Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AC1-071

Paupack-Lackawanna 230kV

67.25 MW Energy / 8.74 MW Capacity

October 2017

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, 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 System Impact Study, but the actual allocation, if any, will be deferred until the Facilities Study is performed.

The Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The Interconnection Customer may be 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

Waymart Wind II, LLC, the Interconnection Customer (IC), has proposed a wind generating facility located in Wayne county of Pennsylvania. The installed facilities will have a total capability of 67.25 MW with 8.74 MW being recognized by PJM as capacity. The planned in-service date is December 2018. **This study does not imply a PPL EU commitment to this in-service date.**

Point of Interconnection (POI)

The IC requested a transmission level interconnection. As a result, AC1-071 will interconnect with the PPL EU transmission network via the Lackawanna-Paupack (LACK-PAUP) 230kV line. The POI will be where the IC generator lead line terminates (with insulators) at the dead-end structure inside the new BAAH 230kV switchyard. See Attachment 1 of this System Impact Study Report for more information.

Cost Summary

Description	Total Cost
Direct Connection Network Upgrades	$ 14,919,000
Non-Direct Connection Network Upgrades	$ 4,908,000
Total Costs	**$ 19,827,000**

Attachment Facilities

There are no attachment facilities included as part of the Transmission Owner scope. The IC will be responsible for the ownership and construction of the new generator lead line from the IC collector substation dead-end structure to the new BAAH 230kV switchyard respective dead-end structure. The new generator lead line shall conform to the latest PPL EU standards. Although Attachment 1 of this System Impact Study Report illustrates the generator lead line terminating in a separate bay, the IC shall not have exclusive rights to this bay.

Direct Connection Cost Estimate

New Standard Four Bay BAAH 230kV Switchyard ($14,919,000)

- Construct one (1) new standard four bay BAAH 230kV switchyard. Include all required foundations, grounding, support structures, termination structures, cabling and bus work. Also include a new control cubicle with protection, control and SCADA equipment, yard lighting, signage and perimeter security system.
- Provide testing, commissioning and start-up of all metering equipment.
- Develop all engineering packages including BOM, construction support and close-out in compliance with PPL EU Standards and Specs:
  - Rigid-and Strain- Bus Calculations. New bus work shall be designed with appropriate structural and electrical properties to accommodate the ultimate fault levels
  - AC and DC loading, short-circuit, coordination studies and arc-flash calculations
  - Lightning protection calculations
  - Cable and conduit sizing calculations
  - Station Ground Grid design. Involves Grounding Study to determine safe step and touch voltages based on soil resistivity and grid resistance test
  - Equipment sizing and selection, as applicable
  - Pre-Fabricated Control Cubicle designed to the ultimate development of the switchyard
  - Underground Cable (Power, Control and Fiber Optic) raceway and conduit design.
  - Yard lighting and Perimeter Security System design.
  - Geotechnical Investigation and Site Survey
  - Equipment and Structural Foundation Design including loading calculations.
  - Structural Steel Design Package including loading calculations.
  - Access Roads Design

Non-Direct Connection Cost Estimate

Transmission ($4,500,000)

Develop all engineering packages including bill of material (BOM), construction support and close-out in compliance with PPL EU Standards and Specs:

- Break and cut in-between the LACK-PAUP 230kV line.
- Reroute the LACK line into one bay of the new breaker-and-a-half (BAAH) 230kV switchyard.
- Reroute the PAUP line into another bay of the new BAAH 230kV switchyard.

Relay and Communications at Paupack and Lackawanna Substations ($408,000)

Develop all engineering packages including BOM, construction support and close-out in compliance with PPL EU Standards and Specs:

- Model IC in CAPE and conduct a wide area short-circuit study two busses away from the IC facilities. Identify affected relays and revise settings as needed.
- Develop relay settings at three line positions at the new BAAH 230kV switchyard as well as the remote ends including the PAUP and LACK relays.
- Revisit relay settings at both PAUP and LACK to evaluate the effects of infeed from the IC.
- Conduct a review of all relay settings from the IC.
- Develop all relay settings and engineering packages per the latest PPL EU 3GS standards.
- Required Relaying and Communications:
  - Six (6) SEL-451 relays will be required for control and protection of six (6) circuit breakers (CBs) and twelve (12) motor operated disconnect (MOD) switches (two MODs per CB).
  - Three (3) SEL-411L relays will be required for primary protection of three (3) lines.
  - Three (3) SEL-421 relays will be required for backup protection of three (3) lines.
  - Three (3) SEL-2411 relays will be required for direct transfer trip (DTT) protection of three (3) lines.
  - Four (4) SEL-487B relays will be required for primary and backup protection of two (2) busses.
  - One (1) fiber optic entry rack will be required to terminate/marshal all fiber optic protection circuits with the LACK, PAUP and IC substations.
  - One (1) EU Net Cabinet for SCADA communications.
  - One (1) GE JungleMUX (PRISM B) communications cabinet will be required for primary, backup and DTT protection of the LACK and PAUP 230kV lines.

