Generation Interconnection Feasibility Study Report

For

PJM Generation Interconnection Request Queue Position X4-010

Cumberland-W. Shore #2 69kV

April 2012

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 proposed a solar generating facility located in South Middleton Township, Cumberland County, Pennsylvania. The installed facilities will have a total capability of 20.0 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 occur.

Point of Interconnection

X4-010 will interconnect with the PPL EU's 69 kV Transmission System by tapping the Cumberland – W. Shore #3 69 kV network line with approximately 2 miles of 69 kV tap.

Attachment Facilities

No attachment facilities required.

Direct Connection Cost Estimate

The total estimated cost of Direct Connection Facilities needed to connect Queue X4-010 to the Cumberland-W. Shore #3 69 kV line is:

$1,738,580 (Transmission Cost) + (Siting/rights of way Cost) + (Substation Cost) (excluding any applicable state or federal taxes).

Note: Before the Impact Study stage, the exact location of the Interconnection Substation must be identified by the X4-010 IC in order to refine the cost estimate.

This cost represents a 50% cost allocation for work associated with the X4-009 project. Additional cost for this project is towards PPL EU's review and commissioning of X4-010. This cost estimate may vary if the location of the project changes or if X4-009 withdraws from the PJM IPP Queue.

The total preliminary cost estimate for Direct Connection work is given in the following tables below:

For PPL EU building Direct Connection cost estimates:

Description	Total Cost
New ~2 Miles of 69 kV tap to X4-010	$ 1,213,323
Line Siting/rights of way for new 2 miles of 69 kV tap to X4-010	$ 307,989
Cumberland 230-69 kV Substation work to accommodate X4-010	$ 87,831
W. Shore 230-69 kV Substation work to accommodate X4-010	$ 79,437
Additional Work for X4-010	$ 50,000
Total Direct Connection	**$ 1,738,580**

69 kV Transmission Tap Direct Connection Work

$ 1,213,323 New ~2 Miles of 69 kV tap to X4-010

Work is covered in the scope of project X4-009 from the same developer and connected to the same transmission tap, see figure in Attachment 1 (at the end of the document).

69 kV Transmission Siting/rights of way Work

$ 307,989 Line Siting/rights of way for new 2 miles of 69 kV tap to X4-010

Work is covered in the scope of project X4-009 from the same developer and connected to the same transmission tap, see figure in Attachment 1 (at the end of the document).

Substation Direct Connection Work at Cumberland 69 kV Source Substation

$ 87,831 Cumberland 230-69 kV Substation work to accommodate X4-010

Work is covered in the scope of project X4-009 from the same developer and connected to the same transmission tap, see figure in Attachment 1 (at the end of the document).

Substation Direct Connection Work at W. Shore 69 kV Source Substation

$ 79,437 W. Shore 230-69 kV Substation work to accommodate X4-010

Work is covered in the scope of project X4-009 from the same developer and connected to the same transmission tap, see figure in Attachment 1 (at the end of the document).

Substation Direct Connection Work

$ 50,000 Additional Substation Work

Total Substation Direct Connection scope of work to accommodate the connection of X4-010 and includes the following work:

- PPL EU review of drawings and other IPP X4-010 equipment specifications
- PPL EU interface and support in commissioning the IPP X4-010

Preliminary PPL EU Direct Connection Work Schedules

X4-010 work schedules would be the same as the X4-009 since both are connected to the same PPL EU tap.

Assumptions and Notes

- Long lead-times for leased telephone lines may be encountered. Therefore, the X4-010 Interconnection Customer should investigate as soon as possible the availability of leased telephone facilities to meet its in-service schedule.

- The IPP will be able to obtain the required DTT (type PRDA) telephone lines from the local telephone service provider. These lines are no longer a tariffed service, and therefore may not be available in these locations.

- During construction, if extreme weather conditions or other system safety concerns arise, field construction may need to be rescheduled, which could possibly delay the schedule.

- Excepting any operational, governmental, and/or environmental regulatory delays, the use of additional resources, such as overtime, premiums for expedited material, and/or contractor labor, may enable PPL EU to decrease this construction period but no guarantees can be made. It is also assumed that all rights-of-way and easements are secured by the anticipated construction start dates.

- PPL EU recommends that an Interim ISA be completed during the Facilities Study stage to address critical path items, such as long lead-time purchases and any other compressed project schedule issues.

