PJM Generator Interconnection Request
Queue AB1-032
Lee Station Southwest 12 kV
Feasibility/Impact Study Report

April 2016

Preface

The intent of the Feasibility/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 Feasibility/System Impact Study is performed.

The Feasibility/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.

This report is divided into two sections:

Part I – AEP Distribution Planning Analysis and Results
Part II – Transmission Planning Analysis and Results

Part I - AEP Distribution Planning Analysis and Results

Request

The AEP CUSTOMER GUIDE TO THE INTERCONNECTION OF DISTRIBUTED RESOURCES TO THE AEP DISTRIBUTION SYSTEM is referred to throughout this document as the Interconnection Guide.

Hecate Energy Carpenter Road LLC (Generator) has requested an interconnection impact study through PJM for a solar-powered distributed generation (DG) facility capable of 3.3MW maximum output power. The DG system consists of 13,824 solar modules divided between four inverters. Each inverter is an SMA 850 CP derated to 833.3 kW each. The output of the inverters will be connected in pairs to two skids. Each skid will consist of a 2000 kVA step-up transformer with a 12.47 kV wye grounded high side connection and two 386 volt wye ungrounded low side connections with Z=6%, 6.0 X/R ratio. Each inverter will be connected to one of the 386 volt transformer windings via an AC breaker. The two skids will be daisy-chained with direct buried underground cables to a main 12.47 kV breaker. The primary metering pole will be the Point of Common Coupling (PCC) for the interconnection. AEP will install an overhead tap with recloser and switch to its F-11002 12.47 kV circuit served from its Lee Station, to interconnect the DG facility. See Figure 3 and Figure 4 of this report for the approximate locations and single line drawing of the Transmission system Point of Interconnection (POI), and the Distribution System Point of Common Coupling (PCC).

Disclaimer

As per the documentation provided at the kick off meeting (Refer to Appendix), the connection for this project will be to the overhead line along Carpenter Road near Raymar Drive served from feeder F-11002 out of Lee Station. The contents of this feasibility/impact study apply only to the facility described in the attached Distributed Generation (DG) Request Documents. All modeling is based on the PCC near grid number 2085004-444193 on Carpenter Road.

Modeling and Assumptions

The Lee Station Southwest circuit (feeder F-11002) is a radial configuration, three-phase multi-grounded four-wire wye system. The primary voltage is 12.47 kV line-to-line and 7.2 kV line-to-ground. The Southwest circuit is served from the 12 kV station bus via a 69/12 kV, 9.375 MVA transformer. See Figure 1.

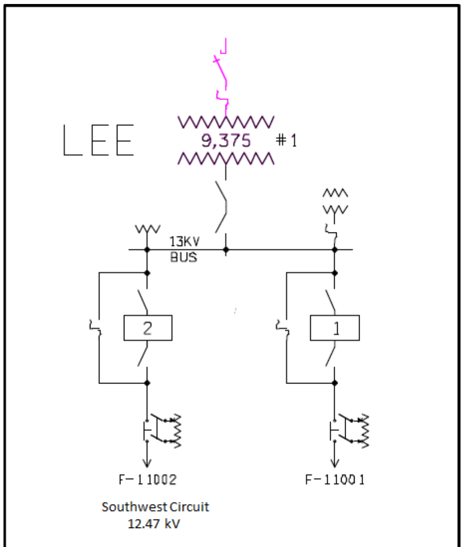

Figure 1

Generator Provided Information

In addition to the information provided with the application, the Generator has provided information on the cable wire size (#1 AWG Cu) and islanding detection methodology.

AEP Fault Values and Thevenin Impedances

The following are AEP symmetrical fault values and AEP Thevenin impedances calculated at the Generator PCC without the DG facility connected. These values assume that the improvements described later in this report have been completed. The nominal voltage can vary +/- 5%.

F-11002 Circuit

- LLL = 2768 A LG = 2346 A
- Z1 = Z2 = 0.5616 + j 2.6767 ohms @ 12.47 kV
- Z0 = 0.8415 + j 3.5028 ohms @ 12.47/7.2 kV

Analysis

Cymdist Version 7.1 revision 08 was utilized to model the DG effects on the following:

System Load Flows
System Voltage Levels
System Fault Levels and Overcurrent Protection

System Load Flows

The system model indicates that no AEP equipment will experience conditions exceeding equipment rating due to the Generator operating under peak load, light load, or abnormal operating conditions.