Major Equipment

- Transmission Tension Custom Steel Foundation Pole (45,000 lbs., 115 ft., 8 ft. x 20 ft.), Single Circuit, 230kV — Qty. 8
- Security System (Cameras, Lighting, etc.) with Perimeter Level 2 Fencing, Mesh, 12 Feet Tall (per PPL EU Spec EU00529820) — Qty. 1
- Line Deadend Support Structure, 230kV — Qty. 3
- Bus Deadend Support Structure, 230kV — Qty. 4
- Surge Arresters, 230kV Application — Qty. 9
- Lightning masts, 230kV Application — Qty. 6
- Dead Tank CB, 230kV, 3000A, 63kA, 2 cycle — Qty. 6
- MOD Switch Support Structure, 230kV — Qty. 6
- MOD Switch, 230kV, 3000A — Qty. 12
- Station Service Voltage Transformer (SSVT) Support Structure, 230kV — Qty. 6
- SSVT, Single Phase, 230kV, 100kVA, 132.8kV-120/240V — Qty. 6
- Coupling Capacitor Voltage Transformer (CCVT) Support Structure, 230kV — Qty. 6
- CCVT, Single Phase, 230kV, 132.8kV-67/115V — Qty. 15
- 18” Deep x 24” Wide Cable Trench Raceway (≈ 1000 feet) — Qty. 1
- Control Cubicle (per PPL EU Standard EU00517973) — Qty. 1
  - Automatic Transfer Switch (ATS), 240VAC, 800A — Qty. 1
  - Non-Fused Safety Switch, 240VAC, 800A — Qty. 4
  - AC Power Panel, 120/240VAC, 800A — Qty. 1
  - AC Lighting Panel 120/240VAC, 200A — Qty. 2

- HVAC Unit, 240VAC Qty. 4
- Battery Charger, 240VAC, 125VDC, 40ADC Qty. 4
- DC Distribution Panel, 250VDC, 400A Qty. 5
- Battery Bank, 60-Cell, 125VDC, 825Ah Qty. 2
- Relay/Control Panel, Triplex Style Qty. 17
  - SCADA Control Qty. 2
  - Breaker/MOD Control and Protection Qty. 6
  - Line Primary Protection Qty. 3
  - Line Backup Protection including DTT Qty. 3
  - Bus Primary and Backup Protection Qty. 3
- Fiber Optic Entry Cabinet Qty. 1
- SCADA EU Net Communications Cabinet Qty. 1
- GE JungleMUX (PRISM) Protection Cabinet Qty. 1
- Metering Cabinet Qty. 1

Schedule:
The estimated schedule for the Transmission Owner scope of work outlined above is 30 months from engineering start to construction finish, after the PJM three-party Interconnection Service Agreement (ISA) and Construction Service Agreement (CSA) are signed.

Note
- The land purchase for the interconnection substation is not included in the costs above.
- It is assumed that an approximate four (4) acre, relatively square lot is available for use.
- Site clearing, drainage study and grading will be performed by the IC.

Interconnection Customer (IC) Requirements

IC Voice Communication Circuit Requirements
PPL EU will require independent communication path for one (1) voice circuit. The IC will be responsible to procure one (1) 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 IC 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 IC.

IC Protective Relaying Requirements
At a minimum, the IC shall install the following relaying equipment at their substation for protection of the 230kV generator lead line:

- One (1) SEL-411L relay for primary protection
- One (1) SEL-421 relay for backup protection
- One (1) SEL-2411 relay for DTT protection

The above relaying equipment shall communicate with their respective matching relaying equipment, via individually dedicated fiber optic circuits, at the new BAAH 230kV switchyard.

All relay schemes and settings shall be developed per PPL EU 3GS standards and to be submitted by the IC to PPL EU for review.

