Generation Interconnection
Feasibility Study Report
Queue Position Z1-120

The Interconnection Customer (IC), has proposed a 10 MWE (5.88 MWC; 10 MW MFO) solar powered generating facility to be located in Somerset County, Maryland and Accomack County, Virginia. PJM studied Z1-120 as a 10 MW injection into the Delmarva Power and Light (DPL) system and evaluated the project for compliance with reliability criteria for summer peak conditions in 2017.

Point(s) of Interconnection

The Interconnection Customer requested a Primary and Secondary Point of Interconnection (POI) be evaluated for the Z1-120 project. The Primary POI selected was a 25 kV connection into the Loretto substation. The Secondary POI selected was a line tap of the Loretto-Piney Grove 138 kV circuit. The study results are provided in the Transmission Network Impacts section below.

Primary POI Option

Z1-120 will interconnect with the Delmarva Power and Light transmission system via a dedicated 25 kV feeder emanating from the Loretto substation to the Interconnection Customer's generating facility. The Point of Interconnection (POI) will be located at the fence line of the generating facility.

Direct Connection Requirements

Criteria Limits for Distributed Energy Resource (DER) Connections to the ACE, DPL and Pepco Distribution Systems (less than 69kV)

1. Single Phase Limit

Any DER with a capacity that exceeds 100kW shall be a balanced 3 phase system.

2. Voltage Limits

DER's are permitted to cause a voltage fluctuation of up to 2% at the Point of Interconnection, ½ the band width of any voltage regulator at its terminals, and ½ the net dead band of a switched capacitor bank at its connection point. When a DER is at maximum output, it shall not raise the feeder voltage above the ANSI C84.1 or state limit, whichever is more conservative.

3. Existing Distribution Circuit Capacity Limits

The aggregate limit of large (250 kW and over) generators running in parallel with a single, existing distribution circuit is 0.5 MWs on the 4kV, 3MWs on the 12 kV, 6 MWs on the 25 kV, and 10 MWs on the 34 kV.

4. Express Circuit Capacity Limits

Distributed generation installations which exceed the limit for an existing circuit require an express circuit.

The maximum generator size for express circuits shall be:

- 4 kV 0.5 MW
- 12 – 13.8 kV 10 MWs
- 23 – 25 kV 10 MWs
- 33.26 – 34.5 kV 15 MWs

5. Distribution Power Transformer Limit
The aggregate limit of large (250 kW and over) generator injection to a single distribution transformer of 22.5 MVA nameplate or larger is 10 MWs. Transformers with nameplate ratings lower than 22.5 MVA will be given lower ratings on an individual basis. If the transformer rating is significantly greater than 40 MVA it may be possible to consider a greater generation capacity.

Adding a new transformer will be considered if there is no availability on any of the existing transformers and space is available in an existing substation. Any proposed transformers would be PHI's standard distribution transformer (37 MVA nameplate rating.)

6. Express Circuit Length Limit
If there is no more injection capacity or space for an additional transformer at the closest substation, the next closest substation will be considered. The length of an express circuit is limited to 5 miles, or for the sake of the feasibility study, 3.8 straight line miles to the substation. This simplification is used because the feasibility study phase does not allow for the time and resources to examine routes in detail (including existing pole lines, easements, ROW, and environmental issues etc.)

7. When a New Substation is Required
If a distribution express circuit can't be built from an existing substation for a project, it will be necessary to construct a new distribution substation with a standard ring bus design. It will be supplied by extending existing transmission lines. In NJ, it is the developer's responsibility to verify eligibility of this configuration for solar renewable energy certificates with New Jersey's Clean Energy Program if desired.

All limits, given above in MWs, are subject to more detailed study to ensure feasibility.

