Generation Interconnection Feasibility Study Report (Web Version)

For

PJM Generation Interconnection Request Queue Position W4-022

Hunterstown 230 kV Project

June, 2011

Introduction

This Feasibility Study report provides the documentation of a system assessment performed by PJM Interconnection and FirstEnergy (FE) in response to a request made by Interconnection Customer for the connection of a solar power project with a total capability of 100 MW to the Met-Ed Transmission network. This assessment was accomplished by: 1. Evaluating the reliability impact of the proposed facilities and connection on the interconnected transmission system by the performance of a power flow study; 2. Ensuring compliance with the NERC, ReliabilityFirst, PJM and FE Reliability Standards by identifying the system reinforcements that will need to be installed for an interconnection of the proposed project; 3. Coordinating and cooperating with the PJM staff and Interconnection Customer by conducting meetings and issuing this report as a part of the PJM Generation Interconnection study process; 4. Performing a Steady State, Short-Circuit and Dynamics Study as necessary; 5. Conducting all studies in accordance with the PJM Manuals and the "FE Requirements for Transmission Connected Facilities" documents to assure that the assessment performed incorporates study assumptions, follows the documented system performance procedures, considers alternative connection and reinforcement plans, and jointly coordinates the study recommendations.

Connection Facilities

In compliance with the PJM Generation Interconnection protocol, Interconnection Customer has submitted a "Form of Generation Interconnection Feasibility Study Agreement" to PJM that identifies its plan to construct a Hunterstown 230 kV Generation Project comprised of photo-voltaic solar panels and inverters on two plots of land in Pennsylvania. The installed facilities will have a total capability of 100 MW with 38 MW of this output being recognized by PJM as capacity. This means that the remaining 62 MW will be subject to curtailment should a system reliability constraint occur. The proposed in-service date for this Hunterstown 230 kV Project is Dec 21, 2014.

The Interconnection Customer will be responsible for constructing a radial attachment line from the W4-022 230 kV solar collector bus to the chosen point of interconnection. The Interconnection Customer may not install above ground equipment within any FirstEnergy right-of-way unless permission to do so is expressly granted by FirstEnergy. The Interconnection Customer will also be responsible for constructing as a minimum requirement, a three breaker ring bus substation along the interconnected line if the primary POI option is chosen, or a breaker and a half scheme at the Hunterstown 230 kV substation for the project attachment if the secondary POI option is chosen.

Interconnection Customer will be responsible for constructing all of the facilities on its side of the point of interconnection including the attachment line.
No cost estimate is furnished for the secondary interconnection option.

PJM Report on the Transmission System

This portion of the report addresses the impacts on and the required reinforcements to the transmission system under direct PJM jurisdiction.

Network Impacts

Queue project W4-022 was studied as a 100.0 MW (38.0 MW of which was Capacity) injection into METED's system. Project W4-022 was evaluated for compliance with reliability criteria for summer peak conditions in 2014.

Option 1: HUNTRSTN 230.0 kV substation

Potential transmission network impacts are as follows:

Generator Deliverability

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

No violations identified.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies only with full energy output. Stuck Breaker and Bus Fault contingencies will be applied during the Impact Study)

No violations 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.)

No violations identified.

New System Reinforcements

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

None required.

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.)

None required.

Short Circuit

PJM has completed the short circuit analysis of the W4-022 queue project Huntertown 230 kV. One option was considered during this study: the option was a direct connection to Huntertown 230 kV Substation. Our analysis found no new breakers to be over-duty in the METED transmission area.

The study also showed no significant fault current contribution (i.e. above 3%) for the already identified over-duty breakers. This study was performed on the 100 kV and above system.

Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of the surrounding generation. Any potential 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 Transmission Interconnection request.

Note: *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 analyzes all overload conditions associated with the overloaded element(s) identified. As a result of the aggregate energy resources in the area, the following violations were identified.*

No violations identified.

Option 2: HUNTRSTN 230.0 kV substation

Potential transmission network impacts are as follows:

Generator Deliverability

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

No violations identified.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies only with full energy output. Stuck Breaker and Bus Fault contingencies will be applied during the Impact Study)

No violations 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.)

No violations identified.

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

None required.

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.)

None required.

Short Circuit

None required.

Energy Portion of Interconnection Request
PJM also studied the delivery of the energy portion of the surrounding generation. Any potential 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 Transmission Interconnection request.
Note: *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 analyzes all overload conditions associated with the overloaded element(s) identified. As a result of the aggregate energy resources in the area, the following violations were identified.*

No violations identified.

