Generation Interconnection
Feasibility Study Report
Queue Position AC1-071

The Interconnection Customer (IC) has proposed a 68.2 MW (8.9 MWC) wind generating facility located in Wayne, Lackawanna, and Susquehanna Counties of Pennsylvania. PJM studied the AC1-071 project as a 68.2 MW injection into the PPL Electric Utilities (PPL EU) Northeast Region system at a tap of the Lackawanna-Paupack 230 kV circuit and evaluated it for compliance with reliability criteria for summer peak conditions in 2020. The planned in-service date, as stated during the project kick-off call, is December 14, 2018. This date may not be attainable due to remaining PJM studies and the Transmission Owner's construction schedule.

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 230kV line.

Transmission Owner Scope of Work

- Build one (1) new standard four bay breaker-and-a-half (BAAH) 230kV switchyard.
- Break the Lackawanna-Paupack 230kV line.
- Reroute the Lackawanna line into one bay of the new BAAH 230kV switchyard.
- Revise protective relaying and communications accordingly at the Lackawanna substation.
- Reroute the Paupack line into one bay of the new BAAH 230kV switchyard.
- Revise protective relaying and communications accordingly at the Paupack substation.
- Route the new IC generator lead line into one bay of the new BAAH 230kV switchyard. Although the attached single line diagram illustrates the generator lead line terminating in a separate bay, the IC shall not have exclusive rights to this bay.

Major Equipment Included in Estimate:

• Tension Steel Structure, Single Circuit, 230kV	Qty. 3
• Tangent Steel Structure, Single Circuit, 230kV	Qty. 2
• Control Cubicle, 40' x 80'	Qty. 1
• Circuit Breaker (CB), 230kV, 3000A, 63kA, 2 cycle	Qty. 6
• Motor Operated Disconnect (MOD) Switch, 230kV, 3000A	Qty. 12
• Coupling Capacitor Voltage Transformer (CCVT), 230kV	Qty. 15
• Station Service Voltage Transformer (SSVT), 230kV/240-120V, 100kVA	Qty. 6
• Relay/Control Panel, Triplex Style	Qty. 5
• CCVT/SSVT Support Structure, 230kV	Qty. 12
• MOD Switch Support Structure, 230kV	Qty. 6
• Line Deadend Support Structure, 230kV	Qty. 3
• Bus Deadend Support Structure, 230kV	Qty. 4
• 18" Deep x 24" Wide Cable Trench Raceway	Qty. 1000'
• Security System with Perimeter Fencing/Walls	Qty. 1

Required Relaying and Communications:

- Six (6) SEL-451 relays will be required for control and protection of six (6) CBs (including two MOD switches 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 Lackawanna, Paupack and IC substations.
- One (1) GE JungleMUX (PRISM B) communications cabinet will be required for primary, backup and DTT protection of the Lackawanna and Paupack 230kV lines.

Cost Estimate: $21,912,000

Time Estimate: 48 months from engineering start to construction finish, after the PJM three-party Interconnection Service Agreement (ISA) and Construction Service Agreement (CSA) are signed.

Estimate Assumptions:

- Includes generator lead line.
- Land purchase for the substation is not included.
- A four (4) acre, relatively square lot is available for use.
- Site clearing and grading will be performed by the IC.

Interconnection Customer (IC) Requirements

IC Point of Interconnection (POI)

The IC will interconnect with the PPL EU transmission system into the Lackawanna-Paupack 230kV line. The POI will be where the IC generator lead line terminates (with insulators) at the first structure outside of the new BAAH 230kV switchyard.

IC RTU/SCADA and Voice Communication Circuit Requirements

PPL EU will require independent communication paths for RTU/SCADA and voice circuits. In this case, PPL EU anticipates that either telephone circuits or an IP interface will be required to establish these paths. The IC will be responsible to procure the following:

- One (1) 4-wire dedicated FDDA-type phone line or DNP over IP (DNP/IP) for SCADA. It is at PPL EU's discretion as to which SCADA (4-wire or DNP/IP) is required to be provided.
- 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.

IC Substation Fault Interrupting Device (FID) Requirements

The IC provided 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 2 cycles or less. The FID circuit breaker shall be operated by its respective SEL-411L; -421 and -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 under conditions in which a wind-powered generation facility's real power output exceeds 25 percent of its continuous rated power output and, for all other non-synchronous generation facilities, 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 initial 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.

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 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 IC substation. SCADA equipment will also provide capability to trip and monitor the IC FID isolating circuit breaker. PPL EU will provide detailed specifications and design drawings for this equipment should the IC proceed to an ISA/CSA.