- The ISA/CSA or an Interim Interconnection Service Agreement (IISA) must be signed by the X4-010 Interconnection Customer, PJM, and PPL EU before any PPL EU design and construction activities may commence.

Non-Direct Connection Cost Estimate

69 kV Transmission Network Upgrade Work- Install an LSAB on the Cumberland - W. Shore #3 69kV line

Description	Total Cost
One LSAB switch (50%)	$ 94,075
Total Non-Direct Connection	**$ 94,075**

The transmission network upgrade work includes installation of one LSAB (Load Sectionalizing Air Break) switch on the PPL EU Cumberland - W. Shore #3 69 kV line on the Carlisle substation side of the interconnection point for the isolation of X4-009 tap. The switch would be installed on a custom designed steel pole with concrete foundations. X4-010's estimated cost for the installation of the LSAB switch work is **$94,075**. See Attachment 1 (at the end of the document) for the connection schematic.

Revenue Metering and SCADA Requirements

PJM Requirements

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

PPL EU Requirements

SCADA Equipment Requirements

PPL EU will require installation of PPL EU approved SCADA equipment that will connect to its existing SCADA system to provide real time values of KW, KVAR, and kV metering data at the POC. SCADA equipment will also provide capability to trip and the status monitoring of the POC isolating circuit breaker. In addition to that monitoring of other abnormal conditions at developer's plant will be provided where deemed necessary. This connection will be a 4-wire dedicated FDDA-type phone line. PPL EU will provide detailed specifications and design drawings for this equipment.

Revenue Metering Equipment Installation at the Point of Interconnection

Installation of revenue grade Bidirectional Metering Equipment will be required at the Queue X4-010 Point of Interconnection (POI) to measure KWh and KVARh. PPL EU will design and supply the required metering equipment but all the installation cost would be borne by the developer including CT/PTs. All metering equipment must meet applicable PPL EU tariff requirements as well as being compliant with all applicable requirements of the PJM agreements. The equipment should be housed in a control cabinet or similar enclosure and must be accessible to PPL EU metering personnel.

Interconnection Customer Facility Requirements

Queue X4-010 Interconnection Customer will be responsible for the construction of all their generating station facilities on the X4-010 side of the POI (Point of Interconnection).

Telephone Circuit Requirements

PPL EU will require communication paths between the X4-010 customer substation and PPL EU's Cumberland and W. Shore Substations for Voice, SCADA, and DTT. **NOTE: these DTT (telephone company type PRDA) telephone circuits are becoming increasingly difficult to obtain, and may not be provided by the telephone company. The IPP will be required to provide suitable alternate communications system, for example, fiber optic, or possibly radio. It may also be possible for X4-010 to use the same communication path as X4-009.**

For the telephone communication path, the Interconnection Customer will be responsible to procure the following to communicate with PPL EU substations Cumberland and W. Shore:

a) Protective relay-grade telephone circuits for the DTT communication requirements, type PRDA.
b) A 4-wire dedicated FDDA-type phone line for SCADA.
c) A normal dialup telephone line for voice communication.

The DTT phone lines (one each for Cumberland and W. Shore) will originate at the X4-010 Substation and terminate at PPL EU Cumberland and W. Shore Substations. The SCADA phone line will go to one of our Service centers, to be determined during the Facility study. Phone lines tend to be long lead-time items and must be in place and operational for DTT equipment testing. The Interconnection Customer should secure the necessary phone lines as soon as possible.

All installation, maintenance, and monthly lease or billing charges for communications facilities for SCADA, Voice, DTT, Metering, etc., are the responsibility of the Interconnection Customer.

Intertie and POC Protective Relaying Equipment

The Interconnection Customer will need to install suitable protection and control equipment at its facilities based on PPL EU parallel generation requirements. This includes both Intertie Protective Relaying (IPR) and Point of Contact (POC) relaying. Please refer to the PPL EU web site for the IPR and POC requirements. The website addresses are shown below:

IPR Requirements:
http://www.pplelectric.com/Business+Partners/Tools+and+Reference+Center/Customer-Owned+Generation/

POC Requirements:
http://www.pplelectric.com/NR/rdonlyres/B0937C7E-B6E9-40AD-AE8C-ED3C9558E528/0/point_of_contact.pdf