FirstEnergy Feasibility Analysis Report

This portion of this Feasibility Study Report has been prepared for PJM queue project W4-022 by FirstEnergy. It addresses the impacts on and required reinforcements to that portion of the network at the distribution level, including the attachment and direct connection facilities.

Power Flow Analysis

A Power Flow study was conducted to determine the reliability impact of the proposed Hunterstown 230 kV Project on the FE Transmission System. This study was completed using a 2014 summer peak load power flow that contains a detailed representation of the Met-Ed transmission networks in the area of the proposed Hunterstown 230 kV Project. The findings and the recommendations from this analysis are based on a contingency review that was performed to identify the facility loadings and/or voltage conditions that violate the ReliabilityFirst, PJM or FE Planning Criteria and are attributable to this project. Note that in accordance with PJM Generation Interconnection study procedures, this Hunterstown 230 kV queue project under study and earlier active queue projects are considered to be in service. Therefore, all active queue projects after (W4-022) are considered not in service.

For the primary choice interconnection option the Hunterstown 230 kV Project is in service for a total of 100 MW (38 MW capacity) connected to the three breaker ring bus along the interconnected line. The results of the FE analysis show that there are no network upgrades required for the deliverability of the Hunterstown 230 kV Project generation to the Met-Ed transmission system. The results from the study Power Flow Analysis showing a comparison of the FE and PJM contingency study results is detailed on Attachment 4. As shown, there also are no reinforcements defined for previous projects for which this project will have an impact, and there are no new upgrades required for the Hunterstown 230 kV Project.

For the second choice interconnection option the 100 MW Hunterstown 230 kV project is connected to a breaker and a half scheme within the Hunterstown 230 kV substation. The results of the FE analysis show that there are no network upgrades required for the deliverability of the Hunterstown 230 kV Project generation to the Met-Ed transmission system. The results from the study Power Flow Analysis showing a comparison of the FE and PJM contingency study results is detailed on Attachment 4. As shown, there also are no reinforcements defined for previous projects for which this project will have an impact, and there are no new upgrades required for the Hunterstown 230 kV Project.

However, voltage criteria violations such as high voltage under light load conditions and high and low voltages caused by swings in MW output of the attached generation may result in curtailment of the energy portion of the Hunterstown 230 kV Projects at times.

Note that a further conclusion of this study is that it will be mandatory for the Hunterstown 230 kV Project to have a range of dynamic reactive capability that supports its operation from a .95 lead to .90 lag power factor. Without a continuous regulation, the FE studies show that the addition of solar projects can cause voltage swings as their output oscillates with moving clouds and system voltages that can exceed the established limits. Should Interconnection Customer fail

to provide a dynamic reactive capability from the Hunterstown 230 kV Projects for any reason once interconnected, the Met-Ed and/or PJM Dispatchers may need to take action to curtail both the energy and capacity portion of its output to prevent a non-compliance with voltage criteria.

Short Circuit and Dynamics Analysis

A short circuit analysis was conducted by PJM and confirmed by the FE Protection staff. An assumption of this study was that solar generation projects will contribute no appreciable fault current to the breakers on the FE transmission system. As defined by EPRI: "Inverters are generally designed to limit fault currents to 130% or less of rated current. Thus they can usually be disregarded when conducting fault studies."1 Based on this fact, the results of the FE analysis showed that no FE circuit breaker will exceed its interrupting capability with the implementation of the Hunterstown 230 kV Project. Therefore no circuit breaker reinforcements will be required.

Note that stability studies will be conducted by the PJM staff should this project proceed to the Impact Study stage of the PJM Generation Interconnection process.

System Protection Analysis

An analysis was conducted to assess the impact of the Hunterstown 230 kV Project on the system protection requirements in the area. The results of this review have identified the following:

New W4-022 Substation (Install the following equipment)

Line to Jackson:

Protection

- SEL - 311C Prim Primary Protection (Carrier) DCB
- SEL - 321 Backup Line
- SEL - 352 Breaker Failure

Communication and metering equipment

- Wave Trap (Tuned to 73 kHz carrier & 127 kHz DTT freq)
- Line Tuner
- RFL 9785 (For DCB carrier) Include Carrier Checkback module
- RFL 9780 (TX/TX DTT and BF at W4-022 to Jackson)
- Set of 230kV CCVT's (Sync Check and Carrier Signal)
- SATEC meter

DTT frequencies

[1] EPRI Document TR-111490 "Integration of Distributed Resources in Electric Utility Distribution Systems: Distribution System Behavior Analysis for Suburban Feeder", published November 1998, page 62

- TX/TX (126.5kHz)/(127.5kHz) (TX/TX DTT to Jackson)

