

***Generation Interconnection  
Feasibility Study Report***

***For***

***PJM Generation Interconnection Request  
Queue Position Z2-007***

***East Palmerton-Harwood 230kV***

**August 2014**

## 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.

The conduct of light load analysis as required under the PJM planning process is not performed during the Generation Interconnection Feasibility Study phase of the PJM study process. Additional reinforcement requirements for this Interconnection Request may be defined during the conduct of the light load analysis which shall be performed following execution of the System Impact Study agreement.

## General

The Interconnection Customer (IC), has proposed a wind generating facility located Carbon County, Pennsylvania. The installed facilities will have a total capability of 212.5 MW with 27 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is June 1, 2015. **This study does not imply a FirstEnergy commitment to this in-service date.**

## Point of Interconnection

Z2-007 will interconnect with the PPL Electric Utilities (PPL EU) transmission system at one of two options. Option 1 is to connect to the East Palmerton-Harwood #3 230kV line. Option 2 is to connect to the Harwood-Siegfried 230kV line.

## **Cost Summary**

The Z2-007 project will be responsible for the following costs for Option 1:

<b>Description</b>	<b>Total Cost</b>
Attachment Facilities	\$ 25,700,000
Direct Connection Network Upgrades	\$ 17,400,000
Non Direct Connection Network Upgrades	\$ 300,000
<b>Total Costs</b>	<b>\$ 43,400,000</b>

The 230 kV connection estimate is based on the assumptions stated in the following Transmission Attachment Facilities, Direct and Non- Direct Connection Work sections. This estimate may vary depending upon the Queue Z2-007 substation location and orientation.

**Note:** Before the Impact Study stage, the exact location of the Interconnection Substation must be identified by the Z2-007 IC in order to refine the cost estimate.

In addition, the Z2-007 project may be responsible for a contribution to the following costs:

<b>Description</b>	<b>Total Cost</b>
New System Upgrades	\$ 0
Previously Identified Upgrades	\$ 0
<b>Total Costs</b>	<b>\$ 0</b>

Cost allocations for these upgrades will be provided in the System Impact Study Report.

The costs given above exclude any applicable state or federal taxes. If at a future date Federal CIAC (cost in aid of construction) 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.

## **Overview**

The Z2-007 project is located south west of the Harwood-Siegfried and Harwood-East Palmerton double circuit 230 kV lines. The Interconnection Customer's (IC's) facilities will be located approximately 6 miles from the transmission lines. In order to interconnect with the PPL EU transmission system, a new 230 kV switchyard will be required. PPL EU's standard calls for a 3-bay breaker-and-a-half 230 kV switchyard.

At this time the Interconnection Customer has not elected option to build and has elected to have PPL EU own the lead line. These selections may be changed by the Interconnection Customer during a later study phase. PPL EU requests location and orientation of a dead-end structure at the customer facility. For the Feasibility Study, this can be an approximation which can be

refined during a later study phase. Please see Attachment 1 for a one-line diagram of the Point of Interconnection (POI). The POI will be where the 230 kV transmission lead line terminates onto the dead-end structure in the IC’s substation.

## Attachment Facilities

The Interconnection Customer has indicated that they would like the Feasibility Study estimate to include PPL EU constructing and owning the 230 kV transmission line to their new facility. The attachment facilities are scoped and estimated accordingly.

The Z2-007 Project will require siting to identify a suitable route for the 150’-wide right of way needed to construct the 6 mile 230 kV single circuit transmission line using 1590 ACSR conductor and optical ground wire (OPGW) to the dead end structure inside the IC’s substation.

From new 230 kV Switchyard to IC Substation (6 miles):

- The installation of a steel self-supporting monopole on concrete foundation will need to be installed outside the switchyard.
- Installation of 6 miles of single circuit 230kV line
- Foundation Structures, ground wells not likely needed
- Average pole height 140’
- Approximately 40 new structures
- Assume 4 dead-end poles, 12 angle structures, and 24 Tangent
- Assume 3 pull sites
- No major crossings
- Approximately 3x 33,000’ of 1590 KCMIL single circuit conductor will need to be installed along with 2x 33,000’ of 0.752 OPGW fibers.
- Clearing of 150’ ROW

PA PUC Certification of the proposed 230 kV transmission line route will be required. The certification will be through submission of a “Full Siting Application” (FSA). The lead time required to prepare, file and obtain PA PUC approval and obtain property rights will be approximately 24-30 months and assumes that no litigation or condemnation is required.

