# *Generation Interconnection Feasibility Study Report*

***For***

# *PJM Generation Interconnection Request Queue Position W3-044*

# *Washington 34.5kV*

**January 2011**

# Preface

The intent of the feasibility study is to determine a plan, with ballpark cost and construction time estimates, to connect the subject generation to the PJM network at a location specified by the Interconnection Customer. The Interconnection Customer may request the interconnection of generation as a capacity resource or as an energy-only resource. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system.

In some instances a generator interconnection may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection, 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 impact study is performed.

The Feasibility 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

The Interconnection Customer (IC) has identified a plan to construct a generation project comprised of photo-voltaic solar panels and inverters on a plot of land at 30 McCullough Road, Warren County, New Jersey (Attachment 1). The installed facilities will have a total capability of 20 MW with 7.6 MW of this output being recognized by PJM as capacity. This means that the remaining 12.4 MW will be curtailable should a system reliability constraint be declared by either PJM or FE when peak load conditions occur. At all other times the project will be subject to the economic and reliability dispatch procedures as defined in the PJM Manuals. This includes the potential for a curtailment of the entire Project output during off peak periods. The proposed in-service date for this W3-044 Project is December 31, 2011.

## Point of Interconnection

W3-044 will interconnect with the Jersey Central Power & Light system at one of two options. The Primary Point of Interconnection was identified as the 34.5kV line Q719 between the Washington and Mobile Chemical substations. The Secondary Point of Interconnection was identified as a 4.8kV circuit from the Washington substation.

# First Energy Analysis and Impacts

As defined by the Interconnection Customer and shown on Attachment 2, the attachment of the W3-044 Project will be made by a looped connection from the Washington - Mobil Chemical section of the Washington - Mobil Chemical - Port Murray - Cooke Color - Newburgh Tap - Pohatcong (Q719) 34.5 kV line to a new three breaker ring bus substation. It will start at a pole that is east of the Washington 34.5 kV substation. From this point Jersey Central will construct a new double circuit 34.5 kV line will be over built on an existing 4.8 kV Distribution path that will extend south. In compliance with the FE Connection Requirements, a new 34.5 kV three breaker ring bus substation will be constructed for the W3-044 Project attachment. As information, a typical 34.5 kV substation requires a plot of land about 150 x 150 foot excluding any setback requirements. A conceptual one-line diagram for the new 34.5 kV substation and its connection are shown on Attachment 3. While FE will construct, own and operate the new 34.5 kV substation and the facilities required for its attachment to the FE system, the Interconnection Customer will be responsible for acquiring all easements, properties and permits that will be needed. The Interconnection Customer will also be responsible for providing a level graded site for the new 34.5 kV substation and an access road as a prerequisite before work can begin. A summary of the W3-044 Project Direct Connection facilities that will be required and their estimated cost are shown on Attachment 4.

Note that the Interconnection Customer has requested a 12.5 kV secondary point of interconnection at a 4.8kV circuit sourced from the Washington substation for study. The Jersey Central Region has reviewed this alternative and concluded that it is not feasible. At a minimum this option will require an expansion of the Washington substation to a ring bus configuration, the installation of dedicated 34.5/12.5 kV distribution transformers, and the construction of at least three new 12.5 kV lines to the project site on new right of ways. While no cost estimate has been developed, it is expected to exceed that of the 34.5 kV connection alternative. If the Interconnection Customer decides to pursue this option, it must provide a definition of the new right of ways from the Washington substation to the project site that it will provide as a prerequisite to the Impact Study.

## Power Flow Analysis

A Power Flow study was conducted to determine the reliability impact of the proposed W3-044 Project on the FE Transmission System. This study was completed using a 2012 summer peak load power flow that contains a detailed representation of the Jersey Central transmission networks in the area of the proposed W3-044 Project. Note that the year 2012 was chosen for study rather than 2015 since this is the first summer period when the W Queue solar projects are scheduled for service. 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 Reliability*First*, PJM or FE Planning Criteria and are attributable to this project.