Transmission Owner Scope of Work
The scope of work and estimated costs for the direct connection facilities is as follows:

The requested distribution voltage of 25 kV is not currently available at Loretto Substation. An interconnection at the 25 kV voltage class will require the installation of a 69/25 kV transformer and 25 kV bus at Loretto Substation. The request will also require DPL to create an express feeder to the Interconnection Customer's generating facility. The estimate will include the construction of an express circuit with a total length of 5 miles according to Section 6 of the "Direct Connection Requirements". The current substation layout will not accommodate a new 69 kV terminal, 69/25 kV transformer, and 25 kV bus. Expansion of Loretto substation is possible in the southern portion of the site. The following estimate includes the costs for the substation expansion.

1. One 69 kV position will be established on the 69 kV ring bus at Loretto Substation. Construction will include installing one 69 kV circuit breaker, two 69 kV disconnect switches,

69 kV bus equipment, protection and control relays, support structures, foundations, and associated below grade equipment.

2. One 69/25 kV transformer will be installed complete with foundations, disconnect switches, bus equipment, protection and control relays, support structures, and below grade equipment.
3. One new 25 kV feeder with 954 kcmil All Aluminum Conductor (AAC) will be constructed from Loretto Substation to the PV site – a distance of approximately 5 miles.
4. One new 25 kV feeder terminal position will be constructed.
5. A utility operated recloser equipped with the proper relaying and communications will be installed for each feeder serving the PV generator.
6. Utility grade primary metering will be required for each feeder.
7. Generation telemetry and remote trip capability will be provided to PHI's Energy Management System with future capability to adjust output and power factor if needed.
8. A detailed, time-based study may be performed during later study phases.
9. Protection, Planning, and other engineering departments will perform studies, design work, and prepare engineering estimates.
10. Transfer trip will be required. Approximately 5 miles of 48SM ADSS fiber optic cable was estimated for this report to provide the communication channel from Loretto Sub to the PV site.

The estimated cost to perform this work is:

Attachment Facilities Estimates			
Loretto Substation 69/25kV Xfmr and 25kV Feeder			
954 AAC Express Feeder		Miles	$2,000,000
Fiber Installation	5	Miles	$250,000
69kV Ring Bus position for 69/25kV Xfmr			$4,000,000
New 69/25kV Xfmr			
New Feeder Terminal			
Recloser w/ Relaying and Communications			$50,000
Utility Grade Metering			$20,000
SCADA Integration into EMS			$10,000
Detailed Time Based Study			$30,000
Various Departments Work			$20,000
Subtotal Cost			$6,380,000
Subtotal Cost with 18% Overheads			$7,528,400
Approximate Total Cost with 15% Contingency			$8,657,660

The estimated time to complete this work is **36 months** after receipt of a fully executed interconnection agreement.

Note: the above cost does not include the Contribution in Aid of Construction (CIAC) tax.

High Voltage Warning

Voltage received at the meter from the utility will be 104% or 105% of nominal. Normal operating procedures dictate that voltage at the substation be raised to the higher end of an acceptable bandwidth in order to provide adequate supply to distant customers. Transformers with no load taps should be used to reduce the voltage by 2.5% to avoid the possibility of inverter trips. Failure to account for this may result in lost energy production.

Special Operating Requirements

1. DPL will require the capability to remotely disconnect the generator from the grid by communication from its System Operations facility. This will be accomplished with a line recloser.

2. It is the Interconnection Customer's responsibility to send the data that PJM and DPL require directly to PJM. The Interconnection Customer will grant permission for PJM to send to DPL the following telemetry that the Interconnection Customer sends to PJM: real time MW, MVAR, volts, amperes, generator/status, and interval MWH and MVARH.

3. The Interconnection Customer will be required to make provisions for a voice quality phone line within approximately 3 feet of each DPL metering position to facilitate remote interrogation and data collection.

4. A mutually acceptable means of interrupting and disconnecting the generator with a visible break, able to be tagged and locked out, shall be worked out with DPL Distribution Engineering.