DTT Equipment Requirements

Telephone line based audio tone DTT (Direct Transfer Trip) equipment will be required to communicate circuit breaker tripping and status monitoring between the X4-010 and the PPL EU Cumberland and W. Shore Substations. (See 'Telephone Circuit Requirements' section of this Study for details on phone circuit requirements). These telephone lines would originate from the X4-010 Substation and are special dedicated 4 wire analog telephone lines, type PRDA. PPL EU will provide detailed specifications and design drawings for this equipment. **NOTE: It may also be possible for X4-010 to use the same communication path as X4-009.**

PPL EU will need signals to both Cumberland and W. Shore Substations from X4-010 that will indicate:

- The X4-010 isolation breaker is open (a breaker 'b' switch)

  Or

- A contact that will indicate when ANY inverter is operating in parallel or still connected with the PPL EU system (contact is in OPEN STATE when any inverter is in parallel and X4-010 system normal) - this contact will change to a close status when ALL inverters are OFF line (disconnected from the PPL EU system).

Isolation Breaker Requirement at the Developer's Substation

Per the customer's preliminary sketches, the customer is planning to provide an high side circuit breaker at 69 kV with a manually operated 69 kV disconnect switch on the PPL EU line side of this breaker, unless otherwise indicated it is assumed that this be will be the "Isolation Circuit Breaker" and will be operated by the IPR relay and the DTT signal. It is requested that the customer confirm this or provide alternate isolation breaker.

X4-010 Inverter and GSU modeling Data

Per the X4-010 supplied, the following was used in modeling the inverters and GSUs:

X4-010 Inverter Units:

Total number of Inverters: Not provided yet by the customer
Rating of each Inverter in kW: Not provided yet by the customer
Gross MW injected in to the PPL EU system: Not provided yet by the customer
Net MW injected in to the PPL EU system: 20

Note: All inverters to be used for connecting generation to the PPL EU system are required to be certified to UL1741 and IEEE 1547. The term certified is understood to indicate that the device has been tested to meet the above standards by a nationally recognized testing laboratory. Any inverter not meeting a nationally recognized testing laboratory certification will either not

allowed to connect to PPL EU system or the customer will be required to install additional suitable external protection equipment to maintain the same level of system protection.

The inverter supplier must provide upon request copies of the certification of inverter equipment testing by a nationally recognized testing laboratory, self certification or certification by a third party that is not listed on the OSHA web site will not be accepted.

Inverter step up transformers or GSU:

No. of Transformers; 20
Each Transformer Rating and Ratio: 1.15 MVA and 34.5/0.69kV
Z = 5.75% at 1.15 MVA base, X/R ratio = 7.5

Intertie Transformers:

Intertie Step-up transformer: One 69/34.5 kV, 15/20/25 MVA
Impedance- 9% at 25 MVA base, X/R ratio = 38
MVA base- Not provided yet by the customer

In the customers one line diagram the intertie transformer is shown as Wye grounded delta. PPL EU requires that this transformer connection be Delta (69kV) and Wye grounded (34.5kV).

The X4-010 Interconnection Customer must provide PPL EU and PJM with the intertie transformer test reports and a model of the inverters once they are available in order to perform a more detailed short circuit analysis.

X4-010 Generator Harmonic and Flicker Requirements

On the PPL EU 69 kV system, the total harmonic distortion to the fundamental voltage wave from a single customer is limited to 1.5% of nominal. In addition, no individual harmonic component can exceed 1.0% of the fundamental system voltage.

If PPL EU discovers that objectionable harmonics in excess of the stated limits are being injected into the system from X4-010's equipment, the Queue X4-010 Interconnection Customer will be responsible for taking corrective measures to mitigate harmonic currents.

Concerning voltage flicker, the X4-010 Project must limit the severity of their voltage variation to within a level which will not cause objectionable flickers to other customers. A voltage drop greater than 5% at the point of interconnection is generally not acceptable. The frequency and severity of the voltage variation will be considered when determining whether a customer's equipment is violating PPL EU flicker guidelines. PPL EU uses the General Electric flicker-irritation curves as a guideline to determine if the system is operating within acceptable limits. PPL EU will require corrective actions by the X4-010 customer if their operation causes flickers that exceed PPL EU guidelines. One such correction could be the installation of static var compensators (SVC) to hold a constant voltage.

