Generation Interconnection
System Impact Study Report

For

PJM Generation Interconnection Request
Queue Position AB1-014

Hillcrest 138kV

September 2016

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.

General

Hillcrest Solar 1, Interconnection Customer, has proposed a solar photovoltaic generating facility located in Brown County, Mt Orab, Ohio. The installed facilities will have a total capability of 125 MW with 47.5 MW of this output being recognized by PJM as Capacity. The proposed in-service date for this project is October 30, 2018. **This study does not imply a Duke Energy commitment to this in-service date.**

Point of Interconnection

AB1-014 will interconnect with the Duke Energy transmission system at the Hillcrest 138 kV Substation. Please refer to the one-line diagram in Appendix 2 for system configuration.

Cost Summary

Cost Estimates for the attachment facilities and network upgrades required for this interconnection project are listed below. Contributions in Aid of Construction (CIAC) tax gross-up is not included. A Facilities Study is required to more accurately develop the costs and schedule for the project.

(a.) Attachment Facilities:

- Estimated total time to complete: 26 Months (concurrent with Network Upgrades)
- Estimated total costs: **$ 400,000** detailed as follows:

(a.1) Hillcrest Substation - Install CT, PT, CCVT foundations. Install CT, PT, CCVT support structures. Install CT's, PT's, CCVT's, relay package, metering, control cable and associated facilities.

(b.) Direct Connection Network Upgrades:

- Estimated total time to complete: 26 Months (concurrent with Attachment Facilities)
- Estimated total costs: **$ 1,400,000** detailed as follows:

(b.1) Hillcrest Substation – Extend grade and ground grid approx. 100' x 350'. Reroute crushed stone roadway to accommodate new equipment. Fence new area. Install take-off tower, circuit breaker, disconnect switch, and bus support foundations. Install take-off tower, circuit breaker, disconnect switch, and bus support structures. Extend 138 kV bus. Install 138 kV breaker, bus/line disconnect switches and associated facilities.

(c.) Non-Direct Connection Network Upgrades: $ 0 (None)

(d.) Direct Connection Local Upgrades: $ 0 (None)

(e.) Non-Direct Connection Local Upgrades: $ 0 (None)

(f.) Contributions for Previously Identified Upgrades: $ 0 (None)

(g.) Baseline Upgrades: $ 0 (None)

(h.) Option to Build Upgrades: $ 0 (None)

Total costs (a.) to (h.): $ 1,800,000

Interconnection Customer Requirements

Interconnection Customer shall engineer, procure and construct an overhead line connecting the storage plant to the take-off structure in the substation. Interconnection Customer shall coordinate protection scheme with Duke Energy Ohio.

Revenue Metering and SCADA Requirements

PJM Requirements

Interconnection Customer will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for Interconnection Customer's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

Interconnected Transmission Owner Requirements

"Requirements for Connection of Facilities to the Duke Energy Midwest Transmission System" may be found at the following link:

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

Schedule

Based on the extent of attachment facilities and network upgrades required, it is expected to take a minimum of twenty-six (26) months to complete the installation for this project.

Network Impacts

The Queue Project AB1-014 was evaluated as a 125.0 MW (Capacity 47.5 MW) injection into the Hillcrest 138 kV substation in the DEOK area. Project AB1-014 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-014 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2019

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

None

Short Circuit

(Summary of impacted circuit breakers)

None

Affected System Analysis & Mitigation

LGEE 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.
Only the most severely overloaded conditions are listed. 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 will study all overload conditions associated with the overloaded element(s) identified.

None

Light Load Analysis - 2019

Not Required

System Reinforcements

Short Circuit

No new breakers to be over-duty in the DEOK transmission area.

Stability and Reactive Power Requirement

No mitigations were found to be required. Refer to Appendix 3 for dynamic analysis summary.

