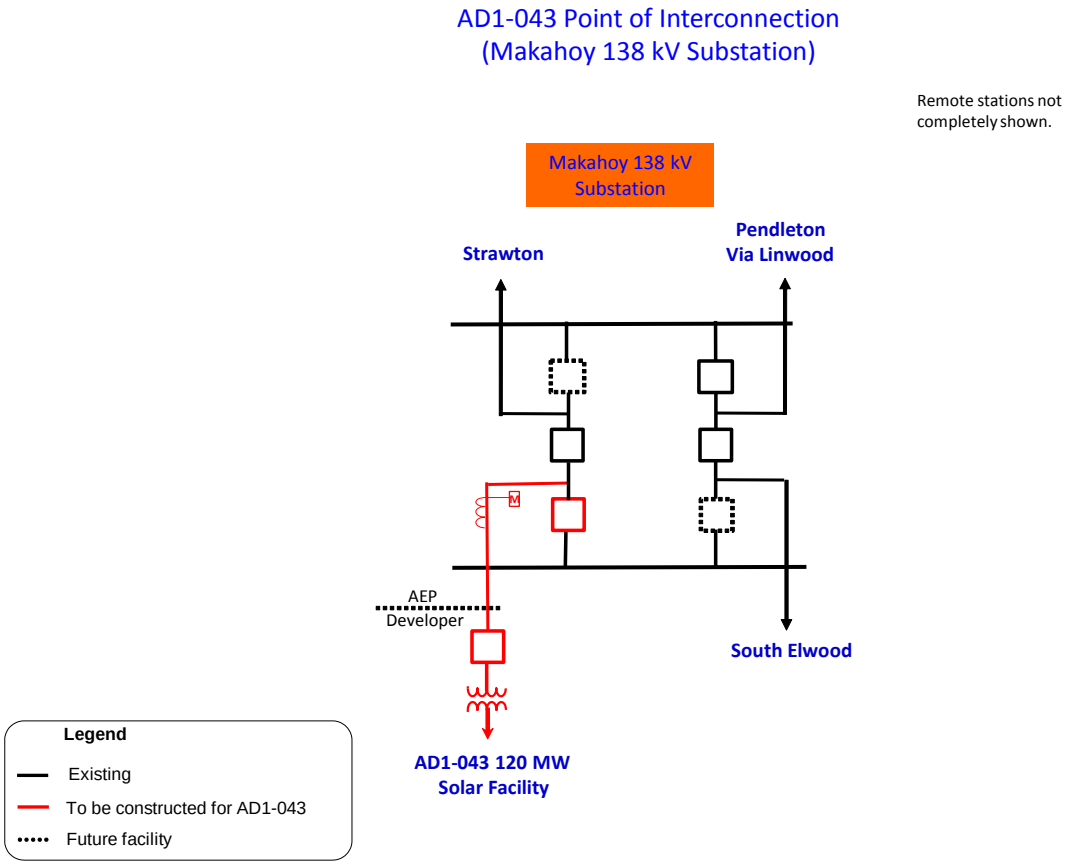

Figure 2: Customer Project Site and Point of Interconnection (Makahoy 138kV Substation)

Figure 3: Dynamic Simulation Analysis

Executive Summary

Generator Interconnection Request AD1-043 is for a 120 MW Maximum Facility Output (MFO) solar generating facility. AD1-043 consists of 43 x Power Electronics FS3000 MU inverters rated at 2.808 MW each. The Point of Interconnection (POI) is at Makahoy 138 kV substation in the American Electric Power (AEP) transmission system, Madison, Indiana.

This report describes a dynamic simulation analysis of AD1-043 as part of the overall system impact study.

The loadflow scenario for the analysis was based on the RTEP 2021 peak load case, modified to include applicable queue projects. AD1-043 has been dispatched online at maximum power output, with 1.0 p.u. voltage at the generator bus.

AD1-043 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. Steady-state condition and 46 contingencies were studied, each with at least 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;

d) Single-phase faults with delayed clearing due to stuck breaker;

e) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from 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 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.

For all of the fault contingencies tested on the 2021 peak load case:

a) AD1-043 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 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.

The reactive power capability of AD1-043 does NOT meet the 0.95 lagging PF requirement whereas 0.95 leading PF requirement was met at the high side of the main transformer.

No mitigations were found to be required due to instability; however, it was observed that AD1-043 is deficient in lagging power factor requirement by 2.56 MVAr. This may need to be addressed through reactive power compensation.