X4-010 Inverter Regulation or Reactive Supply Requirements

As specified in Interconnection Service Agreement, Appendix 2, and Section 4.7.1.1 of the PJM OATT (Open Access Transmission Tariff), the X4-010 Project shall design its Facility to meet the following power factor requirement:

"For all new wind-powered and other non-synchronous generation facilities, if determined in the system Feasibility study to be required for the safety or reliability of the Transmission System, the Generation Interconnection Customer shall design its Customer Facility with the ability to maintain a composite power delivery at continuous rated power output at a power factor of at least 0.95 leading to 0.95 lagging."

This indicates that the interconnection customer must maintain a composite power factor at the point of interconnection in between .95 leading (absorbing 6.6 MVARs) or .95 lagging (supplying 6.6 MVARs). If this capability cannot be met, the X4-010 Project must provide a STATCOM or SVC device at its substation.

PPL EU preliminary load flow studies have indicated that the X4-010 Project may require to operate at .95 pf leading that is **absorbing** vars from the PPL EU system. If this operation can't be tolerated by the inverters then an SVC would be required to maintain the required voltage regulation on the Cumberland-W. Shore #3 69 kV line within its required range.

X4-010 will need to verify that its inverters can adjust to the required power factor range or purchase inverters that can. In future studies, PPL EU will calculate and issue a table of MW versus MVAR for various levels of generation output for operating purposes. Further, X4-010 must provide details on how these requirements will be met at the POC (the 69 kV point of contact). Most inverters monitor to their output terminals, but the voltage, frequency, and power factor must also be monitored at the 69 kV level.

Distribution Service Requirements

The Interconnection Customer must submit a request for electric service through PPL EU's Industrial and Commercial Services (ICS) group if the X4-010 solar park requires back-up electric service at a voltage less than 69 kV. The ICS Help Desk can be reached at 1-888-220-9991. Cost for distribution electric service is NOT included in the PPL scope of work transmission or substation estimates below.

PPL EU phase rotation at 69 kV

PPL EU 69kV phase rotation in this region is CBA and will require connection of POC transformer high side bushings in a certain way. Pleaser refer to the below mentioned POC document for phase rotation and transformer connection requirements.

POC Requirements:
http://www.pplelectric.com/NR/rdonlyres/B0937C7E-B6E9-40AD-AE8C-ED3C9558E528/0/point_of_contact.pdf

Intertie 69-34.5 kV Transformer Turns Ratio

PPL EU typically procures the transformers with the following high side (69 kV) taps:

70.6 kV, 68.8 kV, 67.0 kV, 65.2 kV, 63.4 kV with nominal mid point voltage is 67 kV, this provides a range of 5% above (in two 2.5% steps) and 5% below (in two 2.5% steps) to the mid point range of 67 kV. The PPL 69 kV system is operated at around 67.9 kV at the PPL EU Cumberland and W. Shore substations.

Network Impacts

The Queue Project #X4-010 was studied as a 20.0MW(Capacity 7.6MW) injection at Carl Tap4 69kV substation in the PPL area. Project #X4-010 was evaluated for compliance with reliability criteria for summer peak conditions in 2015. Potential network impacts were as follows:

Generator Deliverability

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

None.

Multiple Facility Contingency

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

None.

Short Circuit

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

Not required.

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)

To be determined during System Impact Study phase.

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

Stability is to be determined during System Impact Study phase.

Attachment O, Appendix 2 - Section 4.7.1.1 of the PJM OATT (Open Access Transmission Tariff) indicates that the interconnection customer must maintain a composite power factor at the point of interconnection in between .95 leading (absorbing 6.6 MVARs) or .95 lagging (supplying 6.6 MVARs). If this capability cannot be met, the X4-010 Project must provide a STATCOM or SVC device at its substation.

PPL EU preliminary load flow studies have indicated that the X4-010 Project may require to operate at .95 pf leading that is **absorbing** vars from the PPL EU system. If this operation can't

be tolerated by the inverters then an SVC would be required to maintain the required voltage regulation on the Cumberland-W. Shore #3 69 kV line within its required range.

X4-010 will need to verify that its inverters can adjust to the required power factor range or purchase inverters that can. In future studies, PPL EU will calculate and issue a table of MW versus MVAR for various levels of generation output for operating purposes. Further, X4-010 must provide details on how these requirements will be met at the POC (the 69 kV point of contact). Most inverters monitor to their output terminals, but the voltage, frequency, and power factor must also be monitored at the 69 kV level.

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.

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.

Attachment 1
System Configuration