The results of the FE analysis show that there are no network upgrades required for the deliverability of the W3-044 Project generation to the Jersey Central and PJM transmission systems. There also are no reinforcements defined for previous projects for which this project will have an impact. However, there are numerous solar generation projects proposed in the vicinity of the W3-044 Project that will cause system constraints. Specifically, the FE study

results show that the Q719-1 34.5 kV line can be overloaded by 2.5% with the W3-044 Project modeled. In addition, there is the potential for high voltage during light load periods and voltage criteria violations due to swings in the MW output of the cumulative attached solar generation. A conclusion of this analysis is therefore that the curtailment of the W3-044 Project output can be expected at times to maintain the Jersey Central system reliability within the NERC, Regional and FE operations and planning standards.

Note that a further conclusion of this study is that it will be mandatory for the W3-044 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 the Interconnection Customer fail to provide a dynamic reactive capability from the W3-044 Project for any reason once interconnected, the Jersey Central 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

In accordance with the Interconnection process, a short circuit analysis will not be conducted by PJM since the W3-044 Project connection is to the 34.5 kV system. Therefore, the FE Protection staff conducted a short circuit review of the project connection. An assumption of this study is 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 W3-044 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 Facilities Study stage of the Interconnection process.

## System Protection Analysis

An analysis was conducted to assess the impact of the W3-044 Project on the system protection requirements in the area. The results of this review have identified the following:

Under the assumption that the W3-044 Project generation will not supply fault current to the Jersey Central transmission system, there will be no protection upgrades needed for the Washington – Pohatcong (Q719) 34.5 kV path. However, a new Washington - Mobil Chemical (Q719-1) 34.5 kV line relay panel will be needed at Washington substation. The W3-044 Project will also be required to have two independent high-speed zones of protection to sense and clear faults on the interconnection transformer.

[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

Fault currents on the Washington - Mobil Chemical (Q719-1) 34.5 kV line are as follows:

Three Phase: 7,165 amperes
Line to Ground: 4,000 amperes

Thevenin Impedances in ohms:
Positive Sequence: 0.908 + j2.628
Zero Sequence: 2.759 + 8.969

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 an Interconnection Customer responsibility to make any protection upgrades required should this occur.

The system protection requirements to support the W3-044 Project three breaker ring bus substation are as follows:

**Washington Substation**

A new Washington - Mobil Chemical (Q719) 34.5 kV line relay panel containing:

(1) SEL-501 Dual-Overcurrent relay
(1) SEL-311B (Backup line relay to McCullough Road)
(1) SEL-321 (Primary line relay to McCullough Road)
(1) SATEC Meter

**Interconnection Substation (FE Owned)**

(3) 34.5kV 3000A, minimum 30kA (interrupting) rated breaker
(2) sets of CTs on each side of breaker bushings
C800 Accuracy Class
2.0 Thermal Factor
1200/5 minimum MR
(3) 34.5kV PTs (300/175:1)
(2) SEL-501 Dual-Overcurrent relays
(2) SEL-311B (Backup line relay to Washington and Pohatcong)
(2) SEL-321 (Primary line relay to Washington and Pohatcong)
(1) SEL-311L with fiber optic line to customer owned generating substation
(1) SEL-387L with fiber optic line to customer owned generating substation
(3) SATEC Meters
(1) SEL-2032 for remote relay communication
(1) Arbiter 1094B GPS clock
(1) Latching relay for dial-in access (phone line)

**W3-044 Generating Substation (Customer Owned)**

(1) 34.5kV PT (300/175:1)
(1) SEL-501 per 34.5kV breaker

(1) SATEC Meter
(1) SEL-311L with fiber optic line to FE owned interconnection substation
(1) SEL-387L with fiber optic line to FE owned interconnection substation

A cost estimate of the FE system protection facilities required for the W3-044 is included on Attachment 4.

## Metering

The Interconnection Customer will be required to comply with all FE Revenue Metering Requirements for Generation Interconnection Customers. These FE requirements are detailed on Attachment 5 to 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 6.57 MVAR) and .90 lagging (producing 9.69 MVAR). If this capability cannot be provided by the solar units, a dynamic device such as a STATCOM or SVC must be installed at the W3-044 Project substation at the Interconnection Customer's cost.

The Interconnection Customer will 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. In addition, the Interconnection Customer will be required to meet all PJM, Reliability*First* and NERC reliability criteria and operating procedures for standards compliance. For example, the Interconnection Customer 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 Reliability*First* audits. 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 W3-044 Project for the conditions studied. Therefore the conclusion is that no Transmission or Distribution system reinforcements will be required to provide the requested service.

