PJM Generator Interconnection V2-004 Harwood-East Hazleton 5 MW Feasibility/Impact Study

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General

Queue V2-004 is a Suez Renewable Energy NA, LLC request to interconnect a 5 MW (1.9 MW Capacity) solar park. Queue V2-004 is located in Kline Township, Schuylkill County, PA approximately 6 miles south of PPL Electric Utilities' (PPL EU's) Harwood 230/69 kV Substation. Queue V2-004 generation interconnection desires commercial operation by December 2010. **This study does not imply a PPL EU commitment to this in-service date.**

Direct Connection

Queue V2-004 can be connected to PPL EU's 69 kV system by tapping the Harwood-East Hazleton #1 line off the existing NEPCO Tap. The V2-004 substation at grid block 490-S-567 would be connected to the Harwood - E. Hazleton #1 line via a short tap as shown in Figure 1.

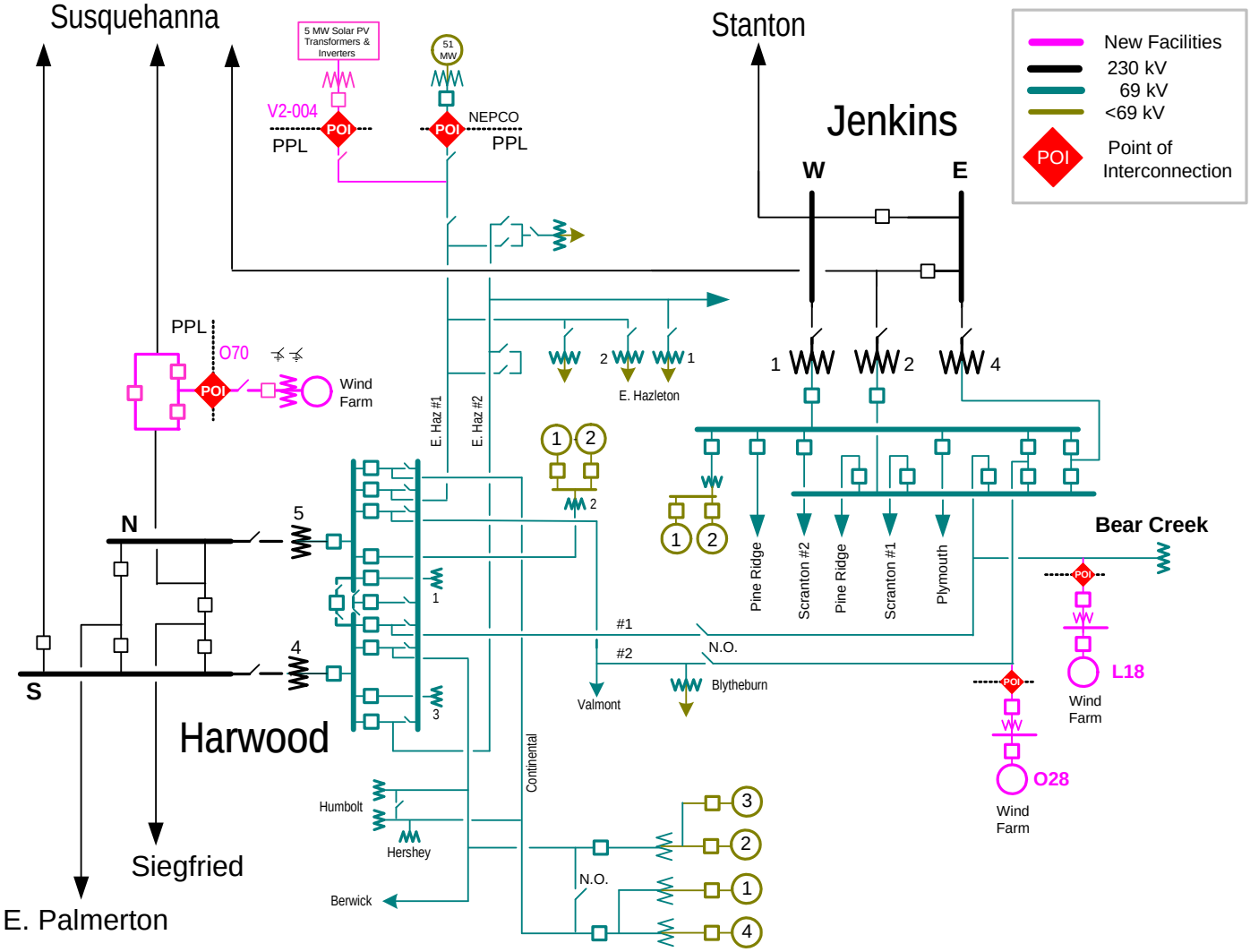

FIGURE 1

Interconnection Customer Scope of Direct Connection Work

Queue V2-004 Interconnection Customer will be responsible for the construction of all generating station facilities on the V2-004 side of the POI (Point of Interconnection) as shown on Figure 1 on the previous page.