5. DPL reserves the right to charge the Interconnection Customer operation and maintenance expenses to maintain the Interconnection Customer attachment facilities, including metering and telecommunications facilities, owned by DPL.

Interconnection Customer Scope of Work

The Interconnection Customer (IC) is responsible for all design and construction related to activities on their side of the Point of Interconnection. Site preparation, including grading and an access road, as necessary, is assumed to be by the IC. Route selection, line design, and right-of-way acquisition of the direct connect facilities is not included in this report, and is the responsibility of the IC.

The IC will be required to install metering and telemetry equipment to provide revenue metering and real-time telemetry data to PJM. The requirements for this equipment are listed in Appendix 2, Section 8 of Attachment O to the PJM Tariff, as well as PJM Manuals 01 and 14D. Protective relaying and metering design and installation must comply with PHI's Applicable Standards.

The Interconnection Customer will purchase and install all metering instrument transformers as well as construct a metering structure per PHI's specifications. The secondary wiring connections at the instrument transformers will be completed by the Interconnection Customer's contractors and

inspected by PHI, while the secondary wiring work at the metering enclosure will be completed by PHI's meter technicians. The metering control cable and meter cabinets will be supplied by PHI and installed by the Interconnection Customer's contractors. PHI's meter technicians will program and install two solid state multi function meters (Primary & Backup) for the new metering position.

Inverter Requirements and Capabilities

The inverter at the DG location shall have the following capabilities:

- Voltage flicker reduction through dynamic VAR or fixed PF response
- Ramp rate control
- SCADA communications
- Curtailment or other mitigation ability if high voltage were to occur
- Low voltage and system disturbance ride through
- Ability to receive and respond to a transfer trip signal
- Ability to adjust PF or VARs based on utility signal
- Ability to Adjust Real Power Output based on utility signal

The inverter shall operate in accordance with the IEEE 1547 series of standards that have been approved. While inverters should be capable of voltage stabilization thru dynamic VAR response and capable of low voltage and system disturbance ride through, neither of these capabilities shall be implemented until such time that the IEEE 1547 series of standards are revised and approved to include standards for these capabilities. At such time as these revised standards become available, the PV owner/operator shall cooperate with the Company (the 'Company' referring to ACE, DPL, or PEPCO) to implement these capabilities with settings acceptable to the Company. Until such time, the inverters shall operate with a fixed power factor schedule as supplied by the Company.

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, Line with Failed 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

Short Circuit

No overstressed breakers were identified.

Stability and Low Voltage Ride Through Analysis

Will be performed during the System Impact study phase of the project (if necessary).

Light Load Analysis

(Light Load Studies to be conducted during later study phases (applicable to wind, coal, nuclear, and pumped storage projects).

Not required.

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. "Network Impacts," initially caused by the addition of this project's generation)

None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. Cost allocation for these overloads will be provided in the System Impact Study Report.

None

Potential Congestion due to Local Energy Deliverability

(PJM also studied the delivery of the energy portion of the surrounding generation. Any potential problems identified below are likely to result in operational restrictions to the project under study. The Interconnection Customer can proceed with Network Upgrades to eliminate the operational restriction at their discretion by submitting a Transmission Interconnection Request.

Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full deliverability for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which analyzes all overload conditions associated with the identified overloaded element(s). As a result of the aggregate energy resources in the area, the following violations were identified:

These are ***not*** required reliability upgrades.

1. (DP&L - DP&L) The LORET_69-FRUITLND 69 kV line (from bus 232275 to bus 232288 ckt 1) loads from 99.16% to 101.52% (**DC power flow**) of its emergency rating (137 MVA) for the single line contingency outage of 'CKT 6728'. This project contributes approximately 3.23 MW to the thermal violation.