The following is a summary of the FE facilities that will be required for the Direct Connection of the W3-044 Project:

1. Construct a new 34.5 kV Substation designed in a three breaker ring bus configuration for the project attachment with one spare position. This includes the design and engineering, relaying, fuses, metering, RTU, SCADA, acquisition of materials and construction of the required facilities.

2. Construct a new double circuit loop from the Washington - Mobil Chemical (Q719-1) 34.5 kV line to the new substation (.22 mile)

    - Replace pole NJ35WX to accommodate a double circuit 34.5 kV line extension

    - Overbuild a local Distribution line with a double circuit 34.5 kV line about .22 miles to a point adjacent to the project site.

    - Install structures adjacent to the project site for extension to the new 34.5kV substation

    - Install line conductor for loop and disconnect switch - 556.5 Kcmil 26/7 ACSR wire.

3. Provide engineering oversight and commissioning support of the generation substation including support of the protective relay installation.

4. Provide revenue metering current and potential transformers for the Interconnection Customer to install at the generation substation.

As identified on Attachment 5, the total Direct Connection upgrade cost is $3,987,400.

*All cost data contained in this document should be considered estimated. 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.*

## Interconnection Customer Requirements

In addition to the FE facilities, the 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. Since the W3-044 Project will be connected to the 34.5 kV network, the Interconnection Customer will also be responsible for compliance with the FirstEnergy "Technical Requirements for the Interconnection of Parallel-Operated Generation to the FirstEnergy Distribution System". This includes but is not limited to the following:

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. The purchase and installation of a 34.5 kV interconnection metering instrument transformer. FE will provide the ratio and accuracy specifications based on the customer load and generation levels.

3. A compliance with the FE and PJM generator power factor and voltage control requirements. Note that the W3-044 Project will 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

4. The execution of a back-up service agreement to serve the customer load supplied from the McCullough Road 34.5 kV substation when the units are out-of-service. This assumes the intent of the Interconnection Customer is to net the generation with the station load.

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

6. 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 the Washington PV Generation, LLC. The RTU must communicate with the FirstEnergy EMS via DNP 3.0 protocol.

7. 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.

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

9. 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 Reliability*First* and PJM.

10. A provision of the necessary generator protection, synchronization controls, and fault detection to initiate a trip to protect the W3-044 Project equipment from faults on the Jersey Central System.

11. 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 W3-044 Project when network constraints occur.

The above requirements are in addition to any metering or other requirements imposed by PJM.

Note that an assumption of this study is that the W3-044 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 the Interconnection Customer’s cost.

# PJM Network Impacts

Queue project W3-044 was studied as a(n) 20.0 MW (7.6 MW of which was Capacity) injection into JCPL's system. Project W3-044 was evaluated for compliance with reliability criteria for summer peak conditions in 2014.

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

Not 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.

## Summary

The connection of the W3-044 Project to the FE transmission system will require no network upgrades. Therefore the Interconnection Customer will only have a cost responsibility for the Direct Connection of the W3-044 Project to the Jersey Central transmission system. As shown on Attachment 4, the estimated cost of these facilities is $3,987,400.