IC Metering Equipment Installation at the IC Substation

Installation of revenue grade Bi-directional Metering Equipment will be required in the vicinity of the IC substation to measure kWh and kVARh. PPL EU will design and supply the required metering equipment; all installation costs would be borne by the IC 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 must provide bi-directional revenue metering (kWh and kVARh) and real-time data (kW, kVAR, circuit breaker status, and generator bus voltages) for the IC's generating resource. The metering equipment should be housed in a control cabinet or similar enclosure and must be accessible to PPL EU metering personnel.

The IC is also 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. Any data from the PPL EU revenue meters can be transferred by fiber optic link to the PJM RTU located at the IC facility.

Summer Peak Analysis - 2020

Transmission Network Impacts

Potential transmission network impacts are 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, 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)

1. (PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 3) loads from 114.14% to 115.63% (DC power flow) of its emergency rating (1165 MVA) for the line fault with failed breaker contingency outage of 'PL100873_A'. This project contributes approximately 17.45 MW to the thermal violation.

   CONTINGENCY 'PL100873_A'/* SUSQ-LACK 500KV - STUCK CB AT LACK500 1E
   DISCONNECT BRANCH FROM BUS 200022 TO BUS 917350 CKT 1
   DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 4
   END

   Please refer to Appendix 1 for a table containing the generators having contribution to this flowgate.

2. (PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 4) loads from 114.14% to 115.63% (DC power flow) of its emergency rating (1165 MVA) for the line fault with failed breaker contingency outage of 'PL100872_A'. This project contributes approximately 17.45 MW to the thermal violation.

   CONTINGENCY 'PL100872_A'/* SUSQ-LACK 500KV - STUCK CB AT LACK500 1W
   DISCONNECT BRANCH FROM BUS 200022 TO BUS 917350 CKT 1
   DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 3
   END

   Please refer to Appendix 2 for a table containing the generators having contribution to this flowgate.

3. (PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 4) loads from 111.74% to 113.7% (DC power flow) of its emergency rating (1165 MVA) for the line fault with failed breaker contingency outage of 'PL100858'. This project contributes approximately 22.84 MW to the thermal violation.

   CONTINGENCY 'PL100858'/* SUMT-LACK 230KV 1- STUCK CB AT LACK 3W

DISCONNECT BRANCH FROM BUS 208009 TO BUS 211681 CKT 1/* LACK T1 230-69 KV
DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 3/* LACK T3 500-230 KV
DISCONNECT BRANCH FROM BUS 208009 TO BUS 208090 CKT 1/* SUMT-LACK 1
END

4. (PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 4) loads from 111.74% to 113.7% (DC power flow) of its emergency rating (1165 MVA) for the line fault with failed breaker contingency outage of 'PL100855'. This project contributes approximately 22.84 MW to the thermal violation.

   CONTINGENCY 'PL100855'/* SUMT-LACK 230KV 2 - STUCK CB AT LACK 4W
   DISCONNECT BRANCH FROM BUS 208009 TO BUS 211681 CKT 1
   DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 3/* LACK T3
   DISCONNECT BRANCH FROM BUS 208009 TO BUS 208090 CKT 2/* SUMT-LACK 2
   END

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)

1,2,3,4. To mitigate the Lackawanna 500/230 kV transformer overloads will require replacement of the Lackawanna T3 and T4 transformers (250 MVA single phase units) with new 300 MVA single phase units which will increase the emergency rating from 1200 MVA to 1440 MVA. The estimated cost to perform this work is **$20,900,000** and will take **24 months** to complete.

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

To be performed during later study phases.

Short Circuit

No issues identified.

Stability and Reactive Power Requirement

To be performed during later study phases.

Light Load Analysis - 2020

Light Load Studies to be conducted during later study phases (as required by PJM Manual 14B).

Facilities Study Estimate
(If a Facilities Study is required, provide the estimated duration and cost estimate to perform the Study)

7 months; $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.

1. (PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 3) loads from 109.23% to 111.13% (DC power flow) of its emergency rating (1165 MVA) for the single line contingency outage of 'PL100348'. This project contributes approximately 22.19 MW to the thermal violation.

   CONTINGENCY 'PL100348'/* LACK 500/230KV T4
   DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 4
   END

2. (PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 4) loads from 109.23% to 111.13% (DC power flow) of its emergency rating (1165 MVA) for the single line contingency outage of 'PL100347'. This project contributes approximately 22.19 MW to the thermal violation.

   CONTINGENCY 'PL100347'/* LACK 500/230KV T3
   DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 3
   END

Appendices

The following appendices contain additional information about each flowgate presented in the body of the report. For each appendix, a description of the flowgate and its contingency was included for convenience. However, the intent of the appendix section is to provide more information on which projects/generators have contributions to the flowgate in question. Although this information is not used "as is" for cost allocation purposes, it can be used to gage other generators impact.
It should be noted the generator contributions presented in the appendices sections are full contributions, whereas in the body of the report, those contributions take into consideration the commercial probability of each project.