No protective or voltage regulating devices outside of the substation are expected to see current back feed under peak or light loading conditions. Under peak loading conditions there is not expected to be back feed into the station. Under light loading conditions current will back feed into the station, through the feeder regulators and feeder breaker on circuit F-11002 into the 12 kV bus. Due to loading on the F-11001 circuit, no current would be expected to back feed the transformer and into the 69 kV system under either peak or light loading conditions with maximum solar generation.

If a contingency would occur under light loading conditions where circuit F-11001 would trip out, then back feed of the station transformer and 69 kV could occur. No significant adverse results would be expected under this situation.

System Voltage Levels

Steady state voltage level studies indicate that voltage inside of the +/-5% range required by tariff will not be maintained under all combinations of generation and circuit loading. As a result it will be necessary to re-conductor a 3200' section of the circuit main-line with larger conductor starting at the station and proceeding toward the solar interconnection point. In addition an adjustment in the station voltage regulator setting is also required.

It is anticipated that the output of the solar facility will vary significantly during periods of clouds and sun and this will affect the Lee Station circuit voltage. Some IEEE research indicates that the output ramp rate for a cloud transient over a large area may be on the order of 3% per second. It is assumed that under this type of ramp rate, the solar facility could go from full output to zero output in approximately 33 seconds. The number of expected cloud transients per hour or per day is unknown.

To analyze the effect of a drop in output from the solar facility, circuit studies were run at full 3.3 MW output during both peak and light circuit loading conditions (light loading was 33% of peak loading). The station feeder regulators were then locked to the calculated position and another study was run for both peak and light circuit loading conditions with the solar facility output at zero. These studies reflect an instantaneous loss of full solar output. Similar studies were conducted for instantaneous zero output to full output. The worst case swing in circuit voltage for the above cases was 0.42%. A 0.42% circuit voltage change over 33 sec is not expected to be perceptible to AEP customers. Because the worst case cloud transient ramp rate is unknown, it is impossible to determine if cloud transients will cause a perception of voltage fluctuations by AEP customers.

System Fault Levels and Overcurrent Protection

The addition of this DG equipment will subject AEP overcurrent protection devices to increased fault current. These increases, measured at the PCC, are outlined as follows:

- With no DG equipment connected:
    - LLL = 2768 A LG = 2346 A
- With DG equipment connected:
    - LLL = 3050 A LG = 2407 A

The fault contribution increase caused by the DG might require a re-coordination study for AEP protective circuit devices. Additionally, the Generator's main protective device will need to be coordinated with the F-11002 Circuit breaker control settings.

Distribution project design will set the breaker reclose instantaneous time to minimum 3 seconds, to allow the Generator time to isolate itself during an island condition.

System Protection

The Generator responsibilities include providing adequate protection to AEP facilities due to events arising from the operation of the Generator under all AEP distribution system and Generator operating conditions. The Generator is responsible for protecting their own facility under all AEP distribution system operating conditions whether the Generator is connected to AEP facilities or not including but not limited to:

1. Abnormal voltage or frequency
Loss of a single phase of supply
Equipment failure
Distribution system faults
Lightning
Excessive harmonic voltages
Excessive negative sequence voltages
Separation from supply
Loss of synchronization

IEEE Standard 1547-2003 “Standard for Interconnecting Distributed Resources with Electric Power Systems” is the basis for interconnection technical requirements for system protection.

The interconnection system hardware and software used by a Distributed Resource to meet the technical requirements do not have to be located at the Point of Common Coupling. However, the technical requirements shall be met at the Point of Common Coupling. For additional information on interconnection technical requirements please refer to the AEP Interconnection Guide and IEEE 1547-2003.

The cost of any damage resulting from a system condition caused by the installation and/or operation of the DG will be borne by the owner of the DG facility.

Abnormal distribution system events will be addressed on an individual basis through the AEP system operator. Corrective action shall be based on the judgment of the AEP system operator. Possible corrective action can include but is not limited to DG isolation from the distribution system.