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

Light Load 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

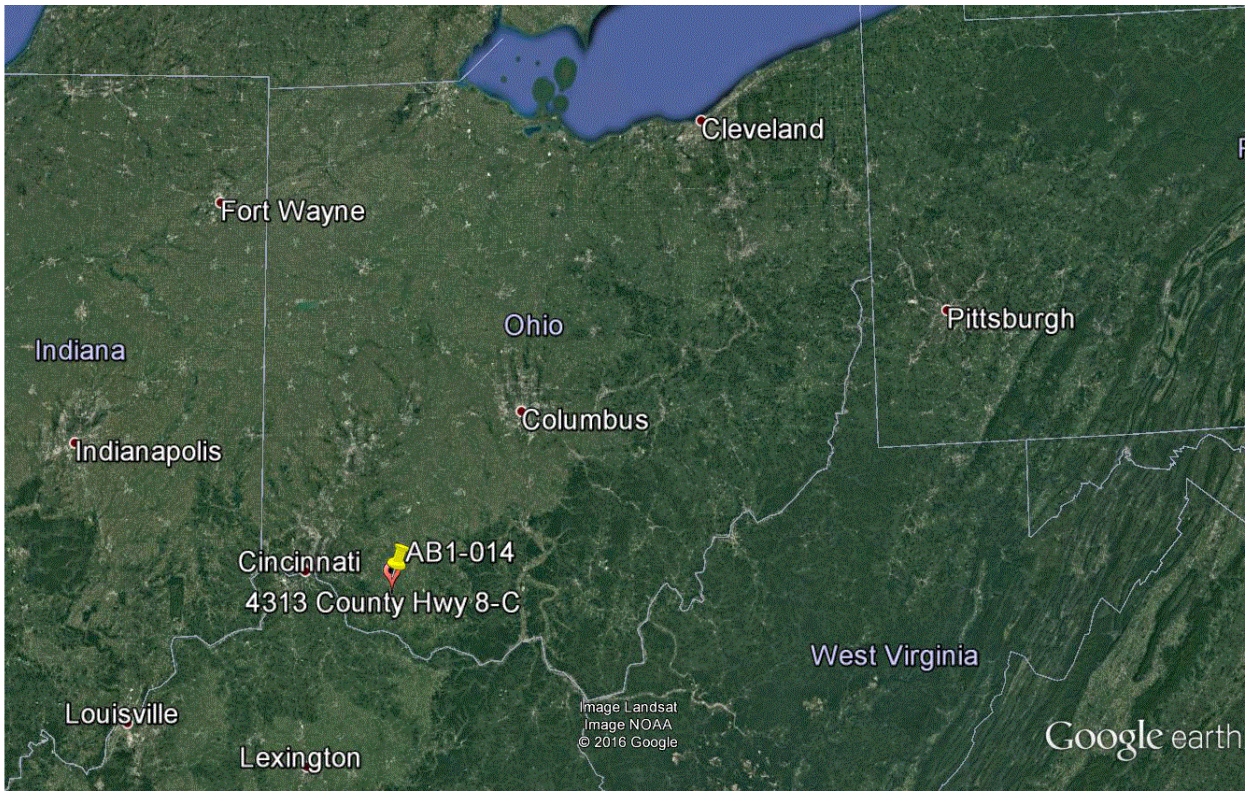
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

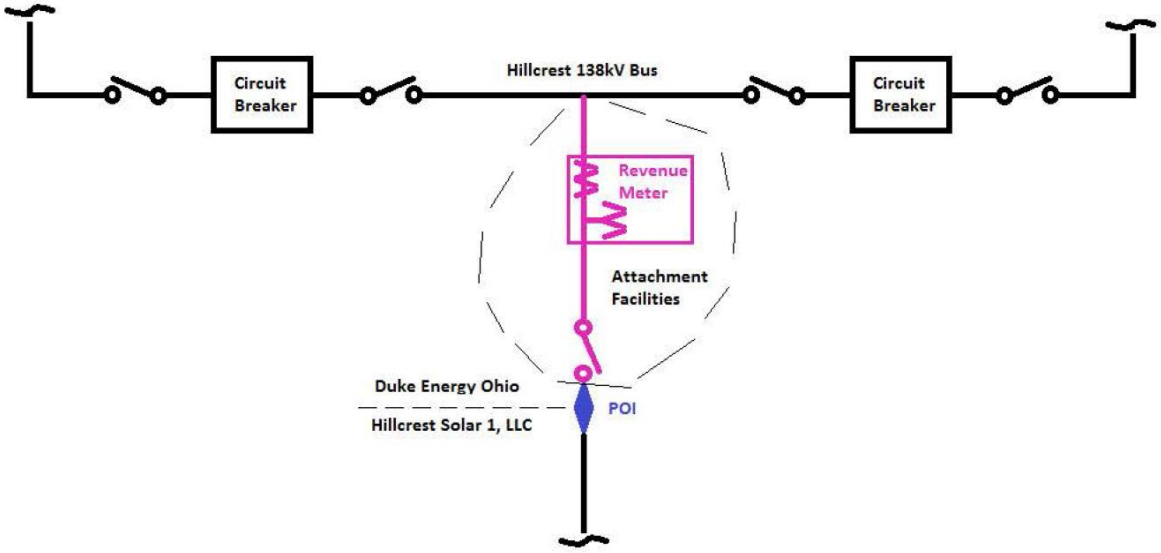
Appendix 1

Facility Location
PJM Queue Position: AB1-014



Appendix 2

Interconnection One-Line Diagram
PJM Queue Project Number: AB1-014



Appendix 3

Dynamic Simulation Analysis – Executive Summary
PJM Queue Project Number: AB1-014

Generator Interconnection Request AB1-014 is for a 125 MW Maximum Facility Output (MFO) solar photovoltaic generating facility consisting of 63 x SMA Sunny Central 2200-US 2.0 MW inverters. AB1-014 has a Point of Interconnection (POI) at Hillcrest 138 kV substation in the Duke Energy transmission system, Brown County, Ohio.

The load flow scenario for the analysis was based on the RTEP 2019 summer peak case, modified to include applicable queue projects. AB1-014 has been dispatched online at maximum power output, with unity power factor and 1.0 pu voltage at the generator bus.

AB1-014 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 39 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation (20 second simulation);

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 fault due to primary communications/relay failure.

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

f) Single phase faults with loss of multiple-circuit bus contingency

No relevant Bus or 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.

A spike in the Pelec output, greater than Pmax, was noted for the AB1-014 generator at fault clearance for contingencies 3N.13, 1B.07 to 1B.18, 1D.01 to 1D.05, 1T.01 to 1T.02, and 1S.01.

For the remaining fault contingencies tested on the 2019 summer peak case:

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

a) The AB1-014 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

No mitigations were found to be required.