   CONTINGENCY 'CKT 6728'
   OPEN LINE FROM BUS 232272 TO BUS 232274 CIRCUIT 1 /MOUNT HERMON - PINEY GROVE 69
   DISCONNECT BUS 230912 / PINEY GROVE 69 CAP
   END

2. (DP&L - DP&L) The LORETTO-PINEY138 138 kV line (from bus 232127 to bus 232128 ckt 1) loads from 102.88% to 104.79% (**DC power flow**) of its emergency rating (159 MVA) for the single line contingency outage of 'CKT 13764'. This project contributes approximately 3.03 MW to the thermal violation.

   CONTINGENCY 'CKT 13764'
   OPEN LINE FROM BUS 232131 TO BUS 232128 CIRCUIT 1 /NEW CHURCH - PINEY GROVE 138
   END

3. (DP&L - DP&L) The FRUITLND-PEMBERTN 69 kV line (from bus 232288 to bus 232273 ckt 1) loads from 99.73% to 103.27% (**DC power flow**) of its emergency rating (91 MVA) for the single line contingency outage of 'CKT 6728'. This project contributes approximately 3.23 MW to the thermal violation.

   CONTINGENCY 'CKT 6728'
   OPEN LINE FROM BUS 232272 TO BUS 232274 CIRCUIT 1 /MOUNT HERMON - PINEY GROVE 69
   DISCONNECT BUS 230912 / PINEY GROVE 69 CAP
   END

Secondary POI Option

PJM studied Z1-120 as a 10 MW injection at a tap of the Loretto-Piney Grove 138 kV circuit.

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, Line with Failed 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

Short Circuit

No overstressed breakers were identified.

Light Load Analysis

(Light Load Studies to be conducted during later study phases (applicable to wind, coal, nuclear, and pumped storage projects).

Not required.

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. "Network Impacts," initially caused by the addition of this project's generation)

None

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. Cost allocation for these overloads will be provided in the System Impact Study Report.

None

Potential Congestion due to Local Energy Deliverability

(PJM also studied the delivery of the energy portion of the surrounding generation. Any potential problems identified below are likely to result in operational restrictions to the project under study. The Interconnection Customer can proceed with Network Upgrades to eliminate the operational restriction at their discretion by submitting a Transmission Interconnection Request. Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full deliverability for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which analyzes all overload conditions associated with the identified overloaded element(s). As a result of the aggregate energy resources in the area, the following violations were identified:

These are ***not*** required reliability upgrades.

1. (DP&L - DP&L) The FRUITLND-PEMBERTN 69 kV line (from bus 232288 to bus 232273 ckt 1) loads from 106.72% to 107.2% (**DC power flow**) of its emergency rating (91 MVA) for the single line contingency outage of 'CKT 6728'. This project contributes approximately 0.98 MW to the thermal violation.

   CONTINGENCY 'CKT 6728'
   OPEN LINE FROM BUS 232272 TO BUS 232274 CIRCUIT 1 /MOUNT HERMON - PINEY GROVE 69
   DISCONNECT BUS 230912 / PINEY GROVE 69 CAP
   END

2. (DP&L - DP&L) The LORETTO 138/69 kV transformer (from bus 916690 to bus 232127 ckt 1) loads from 95.35% to 98.09% (**DC power flow**) of its emergency rating (159 MVA) for the single line contingency outage of 'CKT 13713'. This project contributes approximately 4.35 MW to the thermal violation.

   CONTINGENCY 'CKT 13713'
   OPEN LINE FROM BUS 232129 TO BUS 232127 CIRCUIT 1 /KINGS CREEK - LORETTO 138
   END

3. (DP&L - DP&L) The PINEY138 138/69 kV transformer (from bus 916690 to bus 232128 ckt 1) loads from 100.85% to 104.36% (**DC power flow**) of its emergency rating (159 MVA) for the single line contingency outage of 'CKT 13764_B'. This project contributes approximately 5.57 MW to the thermal violation.

   CONTINGENCY 'CKT 13764_B'
   OPEN LINE FROM BUS 916720 TO BUS 232128 CIRCUIT 1 /NEW CHURCH - PINEY GROVE 138
   END