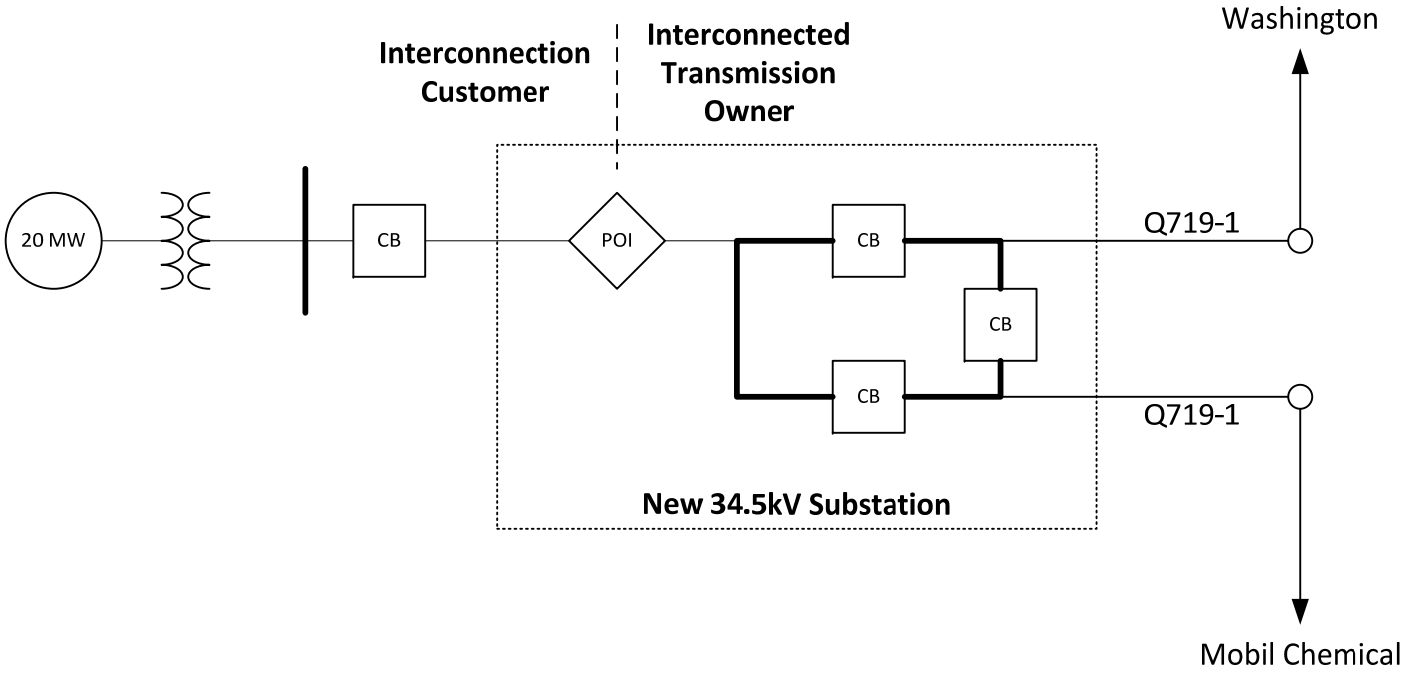
Based on the extent of the FE direct connection and system upgrades required to support this project, it is estimated that it will take one (1) year from the date of a fully executed Interconnection Construction Service Agreement to complete the upgrades required for the W3-044 Project. This includes the requirement for the Interconnection Customer to make a preliminary payment to FE that funds the first three months of engineering design that is related to the construction of the Direct Connection facilities. It further assumes that the Interconnection Customer will provide the property for the attachment, substation 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 a level graded site will be provided for the new 34.5 kV ring bus substation with an access road, that there will be no delays in acquiring the necessary permits for implementing the defined direct connection and network upgrades, and that all 34.5 kV transmission system outages can be scheduled when needed.

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 Impact 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.

# Attachment 1
***Local Site Plan***

# Attachment 2
***Aerial View***

# Attachment 3
***Single Line Diagram***



# Attachment 4
## *Estimated Costs*

| Substation Facility | Direct Connection Substation Facilities | | Cost Estimate |
|---|---|---|---|
| **McCullough Road 34.5 kV** | Construct new 34.5 kV substation for 3 breaker ring bus<br>Construct control building for relay panels, SCADA, etc.<br>Construct new 34.5 kV substation for 3 breaker ring bus<br>Construct control building for relay panels, SCADA, etc.<br>Install three 34.5 kV circuit breakers - standard 2000 amp, 40 kA interrupting capability each<br>Install six new disconnect switches for circuit breakers- standard 2000 amp each<br>Install one new disconnect switch for radial generator attachment - standard 2000 amp each<br>Install 795 ACSR substation conductor or bus-bar as needed<br>Install three line termination structures for the two 34.5 KV lines and generator attachment<br>Install drop loops for the two attachment lines and the generator - 795 ACSR wire<br>Engineering oversight and commissioning support of the interconnection customer generation substation<br>Support of protective relay installation, metering, RTU, SCADA, etc. | $ | 3,455,900 |
| **Washington 34.5 kV** | Replace relaying on the 34.5kV Q-719 (Mobil Chemical) line in support of PJM project W3-044. | | 81,500 |
| | **Total Substation Costs:** | **$** | **3,537,400** |