Appendix 1

(PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 3) loads from 114.14% to 115.63% (DC power flow) of its emergency rating (1165 MVA) for the line fault with failed breaker contingency outage of 'PL100873_A'. This project contributes approximately 17.45 MW to the thermal violation.

CONTINGENCY 'PL100873_A'/* SUSQ-LACK 500KV - STUCK CB AT LACK500 1E
DISCONNECT BRANCH FROM BUS 200022 TO BUS 917350 CKT 1
DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 4
END

Bus Number	*Bus Name*	*Full Contribution*
200894	*26K02*	*7.33*
200823	*26MHP_X3-003*	*11.43*
209003	*KSTN IPP*	*0.29*
292590	*L-018 E*	*3.79*
294573	*P-028 E*	*23.12*
203999	*P-047 E*	*9.81*
209010	*PEIP 1*	*1.15*
209009	*PEIP 2*	*1.64*
297050	*V2-019 E*	*0.06*
901902	*W1-111 E*	*2.01*
209029	*WAYM IPP*	*0.52*
209031	*WAYMART E*	*18.82*
907462	*X1-109 E*	*13.95*
910522	*X3-003 E*	*3.85*
208055	*X4-048*	*58.4*
914041	*Y2-042*	*4.3*
914271	*Y2-089*	*113.99*
LTF	*Z1-019*	*63.92*
916051	*Z1-038*	*3.91*
916351	*Z1-091*	*3.23*
920832	*Z2-104*	*0.38*
920843	*Z2-107 E*	*3.08*
921212	*AA1-077 C*	*13.56*
921213	*AA1-077 E*	*21.26*

921283	*AA1-082 E*	*9.44*
921412	*AA1-106*	*2.68*
921612	*AA1-144 OP*	*26.41*
922062	*AA2-112*	*2.99*
922242	*AA2-132*	*2.94*
922252	*AA2-133*	*3.56*
922952	*AB1-084*	*6.13*
923102	*AB1-108 OP*	*149.42*
923673	*AB1-182 E*	*3.65*
923781	*AB2-012*	*2.79*
925951	*AC1-071 C*	*2.28*
925952	*AC1-071 E*	*15.17*
926031	*AC1-081 OP*	*28.15*
926681	*AC1-151 C*	*0.81*
926682	*AC1-151 E*	*1.32*

Appendix 2

(PL - PJM500) The LACKAW 500/230 kV transformer (from bus 208009 to bus 200074 ckt 4) loads from 114.14% to 115.63% (DC power flow) of its emergency rating (1165 MVA) for the line fault with failed breaker contingency outage of 'PL100872_A'. This project contributes approximately 17.45 MW to the thermal violation.

CONTINGENCY 'PL100872_A'/* SUSQ-LACK 500KV - STUCK CB AT LACK500 1W
DISCONNECT BRANCH FROM BUS 200022 TO BUS 917350 CKT 1
DISCONNECT BRANCH FROM BUS 200074 TO BUS 208009 CKT 3
END

Bus Number	*Bus Name*	*Full Contribution*
200894	*26K02*	*7.33*
200823	*26MHP_X3-003*	*11.43*
209003	*KSTN IPP*	*0.29*
292590	*L-018 E*	*3.79*
294573	*P-028 E*	*23.12*
203999	*P-047 E*	*9.81*
209010	*PEIP 1*	*1.15*
209009	*PEIP 2*	*1.64*
297050	*V2-019 E*	*0.06*
901902	*W1-111 E*	*2.01*
209029	*WAYM IPP*	*0.52*
209031	*WAYMART E*	*18.82*
907462	*X1-109 E*	*13.95*
910522	*X3-003 E*	*3.85*
208055	*X4-048*	*58.4*
914041	*Y2-042*	*4.3*
914271	*Y2-089*	*113.99*
LTF	*Z1-019*	*63.92*
916051	*Z1-038*	*3.91*

916351	*Z1-091*	*3.23*
920832	*Z2-104*	*0.38*
920843	*Z2-107 E*	*3.08*
921212	*AA1-077 C*	*13.56*
921213	*AA1-077 E*	*21.26*
921283	*AA1-082 E*	*9.44*
921412	*AA1-106*	*2.68*
921612	*AA1-144 OP*	*26.41*
922062	*AA2-112*	*2.99*
922242	*AA2-132*	*2.94*
922252	*AA2-133*	*3.56*
922952	*AB1-084*	*6.13*
923102	*AB1-108 OP*	*149.42*
923673	*AB1-182 E*	*3.65*
923781	*AB2-012*	*2.79*
925951	*AC1-071 C*	*2.28*
925952	*AC1-071 E*	*15.17*
926031	*AC1-081 OP*	*28.15*
926681	*AC1-151 C*	*0.81*
926682	*AC1-151 E*	*1.32*