Protection equipment --
The Interconnection Customer will need to install suitable protection and control equipment 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 Relaying Requirements--
Matching phone line based DTT (Direct Transfer Trip) equipment is required. A telephone based DTT will be required for a communications path between the V2-004 Substation and PPL EU's Harwood substation (see 'Telephone Circuit Requirements' section of this Study). However, the telephone line portion would originate from the V2-004 Substation. This is a special dedicated 4 wire analog telephone line, type PRDA.

PPL EU will need a signal from V2-004 that will indicate:

- The isolation breaker is open (a breaker 'b' switch) OR
- A contact that will indicate when ANY inverter is operating in parallel with the PPL system (contact is OPEN when any inverter is in parallel) - this contact will close when ALL inverters are OFF line (disconnected from the PPL system).

Note: PPL has not been able to confirm the impact of the inverters on the system or how multiple inverters are going to interact with each other on the system. Therefore, PPL EU will include the installation of Direct Transfer Trip (DTT) facilities for maximum protection of the transmission line in the Feasibility/Impact Study estimate. PPL EU has been trying to communicate with other utilities that have installed similar solar generation on their system to assist in determining the impact. Unless PPL is able to determine DTT is not required, it will be included in the project scope.

SCADA Requirements--
PPL EU will require the installation of PPL EU approved SCADA equipment that will connect to its existing SCADA system. This connection will be a 4-wire dedicated FDDA-type phone line. PPL EU will provide detailed specifications and design drawings for this equipment.

Metering Equipment Installation at the Point of Interconnection--
Installation of revenue grade Metering Equipment will be required at the Queue V2-004 Point of Interconnection (POI). PPL EU will design and supply the required metering equipment but all the installation cost would be borne by the developer. 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.

Metering / Telemetry for PJM--
Interconnection Customer is also required to provide revenue metering and real-time telemetry data to PJM in compliance with the requirements listed in PJM Manuals M-01 and M-14.

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 V2-004 solar park requires back-up electric service at a voltage less than 13 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.

Isolation Breaker Requirement --
V2-004 Interconnection Customer will have its own isolation breaker. This breaker can be located on either the high or low side of the Interconnection Customer's transformer. It will be operated by the IPR relay and the DTT and, if it is located on the high side, the POC relaying. This device will NOT be used to synchronize or parallel operating generation to the PPL EU system.

Transmission Owner (PPL EU) Scope of Direct Connection Work

The total estimated cost of Direct Connection Facilities needed to connect Queue V2-004 to the Harwood-E. Hazleton 69 kV #1 line is **$1,060,000 (substation cost) + (transmission cost)** (excluding any applicable state or federal taxes). The 69 kV connection estimate is based on the assumptions stated in the following Transmission and Substation Direct Connection Work sections. This estimate will vary depending upon the Queue V2-004 substation location and orientation. Network impacts and associated upgrade requirements are addressed at the end of the report.

The transmission and substation costs given above exclude any applicable state or federal taxes. If at a future date Federal CIAC taxes are deemed necessary by the IRS for this project, both PJM and PPL EU shall be reimbursed by the Interconnection Customer for such taxes.

A further breakdown of the direct connection costs are as follows:

$	700,000	New 100 ft. 69 kV tap to V2-004
$	5,000	Siting/ROW for new 100 ft. 69 kV tap to V2-004
$	355,000	Harwood 230/69 kV Substation work to accommodate V2-004
$	**1,060,000**	**Total Direct Connection**

Note: Before the Facilities Study stage, the exact location of the Interconnection Substation must be identified by the V2-004 developer in order to refine the cost estimate.

After the PJM three-party Interconnection Service Agreement (ISA) and Interconnection Construction Service Agreement (ICSA) are signed and PPL EU receives written authorization by PJM to begin work, PPL EU will commence the siting, engineering design, material purchase, and construction of facilities identified above. The time required for siting and Right-of-Way acquisition is estimated to be 6 months assuming V2-004 will is the only landowner involved and is willing to provide the necessary Right-of-Way. This work could take longer than expected if V2-004 is not the only landowner involved or if unforeseen complications arise. The typical time needed to complete the transmission design and construction work is estimated to be approximately 12 to 15 months. All Right-of-Way will need to be acquired prior to the start of construction. The substation work may require approximately 9 to 15 months and can be completed simultaneously with the 69 kV line construction. This translates into an **12 to 18 month** project time frame for the direct connection work.