| Connection Facility | Direct Connection Transmission Facilities | | Cost Estimate |
|---|---|---|---|
| **Washington - Mobil Chemical (Q719) 34.5 kV** | Construct a new double circuit loop from the Washington - Mobil Chemical (Q719) 34.5 kV line to the new 34.5kV substation<br>- Replace pole with a double circuit structure along the Washington - Mobil Chemical (Q719) 34.5 kV Line<br>- Construct about 1150 feet of new looped 34.5 kV line on the Q719-1 34.5kV line (Washington-Mobil Chemical).<br>- New looped 34.5 kV line will be overbuilt on a Distribution line to the project site.<br>- Will include two loop poles on JC's main line<br>- Will include nine new intermediate poles between the main line and the customer's substation<br>- Will include leads to customer's new termination structures, and all necessary guying, etc.<br>- Will be constructed using 556.5 Kcmil 26/7 ACSR wire<br>- Review of environmental maps shows no need for environmental permitting at the preliminary service point indicated on applicant's submitted sketch. If permitting is needed, an additional $25K (plus gross up) will be added to estimate.<br>- Estimate does not include metering to be mounted in the customer's substation. | $ | 450,000 |
| | **Total Transmission Costs** | **$** | **450,000** |
| | **Total Direct Connection Costs** | **$** | **3,987,400** |

# Attachment 5

***FirstEnergy Revenue Metering Requirements For Generation Facilities Connected 46 kV and Lower***

This document addresses the revenue metering requirements for new generation-only facilities connected to FirstEnergy (FE) system voltages 46 kV and lower. This document is not intended for existing retail or wholesale load facilities where behind-the-meter generation is being installed.

The FE operating company (FEOC) shall provide, own, operate, test, and maintain the revenue metering equipment at the Interconnection Customer's (IC) expense. FE reserves the right to review each proposed generation facility design and determine if the IC shall provide, own, operate, test, and maintain the revenue metering equipment at the IC's expense for engineering reasons.

The revenue metering equipment includes, but is not limited to, current transformers, voltage transformers, secondary wires, meter socket, bidirectional revenue meter, and associated devices.

The revenue metering equipment shall be located at the Point of Interconnection (POI) unless otherwise agreed to by FE and the IC. The revenue metering will be compensated for electrical energy losses if it is not located at the POI.

The IC must provide FE with a facility one line, the estimated bi-directional power flow at the revenue metering point, and any loss compensation data.

The IC shall provide and install the mounting structures (or enclosures) and conduits necessary for the metering installation unless otherwise agreed to by the FEOC. The conduit shall be 1-1/2 inch galvanized rigid steel conduit. Flexible galvanized steel (liquid tight) conduit may be used between instrument transformers. The FEOC will install the wiring in the conduit between the instrument transformers and the meter socket.

The IC shall mount the instrument transformers unless otherwise agreed to by the FEOC. The instrument transformers and meter socket shall be installed in a location that is readily accessible to authorized FEOC representatives. If for any reason the meter socket and/or associated devices must be mounted in a weatherproof enclosure, it shall be provided and installed by the IC. The meter socket shall be installed generally within 50 feet of the instrument transformers unless an alternate design has been approved by the FEOC. The meter socket shall be mounted such that the centerline of the meter is approximately five feet above final grade. Where vehicle traffic may interfere with or damage any revenue metering equipment, the IC must install concrete filled steel barrier posts to protect such equipment.

The bidirectional revenue meter provided and installed by the FEOC will record billing data in intervals typically fifteen minutes or thirty minutes. The IC shall provide, at its sole cost and expense, the installation, operation, and maintenance of the communication link required by the FE billing data collection system for access to the meter. The specifications for the typical telephone communication link are as follows:

- Standard voice grade (analog) with dial tone. No digital telephone lines are permitted.
- Two-pair or four-conductor with RJ-11 / Male termination. The FEOC will make final connection to the meter.
- Must be able to receive incoming calls.
- Must be a direct line to the meter with no operator interception or operation required.
- Install the telephone line and associated conduit between the telephone company source and the meter socket or enclosure.
- The telephone line must be tagged with a phone number, including the area code.
- The telephone line must be installed and operational prior to the IC's service being energized.

The IC shall, at its expense, install, own, operate, test, and maintain any metering and telemetry equipment that may be required to provide real-time meter data to FE or PJM.

The FEOC will provide the IC access to bidirectional kWh and kVARh pulses from the FEOC meter at the IC's expense if requested.

The IC shall provide FE with prior notification of any modifications at the facility that could affect the FEOC revenue meter measurements (substation reconfigurations, generator additions, etc).