PJM Generator Interconnection Request
Queue #X3-001
West Melrose (Edgewood) 12.47kV
Feasibility/Impact Study

683962
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X3-001 West Melrose (Edgewood) Feasibility/Impact Study Report

Request

OneEnergy Edgewood Findlay, LLC (Generator) has requested an interconnection Feasibility/Impact study through PJM for a solar-powered distributed generation (DG) facility capable of 1.82 MW maximum output power. The DG system consists of two sets of photovoltaic panels with one array feeding through four 260 kW inverters, and the other array feeding through three 260 kW inverters. The output of the first array will connect via underground cables to a 1000 kVA, .48/12.47 kV padmounted step-up transformer, configured grounded-wye/grounded-wye. The output of the second array will connect via underground cables to a 750 kVA, .48/12.47 kV padmounted step-up transformer, configured grounded-wye/grounded-wye. The output of the transformers will connect with underground cables to a riser pole, which then will connect to AEP's pole-mounted primary metering via a span of overhead wire. The primary metering pole will be the Point of Common Coupling (PCC) for the interconnection. AEP will install distribution facilities to interconnect the DG facility to its West Melrose Station, North 12 kV Circuit.

Disclaimer

The contents of this feasibility/impact study apply only to the system that includes the aforementioned generation equipment as described in the Generation Interconnection application. All modeling is based on the PCC being located near AEP pole location #41840501B10142, at the western end of Sheffield Drive, Findlay, Ohio, and interconnected as stated above.

Modeling and Assumptions

The West Melrose Station, North 12 kV Circuit 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 North Circuit is served from the 12 kV station bus via a 34.5/12 kV, 12/16/20 MVA transformer. There are three other distribution circuits fed from this bus, the South, East, and West 12 kV Circuits.

The North Circuit feeds north from West Melrose Station approximately .47 miles to the PCC location, using mainly overhead line construction. The main line to the PCC consists of approximately 100' of 750 kcmil aluminum station exit cables, and .46 miles of three-phase overhead line built with 3-556 kcmil aluminum and 1-#4/0 aluminum alloy conductors. It is constructed beneath the 34.5 kV subtransmission line that feeds West Melrose Station.

Generator Provided Information

The Generator submitted the following information in addition to the information contained in their application for interconnection, via subsequent email correspondence:

The inverters will operate at or very near unity power factor.

The Generator revised their specification for transformer connections on January 6, 2012 from delta/grounded-wye to grounded-wye/grounded-wye to be more compatible with AEP system design. Impedance of the transformers is 5.75%.

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The Generator did not have their facility interconnecting cable sizes or lengths determined as yet, so rough estimates of these components were assumed for now based on AEP cable characteristics.

The Generator has stated that the maximum fault current contribution of the inverters, as a percentage of full load current, is 268%.

The Advanced Energy Industries Powervault PVP260kW inverters are IEEE1547 compliant and certified according to their published literature. They are designed to meet or exceed UL1741-2005 which includes testing for IEEE1547.1-2005.

AEP Fault Values and Thevenin Impedances

The following are bolted AEP symmetrical fault values and Thevenin impedances calculated at the PCC without the DG facility connected.

Fault values and impedances are for a 12.47/7.2 kV system. System voltage can vary +/-5%.

- LLL = 4736 A LG = 4388 A
- Z1 = Z2 = 0.2013 + j 1.5877 ohms
- Z0 = 0.3554 + j 1.9502 ohms

Analysis

System Load Flows

With the DG at full output, and peak load conditions on the North Circuit, the DG will supply a portion of the North Circuit load. With the DG at full output, and light load conditions on the North Circuit, the DG will carry the entire North Circuit load and supply power into the West Melrose Station 12 kV bus. Under this condition, if one of the other West Melrose Station circuit breakers opens during a contingency, the DG will not supply enough power to cause a reverse power flow into the station transformer or 34.5 kV subtransmission bus.

Circuit modeling indicates that this DG will not produce adverse load flow conditions on the AEP distribution system.

System Voltage Levels

The Generator indicated that the DG will be controlled to operate at or very near unity power factor. The circuit models have indicated that voltage levels on AEP facilities will be within the acceptable limits of 120 volts +/- 5% (114 volts to 126 volts) with the DG at unity power factor, during peak and light load conditions. There may be certain operating conditions that may necessitate the Generator adjust taps on their equipment to avoid voltages outside this range on their equipment.

It is anticipated that the output of the solar facility will vary significantly during periods of clouds and sun, and this will affect the West Melrose Station 12 kV bus 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. Other sources indicate that this interval could be as low as 4 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 1.82 MW output during both peak and light circuit loading conditions (light loading was 19% of

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peak loading). The station transformer Load Tap Changer (LTC) was 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 at the PCC for the above cases was 0.48%. A 0.48% voltage change over 33 sec is not expected to be perceptible to AEP customers, but because the worst case cloud transient ramp rate is unknown, it is not possible to determine with certainty if cloud transients will cause a perception of voltage fluctuation to AEP customers.

System Fault Levels and Overcurrent Protection

The addition of this DG equipment will not subject AEP overcurrent protection devices to excessive fault current. The small fault contribution increase caused by the DG will not necessitate recoordination of AEP protective circuit devices. However, the Generator's final selection of a main protective device, now shown as 100 amp fuses, will need to be coordinated with the North Circuit breaker control settings.

System Protection

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

1. Abnormal voltage or frequency
2. Loss of a single phase of supply
3. Equipment failure
4. Distribution system faults
5. Lightning
6. Excessive harmonic voltages
7. Excessive negative sequence voltages
8. Separation from supply
9. 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.