In addition, the IC will need to ensure that the protection and control equipment at its facilities also conform to interconnecting PPL EU requirements. This includes DTT, Intertie Protective Relaying (IPR) and Point of Contact (POC) relaying equipment. Refer to the website addresses shown below for the PPL EU IPR and POC requirements:

IPR Requirements
http://www.pjm.com/-/media/planning/plan-standards/private-ppl/parallel-generation-requirements.ashx?la=en

POC Requirements
http://www.pjm.com/-/media/planning/plan-standards/private-ppl/point-of-contact-requirements.ashx?la=en

IC Substation IPR and POC Fault Interrupting Device (FID) Requirements

The IC provided IPR FIDs, up to three (3) 34.5kV rated circuit breakers in this case, shall be equipped with dual trip coils and capable of interrupting worst-case scenario fault currents with a rated speed of three (3) cycles or less. The IPR FID circuit breakers shall be operated by their respective DTT (SEL-2411) and IPR relaying equipment. The IC provided POC FID, one (1) 230kV rated circuit breaker in this case, shall be equipped with dual trip coils and capable of interrupting worst-case scenario fault currents with a rated speed of two (2) cycles or less. The POC FID circuit breaker shall be operated by its respective primary (SEL-411L), backup (SEL-421) and DTT (SEL-2411) relaying equipment.

IC Generator Harmonic and Flicker Requirements

On the PPL EU 230kV 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 the IC equipment, then the IC will be responsible for taking corrective measures to mitigate harmonic currents.

Concerning voltage flicker, the IC 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 POI is generally not acceptable. The frequency and severity of the voltage variation will be considered when determining whether the IC 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 IC 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.

IC Generator Regulation or Reactive Support Requirements

As specified in Part VI, Attachment O Appendix 2 at 4.7.1.1 of the PJM Open Access Transmission Tariff (OATT), the IC generator shall design its "Facility" to maintain a composite power factor delivery at continuous rated power output at the generator terminals at a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs).

The PJM OATT states:

> *"For all new wind-powered and other non-synchronous generation facilities the Generation Interconnection Customer shall design its Customer Facility with the ability to maintain a composite power delivery at a power factor of at least 0.95 leading to 0.95 lagging across the full range of continuous rated power output."*

IC Generator Voltage Schedule Requirements

The PPL EU preliminary load flow studies have indicated that the AC1-071 generation will maintain the required voltage regulation on the 230kV network, based on the latest IC machine and step-up transformer data. PPL EU requires that the IC has a power factor delivery at continuous rated power output, at the generator terminals, of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs). A voltage schedule will be developed at the time of the Facilities Study, based on the latest IC machine and step-up transformer data received to date.

IC Distribution Service Requirements

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

IC PA PUC Certification & Environmental Issues

All required land and right-of-way (ROW) will be made available to PPL EU at no cost from the IC. To avoid overlap of permitting boundaries and duplication of permitting efforts and costs, PPL EU recommends that the IC share pertinent detail with PPL EU during the permitting process. If the IC chooses to self-perform the ROW acquisition, then the IC shall purchase the PPL EU standard bundle of rights.

IC Revenue Metering and SCADA Requirements

PJM Requirements

The IC will be required to install equipment necessary to provide Revenue Metering (kWh, kVARh) and real time (instantaneous) data (kW, kVAR) for IC generation. For more information, refer to PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

PPL EU Requirements

PPL EU will require the PJM equipment above to provide real time values of kW, kVAR, and kV metering data at the IC substation.

IC Metering Equipment Installation at the IC Substation

The IC is required to provide revenue metering (kWh and kVARh) and real-time telemetry data (kW, kVAR, and kV) to PJM in compliance with the requirements listed in PJM Manuals M-01 and M-14.

Transmission Network Impacts

The Queue Project AC1-071 was evaluated as a 67.2 MW (Capacity 8.7 MW) injection as a tapped connection into Lackawanna-Paupack 230kV line in the PPL EU area. Project AC1-071 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-071 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis – 2020

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

None

Multiple Facility Contingency
(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies for the full energy output)

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

Summer Peak Load Flow Analysis Reinforcements

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 System Impact Study)
(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

Steady-State Voltage Requirements
(Results of the steady-state voltage studies should be inserted here)

None.

Short Circuit
(Summary of impacted circuit breakers)

No issues identified.

Stability and Reactive Power Requirement
(Results of the dynamic studies should be inserted here)

No mitigations required.

Light Load Analysis - 2020

No issues were identified.

Facilities Study Estimate

The estimated duration for a Facilities Study is 7 months and the estimated cost is $100,000.

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 – Single Line Diagram