This review has been limited to items which may affect the AEP system or to suggestions which may improve operations. The Generator must take all necessary steps to assure compliance with all laws, ordinances, building codes and other applicable regulations. Approval of this connection by AEP, when granted, is not an endorsement of a particular design nor does it assure fitness to accomplish an intended function.

Any additional AEP work to mitigate power quality issues not foreseen by this study but associated with the interconnection will be at the sole cost and expense of the Generator.

Summary

Metering

The DG delivery into and out of the American Electric Power (AEP) system will be metered at 12.47 kV.

Communication

An AEP communication system will be installed to remotely monitor load and other quantities in real time as metered at the PCC for operational and planning purposes.

AEP System Improvements for Interconnection

- Station Improvements -
  - Reset the feeder regulator controls for the F-11002 circuit for co-generation mode.
  - Change the settings on the F-11002 feeder breaker relay to a three second reclose time (over current settings may also need to be changed to accommodate the Generator’s relaying as well as for the new recloser to be installed by AEP).
- Line Improvements -
  - Install communication equipment for the primary metering point and new recloser.
  - Install one primary metering installation with SCADA (see Figure 2).
  - Install three wood distribution poles (see Figure 2).
  - Install one three phase switch (see Figure 2).
  - Install 85 feet of three phase 12.47 kV primary (see Figure 2).
  - Install one 12.47 kV three phase recloser with SCADA (see Figure 2).
  - Re-conductor 3,200 feet of main line starting at the station in order to reduce voltage fluctuations (see Figure 2).
  - Change settings or replace control (whichever is required) on a line capacitor bank between the station and DG location.