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.

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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.

The Generator is within the North Circuit breaker zone of protection. AEP reclosing interval times for the circuit breaker control are 3 seconds to the first reclose and 20 seconds to the second reclose. These reclose times provide adequate time for the Generator to sense, initiate action, and disconnect from the circuit per the IEEE 1547 abnormal electric distribution system specification before any AEP distribution reclose action occurs.

Summary

AEP System Improvements for Interconnection

The proposed interconnection will require the following improvements to AEP facilities:

1. Relocate the capacitor bank presently on AEP pole #41840501B10142 one span north in order to create a tap pole.
2. Construct approximately 100' of overhead 12 kV distribution pole line using 3-556 kcmil. Al. and 1-#4/0 AA conductors from the tap pole to a new AEP primary metering pole which will be the PCC.
3. Install a three-phase 12 kV primary metering installation.
4. Install a communication system to tie the AEP primary metering into the AEP remote data monitoring system.
5. Recoordinate the North Circuit overcurrent protection scheme to incorporate the Generator's 12 kV main fuses.

Metering

The DG delivery into and out of the AEP system will be metered at 12.47 kV. AEP will install a new 12 kV primary metering installation (dual meter) at the PCC for ancillary load billing and operational monitoring.

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.

Simplified One-Line Diagram

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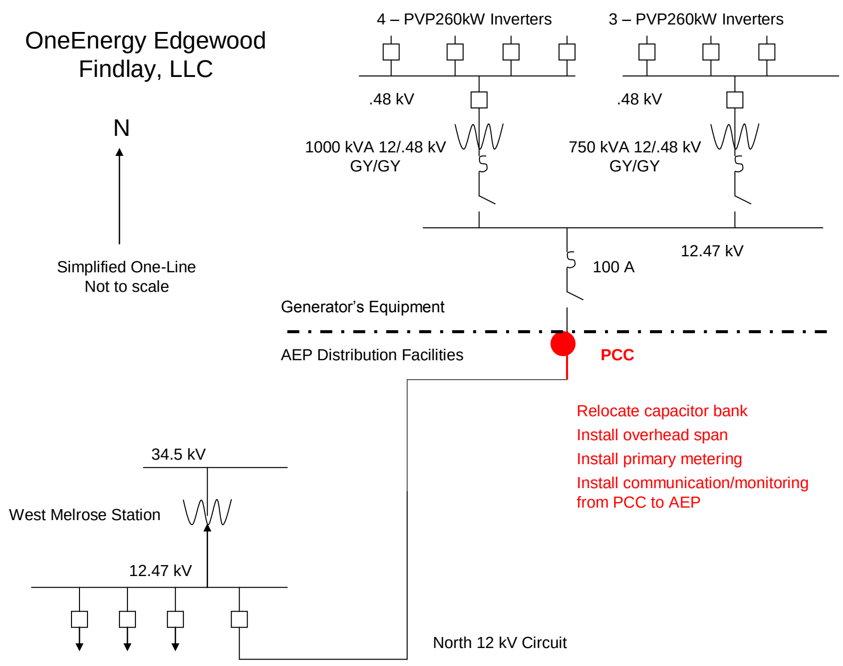

Additional Generator Requirements for Interconnection

The Generator must meet all the requirements in the AEP GUIDE TO THE INTERCONNECTION OF DISTRIBUTED RESOURCES TO THE AEP DISTRIBUTION SYSTEM. Additionally, the Generator must meet the following requirements.

A. A final Distribution Impact Study may be required prior to confirming the interconnection agreement with the Generator.
B. It is requested that the Generator's 1000 kVA and 750 kVA grounded-wye/grounded-wye transformers be of a five-legged Core Form design or a Shell Form design.
C. The Generator shall terminate its overhead line on the AEP primary metering structure utilizing dead-end insulators provided by AEP.
D. AEP requires that the Generator install a group-operated load break disconnecting device located on their first structure. In this case the Generator has indicated the use of a three-pole gang operated disconnect switch. The disconnecting device must be accessible to AEP personnel, must be suitable for use by AEP personnel at all times and must be 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 interconnection customer. 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.
E. Ground Current Sources - The Generator must utilize protective relays to detect line-to-ground faults. The Generator shall provide adequate protection to comply with IEEE

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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 AEP facility damages.

F. Automatic Reclosing – Automatic high speed reclosing is applied to the transmission circuits supplying West Melrose 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 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.
G. All synchronization of the Generator with AEP must be done by the Generator.
H. 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.
I. The Generator has indicated that they will maintain output at unity power factor. 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. The Generator may be asked by AEP to export or import reactive power to support system conditions.
J. Underfrequency control settings on the North Circuit breaker control may need to be adjusted to accommodate this DG.

Cost to the Generator

The conceptual estimate for the cost of AEP improvements previously described is **$74,000**.

Federal Gross-Up Tax, at the applicable rate, must be added to the total cost of the improvements.

It is estimated that the process for AEP to design and construct these improvements will take approximately six to nine months from the time an agreement is reached between AEP and the Generator to proceed.

Network Impacts

The Queue Project #X3-001 was studied as a(n) 1.8MW(Capacity 0.7MW) injection at West Melrose 34.5 substation in the AEP area. Project #X3-001 was evaluated for compliance with reliability criteria for summer peak conditions in 2015. Potential network impacts were as follows:

Potential transmission network impacts are as follows:

Generator Deliverability

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

No problems identified

Multiple Facility Contingency

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

No problems identified

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

No problems identified

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

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)

No problems identified.

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