If the Interconnection Customer chooses at a later study phase to own the 6 mile lead line then the customer will need to install a visible break (circuit breaker, switches, relaying, etc) outside the new PPL-EU 230 kV switchyard. If PPL owns the lead line, the visible break can be located at the Interconnection Customer facility. However PPL will need to certify the line with the PA PUC.

The total preliminary cost estimate for the Attachment work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Total Cost
New 6mile 230 kV line	\$ 25,700,000
<b>Total Attachment Facilities</b>	<b>\$ 25,700,000</b>

## **Direct Connection Cost Estimate**

### **New Substation**

*Note: The scope of work below is consistent with PPL's posted standards, which were revised after the Attachment N for this project was submitted. During the System Impact Study, PPL will provide the cost of a three breaker, breaker-and-a-half substation, which the customer will be responsible for, and the additional costs for the double bus-double breaker substation, which PPL will be responsible for.*

The following describes the direct connection work that will be needed for the proposed 230 kV switchyard (refer to Attachment 1).

- A new 3 bay double bus/double breaker (future breaker-and-a-half) switchyard will be required.
- One bay will terminate the Harwood 230 kV line and will be designed for at least 2000 A. This bay will consist of two 230 kV CBs, each with two 230 kV motor operated disconnect switches.
- Another bay will terminate the East Palmerton 230 kV line and will be designed for at least 2000 A. This bay will consist of two 230 kV CBs, each with two 230 kV motor operated disconnect switches.
- The last bay will accommodate the Z2-007 project and it shall be designed for double bus/double breaker operation (future breaker-and-a-half) and rated for at least 3000 A. This bay will consist of two 230 kV CBs, each with two 230 kV motor operated disconnect switches.
- Each 230 kV line termination will be provided with three 230 kV CCVTs for line potential indication.
- Each 230 kV line will be provided with primary and backup line protection, type and details to be determined during detailed design. Associated 230 kV bus protection and 230 kV breaker failure protection will be required.
- All protection and control equipment will be installed on switchboard panels, located in a switchyard control cubicle. Two high reliable AC station service (diesel generator & three phase PVT's), AC supply, two batteries, chargers, DC supply and telephone protection equipment will be required.
- Install fiber optic splice boxes.
- Fiber optic based direct transfer trip equipment for all 230 kV lines will be required. Fiber optic is available in the Harwood-East Palmerton 230 kV line.
- SCADA and an alarm management system will be required.

### **Transmission Termination**

To tap the existing Harwood – East Palmerton 230kV line the following transmission work will be required:

- Remove and demolish the existing lattice tower to the north and the lattice tower to the south and replace them with an offset two monopole foundation structures. The two

poles on the Harwood – East Palmerton line will require OPGW splice boxes on them and the installation of additional 0.752 DIA 36 count fiber optic overhead ground wire.

- The two poles on the Harwood – Siegfried line will require OPGW splice boxes on them and the installation of additional SFPOC 0.791” diameter 144 fiber count fiber optic overhead ground wire. The existing conductor is 1590 KCMIL 45/7 ACSR, the poles that break the line will need to be installed on concrete foundations. These poles will need to be design for full tension dead ends. The additional fiber required for splices will be approximately 450’ per pole.
- Install spans from switchyard dead-end to new tap poles. Span to consist of 1590KCMIL ACSR will need to be installed along with two 0.752 DIA OPGW.

### **Cost**

The total preliminary cost estimate for the Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

<b>Description</b>	<b>Total Cost</b>
New 230kV substation	\$ 14,800,000
Transmission termination work	\$ 2,600,000
<b>Total Direct Connection Facilities</b>	<b>\$ 17,400,000</b>

### **Non-Direct Connection Cost Estimate**

The protection systems at the remote ends of the Harwood-East Palmerton 230kV line will be modified to support this interconnection.

The total preliminary cost estimate for the Non-Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

<b>Description</b>	<b>Total Cost</b>
Protection work at Harwood and East Palmerton substations	\$ 300,000
<b>Total Non-Direct Connection Facilities</b>	<b>\$ 300,000</b>

### **Preliminary Schedule**

The estimated PPL EU elapsed time to complete the 230 kV Attachment Facilities and Direct and Non-Direct Connection substation work is approximately 36 months after the receipt of a fully executed ISA/CSA.

The schedule for the 230 kV substation work to accommodate Z2-007 would depend on the project’s start date. The work to accommodate Z2-007 will require substation facility 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.