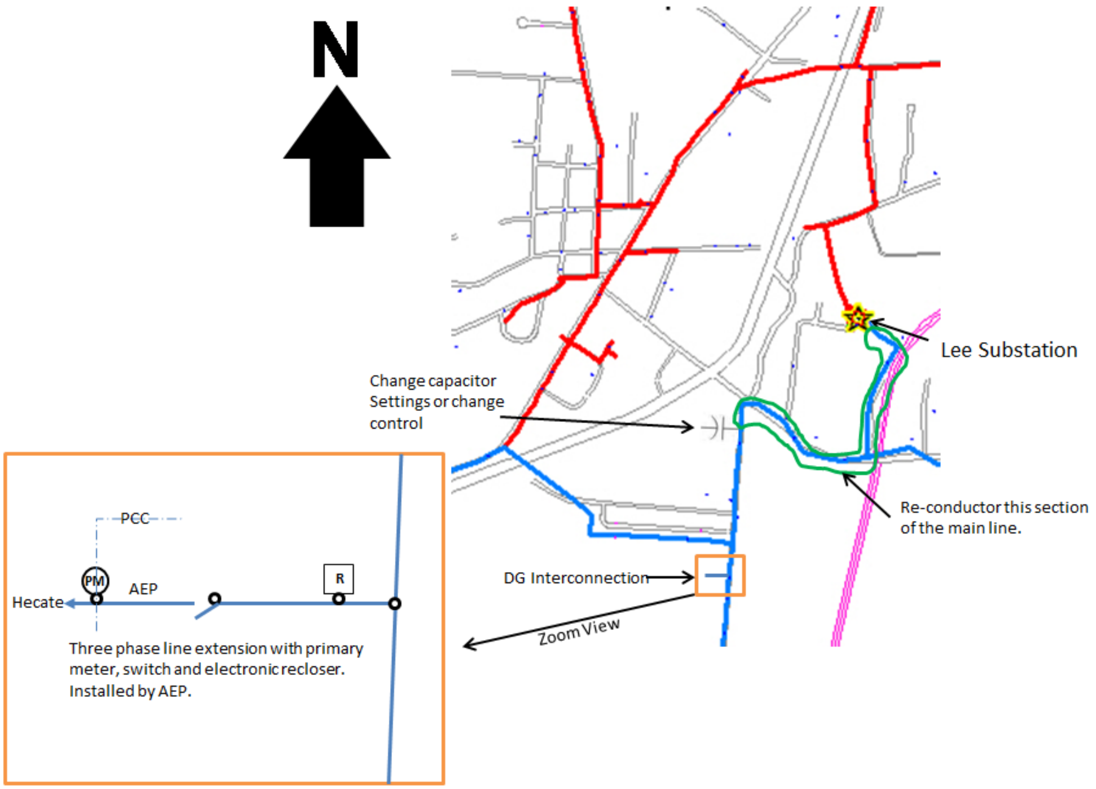

Figure 2

Additional Generator Requirements for Interconnection

The documentation for the inverter references compliance to IEEE 1547 but does not provide certification documents or the US testing authority used. The Ohio Administrative Code (OAC) specifies that certified compliance to IEEE 1547 is required. The Generator will need to provide either the certification documents for the inverters or perform testing in accordance with IEEE 1547.1. If testing needs to be done then AEP will need to provide additional information on that subject. Please note that AEP needs to approve any testing plan prior to testing being performed.

The Generator will need to provide overcurrent protection settings information to AEP so that a coordination study can be performed prior to giving approval to operate.

Due to the fact that the step-up transformers being used are wye-grounded on the high side and ungrounded wye on the low side, there is the strong potential for very unbalanced line to ground voltages to occur if the system becomes isolated from the utility source. These unbalanced voltages could cause damage to anything that would remain connected prior to operation of the anti-islanding mechanism. The protection scheme used on the 12.47 kV side of the Generator's installation must be designed to detect unbalanced line to ground voltage and operate quickly in the event of abnormal conditions.

Additionally:

A. AEP requires that the Generator install a group-operated load break disconnecting device located on their first structure beyond the PCC. The disconnecting device must be accessible to AEP personnel, suitable for use by AEP personnel at all times and suitable for use by AEP as a protective tagging location. The disconnecting device shall have a visible open gap when in the open position and be capable of being locked in the open position. Each disconnecting device must have a ground grid designed in accordance with specifications to be provided by AEP. Operation must be restricted to AEP personnel and properly trained operators designated by the Generator. The disconnecting device must comply with the applicable current ANSI Standard from the C37 series of standards that specifies the requirements for circuit breakers, reclosers and interrupting switches.
B. The Generator is required to install a three phase automatic isolating device (including a loss of phase protection scheme) beyond the aforementioned group-operated load break disconnecting device. This device will isolate faults on the Generator -owned 12.47 kV equipment. The Generator shall contact AEP Ohio Project Design to coordinate the device or other 12.47kV protective equipment with AEP protective settings.
C. Ground Current Sources - The Generator must have the capability to detect line-to-ground faults. The Generator shall provide adequate protection to comply with IEEE Standard 1547 to clear their generation source for all types of faults on the AEP system including any breaker failure event. Adequate protection requires that all fault types are cleared before equipment damage occurs to AEP facilities. If the Generator fails to provide adequate protection for faults on the AEP system, then the Generator will pay all costs associated with resulting facility damages.
D. Automatic Reclosing – Automatic high speed reclosing is applied to the transmission circuits supplying Lee Station. When any AEP source breakers trip and isolate the Generator’s facilities, the Generator shall ensure that their generation equipment is disconnected from AEP facilities in accordance with requirements established in IEEE Standard 1547 item 4.2 and all item 4.2 sub-items prior to automatic reclosing by AEP. Automatic reclosing out-of-phase with the Generator’s generation equipment may cause damage to the Generator’s equipment. The Generator is solely responsible for the protection of their equipment from automatic reclosing by AEP.
E. All synchronization of the Generator with AEP must be done by the Generator.
F. The Generator must inform AEP if they desire remote access to real time primary metering information at the time they indicate their desire to proceed with this project.
G. The Generator must ensure that it does not export or import reactive power (vars) to the extent that it would drive voltage at the PCC outside of the 114-126 volt limit for all system loading conditions.

Cost to the Generator

The conceptual cost estimate for the described work is approximately $250,000. Federal Gross-Up Tax, at the applicable rate, must be added to the total cost of the improvement estimated below.

Work	Estimated Costs
Metering and Communications	$75,000
Line reconductoring	$100,000
Interconnection tap including recloser and switch	$75,000
Total	**$250,000**

It is estimated that the process to design and build will take approximately nine to twelve months from the time an Interconnection Agreement (IA) is fully executed between AEP and the Generator.