69 kV Transmission Tap Direct Connection Work

$	700,000	New 100 ft. 69 kV tap to V2-004
$	5,000	Siting/ROW for new 100 ft. 69 kV tap to V2-004
$	**705,000**	**Total Transmission Direct Connection Work**

The transmission direct connection work includes tapping the Harwood-E. Hazleton #1 69 kV line in the vicinity of grid 490-S-567 and building a 100 ft. connection using 556 ACSR conductor with ½" EHS overhead ground wire (OHGW) to a dead-end structure in the new V2-004 customer-owned substation. The tap line will be a 69 kV steel pole design. The estimated cost of the transmission line termination work is **$700,000** and is included in the above estimate.

The transmission cost estimate includes the cost to site and acquire a 100 ft. right-of-way for an approximate 100 foot 69 kV tap. The estimate does not include costs to litigate or mitigate extraordinary environmental impacts. **The tap will be designed and operated at 69 kV and will therefore not require PUC certification.** The estimated cost to site and acquire right-of-way for this new line is **$5,000** and is included in the above estimate. This estimate was made under the assumption that the necessary Right-of-Way is owned by V2-004 and will be provided to PPL EU.

The lead time required for the transmission line direct connection work is approximately **12 to 18 months** (6 months for the siting/right-of-way work and 12 to 15 months for the transmission engineering/construction work, where both can be done concurrently). This estimate assumes that suitable line outages can be scheduled as required to terminate the new tap onto the existing transmission lines. Failure to meet a scheduled line outage may result in project delays. All right-of-way must be acquired prior to construction of the new transmission line.

Alternate Outlet for Generation Operation During PPL EU Maintenance

An alternate outlet for the generation was not requested. V2-004 will not be able to generate into the PPL EU network during maintenance on either the 69 kV line to V2-004 or during certain bus outages at the Harwood 230/69 kV regional substation.

Harwood 69 kV Substation Direct Connection Work

$ 355,000		Harwood 230/69 kV Substation work to accommodate V2-004
$ 355,000		**Total Substation Direct Connection Work**

To accommodate V2-004, the following upgrades are required at PPL EU's Harwood 69 kV Substation.

- Install one telephone line based Direct Transfer Trip (DTT) system
- Install new telephone line protection equipment
- Modify the controls for the E. Hazleton #1 line for the above equipment
- Modify SCADA for new alarms
- Install new cables for the above equipment

This work includes installation of phone line based DTT equipment and control design modifications for the E. Hazleton #1 terminal. V2-004 will be required to provide a matching set of DTT equipment at their site. The scheme will provide a trip signal to V2-004 for any line fault, or any other condition that will cause the PPL EU breaker at Harwood substation to trip. The DTT scheme provides a block-closing signal to the breaker at Harwood from V2-004. Automatic reclosing of the PPL EU line breaker will be blocked whenever the V2-004 69 kV breaker is closed and V2-004 generation is on-line.

Note: PPL has not been able to confirm the impact of the inverters on the system or how multiple inverters are going to interact with each other on the system. Therefore, PPL EU will include the installation of Direct Transfer Trip (DTT) facilities for maximum protection of the transmission line in the Feasibility/Impact Study estimate. PPL EU has been trying to communicate with other utilities that have installed similar solar generation on their system to assist in determining the impact. Unless PPL is able to determine DTT is not required, it will be included in the project scope.

The estimated total cost for the work at Harwood is approximately **$355,000** and is included in the above estimate.

The lead time required for the substation direct connection work is approximately **9 to 15 months**. This schedule assumes that suitable equipment outages can be scheduled as required. Failure to meet a scheduled line outage may result in project delays.

Telephone Circuit Requirements

PPL will require a communication path between the V2-004 customer substation and PPL EU's Harwood Regional Substation for voice, SCADA, and DTT.

For the telephone communication path, the Interconnection Customer will be responsible to procure the following:

a) A protective relay-grade telephone circuit 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. This may be an extension telephone.

The phone line will originate at the V2-004 Substation and terminate at a location yet to be determined in the Facilities Study Stage. Phone lines tend to be long lead-time items and must be in place and operational for DTT equipment testing. Therefore, once the preferred communication path is known, 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 DTT, metering, etc., are the responsibility of the Interconnection Customer.