## **Transmission Owner Assumptions in Developing the Cost Estimates**

- For the custom-designed steel transmission poles, the lead-time is approximately 32 to 42 weeks. It is estimated that approximately custom designed steel 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 delay the schedule.
- This magnitude estimate has been prepared without extensive research or field review.
- For the new 230 kV line from Z2-007 to the new 230 kV switchyard, it is as assumed that a new ROW and siting study would be required and the line would be owned by PPL EU.
- No environmental, real estate, or permitting issues were reviewed for the estimate of this project.
- This estimate assumes that suitable facility outages can be schedule as required to install the new switchyard. Failure to meet a scheduled facility outage may result in project delays.
- 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 Z2-007 Interconnection Customer, PJM, and PPL EU before any PPL EU design and construction activities may commence.

## **Interconnection Customer Requirements**

### **Z2-007 Generator, GSU, and Line Modeling**

The Generator interconnect consists of thirty- nine GE 2.5XL Wind Turbines and fifty Siemens SWT-2.3 Wind Turbines collected through eight 34.5 kV feeders to a step up substation.

The turbines will be modeled as one unit and will inject 212.5 MW into PPL EU's system.

Per the Z2-007 supplied data the following was used in modeling the generator and the GSU:

#### **Z2-007 Generator:**

- GE 2.5XL Wind Turbine:
  - Number of Turbines: 39
  - Size: 2.5 MW per turbine

- MVA Base: 2.5 MVA
- Voltage Level: 0.69 kV
- 0.95 lead and 0.95 lag power factor at new 230 kV bus
- Siemens SWT-2.3 Wind Turbine:
  - Number of Turbines: 50
  - Size: 2.5 MW per turbine
  - MVA Base: 2.3 MVA
  - Voltage Level: 0.69 kV
  - 0.90 lead and 0.90 lag power factor at new 230 kV bus

### **Transformers:**

- GSU (Generator Step Up Transformer):
  - Number of machines per GSU: 89
  - Rating: 225 MVA
  - MVA Base: 175 MVA
  - Voltage Levels: 230/34.5 kV
  - Impedance: 9.0%
- GSU (Wind Turbine unit):
  - MVA Base (GE 2.5XL Wind Turbine) : 2.7 MVA
  - MVA Base (Siemens SWT-2.3 Wind Turbine): 2.6 MVA
  - Voltage Levels: 34.5/0.69 kV
  - Impedance: 5.33%

### **Transmission Line:**

- Voltage Level: 230 kV
- MVA Base: 100 MVA
- Length: 3.5 miles
- Positive Sequence Impedance:  $0.0002216+j0.03866$
- Zero Sequence Impedance:  $0.0006648+j0.11600$

### **Telephone Circuit Requirements (At the IPP)**

PPL EU will require a communication path for SCADA and voice circuits. PPL EU anticipates that telephone circuits will be required to establish these paths. The Interconnection Customer will be responsible to procure the following:

1. A 4-wire dedicated FDDA-type phone line for SCADA.
2. A normal dialup telephone line for voice communication.

Phone lines tend to be long lead-time items and must be in place and operational for equipment testing. The Interconnection Customer should investigate with the local phone company the possibility of obtaining this type of service at their facility.

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

### **Intertie and POC Protective Relaying Equipment**

At 230 and 500 kV levels, the protection equipment necessary are based on PJM, NERC, FERC, etc, requirements and PPL EU does not use POC or IPR relaying, as this is more like a base load plant. The protection must be suitable for the proposed system and the surrounding or connected lines. This relaying is determined on a case by case basis.

The Interconnection Customer will need to install suitable protection and control equipment based on PPL EU Parallel generation requirements. The new 230 kV customer substation protection must meet all applicable PPL EU, NERC and FERC requirements. The protection equipment and schemes will be identified during the Facilities Study. Relaying requirements for 230 kV and above are not posted, however Intertie Protective Relaying (IPR) and Point of Contact (POC) relaying documents for voltages below 230 kV can be referred to on the PPL EU website. The website addresses are shown below:

#### **IPR Requirements:**

<https://www.pplelectric.com/at-your-service/electric-rates-and-rules/customer-owned-generation.aspx>

#### **POC Requirements:**

<https://www.pplelectric.com/at-your-service/electric-rates-and-rules/point-of-contact-requirements-for-high-voltage-facilities.aspx>

### **Z2-007 Generator Harmonic and Flicker Requirements**

On the PPL EU 230 kV system, the total harmonic distortion to the fundamental voltage wave from a single customer is limited to 1.0% of nominal. In addition, no individual harmonic component can exceed 0.7% 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 Z2-007's equipment, the Queue Z2-007 Interconnection Customer will be responsible for taking corrective measures to mitigate harmonic currents.

Concerning voltage flicker, the Z2-007 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 Z2-007 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.