Line to Hunterstown:

Protection
- SEL - 311L Prim Primary Protection (Line Differential , BU Mho and DTT)
- SEL - 387L Backup Protection (Line Differential)
- SEL - 352 Breaker Failure

Communication and metering equipment
- Fiber connection to Hunterstown Two independent fiber optic cables required.
- Set of 230kV CCVT's(Sync Check)
- SATEC meter

Shared Line Breaker:

Protection
- SEL - 352 Breaker Failure
- SEL – 351A Reclosing (Shared Breaker – and Sync Check)

Generation Line Exit:

Protection
- SEL - 311L Prim (Line exit , B.U. Mho and DTT)
- SEL - 387L B.U. (B.U. Line exit Protection)

Communication and Metering Equipment
- Fiber connection Two independent fiber optic cables required.
- 230 kV PT's or CCVT's (Sync Check and B.U Mho element into plant via 311L)

Substation equipment

- Cooper Cybectec communications processor, and compatible modem with cables
- Arbiter Systems, Inc., GPS satellite-controlled clock Model 1094B with option 1094OPT10
- Required cabling to connect new SEL devices to the communication processor

RTU
- Remote Control and Indication of substation equipment is required (RTU)

<u>Existing Jackson Substation</u>

Line to W4-022:

Protection (New equipment to be installed)

- SEL - 311C Prim Primary Protection (Carrier) DCB
- Remove existing primary line relaying

Protection (Existing equipment to be utilized)

- SEL 352 Breaker Failure
- SEL 279H2 Reclosing (Sync Check)
- Utilize existing back up line relaying

Communication and Metering Equipment (Existing equipment to be utilized)

- Wave Trap (Tuned to 73 kHz and 127 kHz DTT Freq)
- Line Tuner
- SEL 2020 communication processor and Arbiter GPS clock
- 230kV PT and CCVT (Sync Check)

Communication and Metering Equipment (New equipment to be installed)

- RFL 9785 (For DCB carrier) Include Carrier Checkback module)
- RFL 9780 (RX/RX DTT and BF from W4-022)

TT frequencies

- RX/RX (126.5kHz)/(127.5kHz) (RX/RX DTT and BF from W4-022 via 9780)

Substation equipment

- Required cabling to connect new SEL devices to the existing 2020 communication processor

Existing Hunterstown Substation

Line to W4-022:

Protection (New equipment to be installed)

- SEL - 311L Prim Primary Protection (Line Differential, BU Mho and DTT)
  DTT – utilized for breaker failure
- SEL - 387L Backup Protection (Line Differential)
- SEL - 351A Reclosing (Sync Check)

Protection (Existing equipment to be utilized)

- SEL 352 Breaker Failure (Reuse the existing)

Communication and metering equipment (New equipment to be installed)

- Fiber connection to W4-022 Two independent fiber optic cables required.
- Set of 115kV CCVT's(Sync Check)
- SATEC meter

Substation equipment

- Cooper Cybectec communications processor, and compatible modem with cables
- Arbiter Systems, Inc., GPS satellite-controlled clock Model 1094B with option 1094OPT10
- Required cabling to connect new SEL devices to the communication processor

Customer owned W4-022 Substation (customer responsibility)

Generation line exit

Protection

- SEL - 311L Prim (Line exit , B.U. Mho and T.T.)
- SEL - 387L B.U. (B.U. Line exit Protection)

Communication and metering equipment

- Fiber connection Two independent fiber optic cables required.
- PT's or CCVT's (Sync Check and B.U Mho element into plant via 311L)

Under the assumption that the Hunterstown 230 kV Project generation will not supply fault current to the Met-Ed transmission system, there will be no protection upgrades needed due to short circuit duty for the proposed project primary connection to the Hunterstown – Jackson (2053) 230 kV line.

Fault currents at the new Hunterstown 230 kV Project substation are listed below:

Three phase : 11,191 amperes (X/R = 45.992)
Line-to Ground: 10,284 amperes (X/R = 30.258)

These values are for the current system configuration. Any system changes in the area could have a significant impact on these values. It will be a Interconnection Customer responsibility to make any protection upgrades required should this occur.

Metering

Interconnection Customer will be required to comply with all FE Revenue Metering Requirements for Generation Interconnection Customers. These FE requirements are detailed on Attachment 7 of this report..

Compliance Issues

The proposed interconnection facilities must be designed in accordance with the FirstEnergy "Requirements for Transmission Connected Facilities" located at:

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

This includes the provision of a reactive power capability sufficient to maintain a composite power delivery for the facility at the interconnection point at a power factor between .95 leading (absorbing 6.6 MVAR) and .90 lagging (producing 9.7 MVAR). If this capability cannot be provided by the solar units, a 9.7 MVAR STATCOM or SVC device must be installed at the Hunterstown 230 kV Project substation at Interconnection Customer's cost.