Direct Connection Issues

V2-004 Inverter and GSU modeling

Per the V2-004 supplied data, the following was used in modeling the inverter and GSU:

V2-004 Inverter Units:
Inverters: 10 Xantrex GT500 units, 500 kW each, net injected into PPL EU system 5 MW (5.125 MW Gross).

GSU:
Inverter Step Up Transformers: Three 0.48/13.8 kV, 1.5 MVA transformers with 5.75% impedance and X/R of 5 (Given).

Intertie Transformers:
Intertie Step-up transformer base: One 13.8/69 kV, 5 MVA (3.75 MVA base) transformer with 7% impedance and X/R of 20 (Given).

The V2-004 Interconnection Customer must provide PPL EU and PJM with the transformer test reports and a model of the inverters once they are available in order to perform a more detailed short circuit analysis.

V2-004 Generator Harmonic and Flicker Requirements

On the 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 V2-004's equipment, the Queue V2-004 Interconnection Customer will be responsible for taking corrective measures to mitigate harmonic currents.

Maximum Allowable Harmonic Voltage Distortion Table (Tariff Rule 32)		
Voltage Level	**Distortion Factor (% System Voltage)**	**Individual Harmonic (% System Voltage)**
69 kV through 138 kV	1.5	1

Concerning voltage flicker, the V2-004 customer must limit the severity of their voltage variation to within a level which will not cause objectionable flicker 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 must be considered when determining whether a customer's equipment is violating PPL EU

flicker guidelines. PPL EU uses the General Electric flicker-irritation curve as a guideline to determine if the system is operating within acceptable limits. PPL EU will require corrective actions by the V2-004 customer if their operation causes flicker that exceeds PPL EU guidelines. One such correction could be the installation of static var compensators (SVC) to hold a constant voltage.

V2-004 Inverter Regulation or Reactive Support Requirements

PPL EU preliminary load flow studies have indicated that the V2-004 inverters will maintain the required voltage regulation on the Harwood-E. Hazleton #1 69 kV tap bus within its required range.

As specified in Interconnection Service Agreement, Appendix 2, Section 4.7.1.1 of the PJM OATT (Open Access Transmission Tariff), the V2-004 generator 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 impact 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."

The V2-004 Interconnection Customer's inverter manufacturer datasheet indicated that the inverters V2-004 is planning on using may not have the capability of adjusting to the required power factor. V2-004 will need to verify from Xantrex that its inverters can adjust to necessary the 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.

Preliminary Schedule and Notes / Assumptions

PPL EU will begin the project only after the PJM 3-party Interconnection Service Agreement (ISA) and Interconnection Construction Service Agreement (ICSA) are fully executed and PPL EU receives a written authorization by PJM to commence activities.

The estimated PPL EU elapsed time to complete the 69 kV **direct connection** transmission and substation upgrades is approximately **12 to 18 months** after the execution of an ICSA.

The schedule for the 69 kV transmission and substation work to accommodate V2-004 would depend on the project start date. The work to accommodate V2-004 will require transmission line outages. PPL EU's outage windows for construction are typically available in the spring and fall of the year. Missing an outage window could result in project delays.

Notes / Assumptions:

- The ISA/ICSA or an Interim Interconnection Service Agreement (IISA) must be signed by the V2-004 Interconnection Customer, PJM, and PPL EU before any PPL EU design and construction activities may commence.

- 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.

- Long lead-times for leased telephone lines may be encountered. Therefore, the V2-004 Interconnection Customer should investigate the availability of leased telephone facilities to meet its in-service schedule.

- If custom-designed steel transmission poles are required, the current lead-time is approximately **20 to 28 weeks**. It is estimated that custom designed poles will be needed for this project.

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

- 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. It is also assumed that all right-of-way and easements are secured without impact on anticipated construction start dates.

Network Impacts

The Queue V2-004 project was studied as a 5 MW energy (1.9 MW Capacity) injection into the 69kV Harwood-East Hazleton #1 line. The project was evaluated for compliance with reliability criteria for summer peak conditions in 2014. Potential network impacts were as follows:

NETWORK IMPACTS

Generator Deliverability

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

No problems identified.

Multiple Facility Contingencies

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

No problems identified

Contribution to Previously Identified Overloads

(This project contributes greater than the PJM cost allocation threshold loading to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

No problems identified

Stability Analysis

Not required because of size, location and technology of proposed generation.

Short Circuit

No problems identified.

NETWORK UPGRADE REQUIREMENTS

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 will have a % allocation cost responsibility)

None required.