### **Z2-007 Generator Regulation or Reactive Support Requirements**

As specified in Part IV, Subpart E at 54.7 of the PJM OATT, the Project Z2-009 generator shall design its “Facility” to maintain a composite power factor delivery at continuous rated power output at the generators terminals at a power factor of at least 0.95 leading (absorbing vars) to 0.95 lagging (supplying vars).

*“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.”*

The PPL EU preliminary load flow studies have indicated that the Z2-007 generator will maintain the required voltage regulation within the required ranges. A voltage schedule will be developed at the time of the Facilities Study.

## **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 Requirements**

PPL EU will require the installation of PPL EU approved SCADA equipment that will connect to its existing SCADA system. PPL EU will provide detailed specifications and design drawings for this equipment.

#### **Metering Equipment Installation at the POI (Point of Interconnection)**

Installation of revenue grade Bi-directional Metering Equipment will be required at the Queue Z2-007 Point of Interconnection (POI) to measure KWh and KVARh.

PPL EU will review the design of the high voltage metering equipment. PPL EU will supply the required metering equipment but the installation 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 revenue meters

should be housed in a control cabinet or similar enclosure (per PPL EU specification) and must be accessible to PPL EU metering personnel.

# Network Impacts

## Option 1

The Queue Project Z2-007 was studied as a 212.5 MW (Capacity 27.0 MW) injection as a tap of the Harwood – East Palmerton #3 230 kV line in the PPL area. Project Z2-007 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project Z2-007 was studied with a commercial probability of 53%. A Summer 2018 case was used for this analysis.

Potential network impacts were as follows:

### Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
PJM69	CONTINGENCY 'PJM69' DISCONNECT BRANCH FROM BUS 200021 TO BUS 200009 CKT 1 /* SUNBURY JUNIATA 500 500 DISCONNECT BRANCH FROM BUS 200021 TO BUS 200022 CKT 2 /* SUNBURY SUSQHANA 500 500 / CKT 1 -> 2 DISCONNECT BRANCH FROM BUS 200021 TO BUS 208109 CKT 24 /* SUNBURY SUNBURY 500 230 END

**Generator Deliverability**

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

None.

**Multiple Facility Contingency**

*(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)*

None.

**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.

**Short Circuit**

*(Summary of impacted circuit breakers)*

None.

**Potential Congestion due to Local Energy Deliverability**

*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.*

*Note: Only the most severely overloaded conditions are listed below. 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 shall study all overload conditions associated with the overloaded element(s) identified.*

#	Contingency		Affected Area	Facility Description	Bus		Circuit	Power Flow	Loading %		Rating		MW Contribution
	Type	Name			From	To			Initial	Final	Type	MVA	
1	N-1	PJM69	PPL	SUSQHANA 500/230kV transformer	208116	200022	21	DC	110.82	112.88	ER	1165	53.42

### **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)*

None.

## **Option 2**

The Queue Project Z2-007 was studied as a 212.5 MW (Capacity 27.0 MW) injection as a tap of the Harwood – Siegfried 230 kV line in the PPL area. Project Z2-007 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project Z2-007 was studied with a commercial probability of 53%. A Summer 2018 case was used for this analysis.

Potential network impacts were as follows:

### **Contingency Descriptions**

The following contingencies resulted in overloads:

<b>Contingency Name</b>	<b>Description</b>
PJM69	CONTINGENCY 'PJM69' DISCONNECT BRANCH FROM BUS 200021 TO BUS 200009 CKT 1 /* SUNBURY JUNIATA 500 500 DISCONNECT BRANCH FROM BUS 200021 TO BUS 200022 CKT 2 /* SUNBURY SUSQHANA 500 500 / CKT 1 -> 2 DISCONNECT BRANCH FROM BUS 200021 TO BUS 208109 CKT 24 /* SUNBURY SUNBURY 500 230 END

**Generator Deliverability**

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

None.

**Multiple Facility Contingency**

*(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)*

None.

**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.

**Short Circuit**

*(Summary of impacted circuit breakers)*

New circuit breakers found to be over-duty:

None.

**Potential Congestion due to Local Energy Deliverability**

*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.*

*Note: Only the most severely overloaded conditions are listed below. 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 shall study all overload conditions associated with the overloaded element(s) identified.*

#	Contingency		Affected Area	Facility Description	Bus			Power Flow	Loading %		Rating		MW Contribution
	Type	Name			From	To	Circuit		Initial	Final	Type	MVA	
1	N-1	PJM69	PPL	SUSQHANA 500/230kV transformer	208116	200022	21	DC	106.47	108.38	ER	1165	49.37

**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)*

None.

## Attachment 1. Single Line Diagram