Interconnection Customer will also be responsible for following the requirements of the "FirstEnergy Wholesale Generation Interconnection (WGI) Manual" and the FE Approved Vendors and Contractors" documents which are also located at the above link.

Interconnection Customer will also be required to meet all PJM, ReliabilityFirst and NERC reliability criteria and operating procedures for standards compliance. For example, the Developer will need to properly locate and report the over and under-voltage and over and under-frequency system protection elements for its units as well as the submission of the generator model and protection data required to satisfy the PJM and ReliabilityFirst audits. Also, the developer will need to provide documentation that its inverters meet the requirements of UL1741 and IEEE Standard 929. Failure to comply with these requirements may result in a disconnection of service if the violation is found to compromise the reliability of the FE system.

FE Facility Upgrades and Costs

The results of the FE analysis shows that no planning criteria violations are attributable to the addition of the Hunterstown 230 kV Project for the conditions studied. Therefore the conclusion is that no transmission or distribution reinforcements will be required to provide the requested service.

Interconnection Customer Requirements

In addition to the FE facilities, Interconnection Customer will also be responsible for meeting all criteria as specified in the applicable sections of the "FE Requirements for Transmission Connected Facilities" document including:

1. The purchase and installation of the minimum required FE generation interconnection relaying and control facilities. This includes over/under voltage protection, over/under frequency protection, and zero sequence voltage protection relays.

2. A compliance with the FE and PJM generator power factor and voltage control requirements. Note that the Hunterstown 230 kV Project may need to absorb reactive power at the point of interconnection to minimize the voltage change should the units rapidly reduce their output or trip off line.

3. The execution of a back-up service agreement to serve the customer load supplied from the Hunterstown 230 kV substation when the units are out-of-service. This assumes the intent of Interconnection Customer is to net the generation with the station load.

4. Any complaints from other customers (e.g. flicker complaints) will have to be corrected by Interconnection Customer Correction may include changing operation, reducing generation, disconnecting the generators from the Met-Ed system, or other measures.

5. The purchase and installation of supervisory control and data acquisition (SCADA) equipment to provide information in a compatible format to the FE Transmission System Control Center. The RTU, the communications channel and all related equipment will be furnished and maintained by Interconnection Customer. The RTU must communicate with the FirstEnergy EMS via DNP 3.0 protocol.

6. The following status and metering points will be required:
   a. Interconnection breaker position.
   b. Generator real and reactive power output measured at the high-side of the generator step-up transformer.
   c. Generator voltage at the point of interconnection.

7. An installation of two independent high-speed zones of protection to sense and clear faults on the interconnection transformer.

8. A compliance with the inverter standard UL1741 and IEEE 1547, "Standard for Interconnecting Distributed resources with Electrical Power Systems", in addition to the power quality standards defined by ReliabilityFirst and PJM.

9. A provision of the necessary generator protection, synchronization controls, and fault detection to initiate a trip to protect the Hunterstown 230 kV Project equipment from faults on the Met-Ed System.

10. A compliance with the PJM Manuals and Operating instructions to have a plant operator on call 24/7 to respond within a minute to reduce the output of Hunterstown 230 kV Project when network constraints occur.

11. Interconnection Customer will not excavate, construct facilities or locate solar panels under FE transmission facilities or on FE right-of-ways without the express permission of FE.

12. The purchase and installation of the standard voice grade (analog) telephone line and associated conduit between the telephone company source and the meter socket or enclosure.

The above requirements are in addition to any metering or other requirements imposed by PJM and are applicable to both the primary choice and second choice

Note that an assumption of this study is that the Hunterstown 230 kV Project generation will automatically be disconnected whenever the local area network is islanded. If this assumption is not correct, a direct transfer trip scheme will need to be implemented for such situations at Interconnection Customer's cost.

Generation Connection Requirements

The proposed interconnection facilities must be designed in accordance with the FirstEnergy "Requirements for Transmission Connected Facilities" located at:

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

The Interconnection Customer will also be responsible for following the requirements of the "FirstEnergy Wholesale Generation Interconnection (WGI) Manual" and the "FE Approved Vendors and Contractors" documents which are also located at the above link.