Figure 3 – Approximate locations of Point of Common Coupling (PCC) and Point of Interconnection (POI)

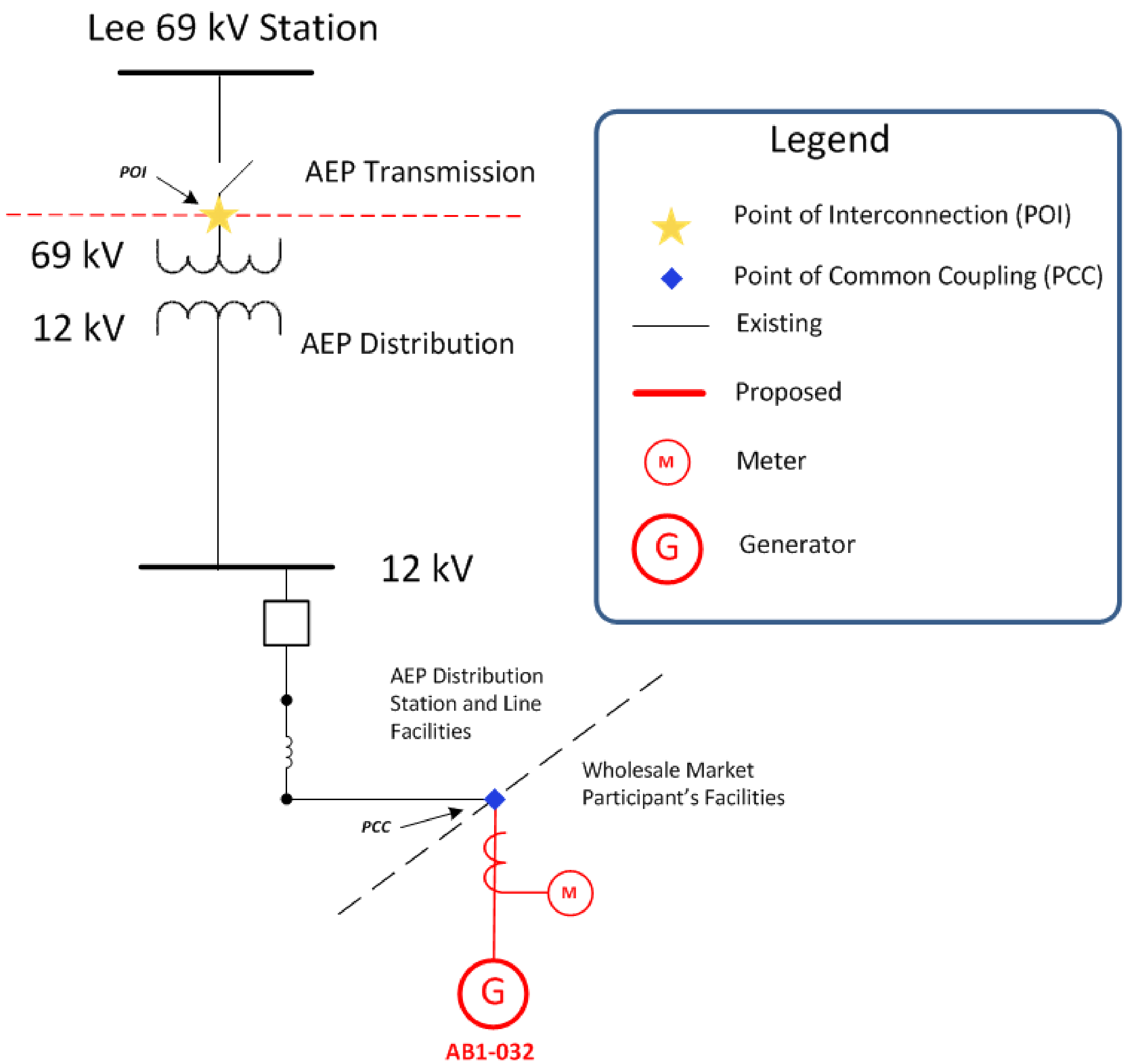

Figure 4 – Single Line Diagram

Part II – Transmission Planning Analysis and Results

Network Impacts

The Queue Project AB1-032 was evaluated as a 3.3 MW (Capacity 1.2 MW) injection at the Lee 69kV substation in the AEP area. Project AB1-032 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-032 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

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

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 - 2018

Not required

System 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

Short Circuit

(Summary form of Cost allocation for breakers will be inserted here if any)

None

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

Not required