Summary

The connection of the Hunterstown 230 kV Project to the FE transmission system will require no network upgrades regardless of whether the primary POI or alternate POI is chosen. Therefore Interconnection Customer will only have a cost responsibility for the Direct Connection of the Hunterstown 230 kV Project to the Met-Ed transmission system. The estimated cost of the facilities for the primary connection to the interconnected line is $6,857,000. No cost estimate is provided for the second choice POI, the Hunterstown 230 kV substation.

Based on the extent of the FE direct connection and system upgrades required to support this project, it is estimated that it will take two (2) years from the date of a fully executed Interconnection Construction Service Agreement to complete the upgrades required for the Hunterstown 230 kV Project. This includes the requirement for Interconnection Customer to make a preliminary payment to FE which funds the first three months of engineering design that is related to the construction of the Direct Connection facilities. It further assumes that Interconnection Customer will provide the property for the attachment and right-of-way facilities that will be needed. A further assumption is that there will be no environmental issues with any of the new properties associated with this project, that there will be no delays in acquiring the necessary permits for implementing the defined direct connection and network upgrades, and that PJM will allow all 230 kV transmission system outages when requested.

Note that the FE findings were made from a conceptual review of this project. A more detailed review of the connection facilities and their cost will be identified in the Facilities Study. Further note that the cost estimate data contained in this document should be considered as only ballpark since it was produced without a detailed engineering review. The applicant will be responsible for the actual cost of construction. FE herein reserves the right to return to any issues in this document and, upon appropriate justification, request additional monies to complete any connections to the transmission system.

FE CONTINGENCY ANALYSIS RESULTS

Attachment 4

Hunterstown 230 kV (W4-022) Feasability Study

FE Contingency Analysis Results

Identified New Project Upgrades

				FirstEnergy Results		PJM Results	
Type	Outage Description	Overloaded Element	N/4-Hr Rating	MVA Flow	% Rating	MVA Flow	% Rating
		No Problems					

Contributions To Previously Identified Overloads

				FirstEnergy Results		PJM Results	
Type	Outage Description	Overloaded Element	N/4-Hr Rating	MVA Flow	% Rating	MVA Flow	% Rating
		No Problems					

Potential Congestion due to Local Energy Deliverability

				FirstEnergy Results		PJM Results	
Type	Outage Description	Overloaded Element	N/4-Hr Rating	MVA Flow	% Rating	MVA Flow	% Rating
		No Problems					

FirstEnergy Revenue Metering Requirements for Generation Facilities Connected 69 kV and Higher

This document addresses the revenue metering requirements for new generation-only facilities connected to FirstEnergy (FE) system voltages 69 kV and higher. This document is not intended for existing retail or wholesale load facilities where behind-the-meter generation is being installed.

The Interconnection Customer (IC) shall install, own, operate, test, and maintain the necessary revenue metering equipment. This includes current transformers, voltage transformers, mounting structures, wiring, meters, communication circuits, and associated devices. The metering equipment must meet the specifications listed in the FE and PJM connection documents.

The revenue metering equipment shall be located at the generation facility on the high voltage side of the generator step-up transformers or facility main step-up transformer and/or station service power transformers. Power flows to and from the facility shall be compensated to the Point of Interconnection.

FE will provide revenue metering equipment for a station service power supply at a generation facility if the supply is from the local FE distribution system.

The revenue metering equipment shall be capable of collecting and storing bidirectional billing data. The billing data shall be stored in intervals specified by FE, typically fifteen minutes or thirty minutes. The IC must provide FE with remote access to the billing data in the revenue meter via a dedicated voice-grade analog telephone circuit. The IC shall provide FE with contact information for the person or persons responsible for meter programming and metering equipment maintenance.

The IC shall consult with FE regarding the revenue metering system design and provide the following information:

- Facility one line and revenue metering installation drawings (schematics, wiring diagrams, etc.)
- Estimated power flows to and from the facility at all revenue metering points
- Current transformer and voltage transformer specifications, including manufacturer, type, nameplate drawings, and certified accuracy test reports
- Revenue meter specifications including manufacturer, type, model number, and accuracy
- Revenue meter program information including but not limited to billing data recorder channel assignments, recorder pulse weights (Ke), and read-only password for access to interval data by the FE billing data collection system (MV-90)
- Revenue meter telephone number
- Revenue meter loss compensation data (if applicable)

The IC shall provide FE with prior notification of any modifications at the facility that will affect the revenue meter measurements, including substation reconfigurations and meter program changes.

The revenue metering system at each location shall be tested for accuracy by the IC once every two years. The IC shall give reasonable notice to FE of the time when the testing is scheduled so that FE may have representatives present. FE and PJM shall have the right to audit the revenue metering equipment and/or related documents. The IC shall be given a reasonable period of time to comply with any requests associated with an audit.