Generation Interconnection
Feasibility Study Report
Queue Position AB1-137

The Interconnection Customer (IC) has proposed a 20.0 MW MFO (14 MWC; 20.0 MWE) solar generating facility to be located in Frankford, Delaware. PJM studied AB1-137 as a 20 MW injection into the Delmarva Power and Light Company's (DPL) system at the Frankford 25 kV Substation and evaluated it for compliance with reliability criteria for summer peak conditions in 2019. The planned in-service date, as stated during the kick-off call, is November 1, 2016.

Point of Interconnection

The IC requested a distribution level Point of Interconnection at Delmarva Power and Light Company's Frankford 25 kV Substation (see Attachment 1). As a result, the AB1-137 project will connect to the DPL system as follows:

> The first 6 MWs will connect to the existing 25 kV feeder DE2207 extending from the T1 transformer at the Frankford 138/25 kV Substation; the next 4 MWs will connect to the Frankford 138/25 kV T1 transformer via an express feeder; the next 10 MWs will connect to a new T2 transformer at the Frankford 138/25 kV via an express feeder.

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 MW
- 23 – 25 kV 10 MW
- 33.26 – 34.5 kV 15 MW

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.

6. Express Circuit Length Limit

If there is no 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. It is the developer's responsibility to verify eligibility of this configuration for solar renewable energy certificates.

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

Transmission Owner (TO) Scope of Work

TO work required to accommodate 6 MW of generation on existing feeder DE2207 from Frankford Substation T1:

1. A utility operated recloser equipped with the proper relaying and communications will be required.
2. Utility grade primary metering will be required.
3. Generation telemetry and remote trip capability will be provided to the control center.
4. A detailed, time-based study may be performed during later study phases.
5. Protection, Planning, and other engineering departments will perform studies, design work, and prepare engineering estimates.
6. Approximately 0.5 miles of three-phase service will need to be extended to the POI.
7. Direct transfer trip will be required. Approximately 3 miles of 48SM ADSS fiber optic cable was estimated for the communication channel. 138 kV potential transformers will need to be installed if none already in-service.

Estimated Costs	
Frankford Substation T1	
Three-Phase Extension	$160,000
Fiber Installation	$150,000
Recloser & Metering	$80,000
SCADA Integration into EMS	$10,000
Various Departments Work	$20,000
Subtotal Cost	$420,000
Approximate Total Cost with 18% Contingency	$483,000

The estimated time to complete this work is **12-18 months** after receipt of a fully executed interconnection agreement.

TO work required to accommodate 4 MW of generation on an express feeder from Frankford Substation T1:

1. Design and construct one new 25 kV feeder with 477 aluminum conductor from Frankford Substation to the generation site – approximately 3 miles.
2. One new 25 kV feeder terminal position will be constructed.
3. A utility operated recloser equipped with the proper relaying and communications will be required.
4. Utility grade primary metering will be required.
5. Generation telemetry and remote trip capability will be provided to the control center.
6. A detailed, time-based study may be performed during later study phases.
7. Protection, Planning, and other engineering departments will perform studies, design work, and prepare engineering estimates.
8. Direct transfer trip will be required. Approximately 3 miles of 48SM ADSS fiber optic cable was estimated for the communication channel. 138 kV potential transformers will need to be installed if none already in-service.

Estimated Costs			
Frankford Substation T1			
477 AAC Express Feeder	3	Miles	$1,200,000
Fiber Installation			$150,000
25 kV Feeder Terminal			$300,000
Substation Relaying & 138 kV PTs			$300,000
Recloser & Metering			$80,000
SCADA Integration into EMS			$10,000
Dynamic Study			$30,000
Various Departments Work			$90,000
Subtotal Cost			$2,160,000
Approximate Total Cost with 15% Contingency			$2,484,000

The estimated time to complete this work is **24-36 months** after receipt of a fully executed interconnection agreement

TO work required to accommodate 10 MW of generation on an express feeder from a new transformer T2 at Frankford Substation:

The addition of a second transformer at Frankford Substation requires the expansion of the 138 kV substation bus from the existing tap configuration to a 138 kV 4 position ring bus. The existing land area of Frankford Substation will need to be expanded in order to accommodate the new 138 kV ring bus. Additional real estate will need to be acquired to accommodate the expansion, and is not included in the following estimate.

1. Design and construct one new 25 kV feeder with 477 aluminum conductor from Frankford Substation to the generation site – approximately 3 miles.
2. One new 37 MVA 138/25 kV transformer will be constructed.
3. One new 25 kV feeder terminal position will be constructed.
4. One new 138 kV feeder terminal position will be constructed.
5. Reconfiguration of the 138 kV bus will be required. The 138 kV substation bus will need to be expanded into a 138 kV 4 position ring bus.
6. A utility operated recloser equipped with the proper relaying and communications will be required.
7. Utility grade primary metering will be required for each feeder.
8. Generation telemetry and remote trip capability will be provided to the control center.
9. A detailed, time-based study may be performed during later study phases.
10. Protection, Planning, and other engineering departments will perform studies, design work, and prepare engineering estimates.
11. Direct transfer trip will be required. Approximately 3 miles of 48SM ADSS fiber optic cable was estimated for this report to provide the communication channel. 138 kV potential transformers will need to be installed.

Frankford Substation New T2			
477 AAC Express Feeder	3	Miles	$1,200,000
Fiber Installation			$150,000
Transformer			$3,000,000
138 & 25 kV Feeder Terminals			$600,000
Ring Bus Reconfiguration			$8,000,000
Substation Relaying & 138 kV PTs			$300,000
Recloser & Metering			$80,000
SCADA Integration into EMS			$10,000
Dynamic Study			$30,000
Various Departments Work			$90,000
Subtotal Cost			$13,460,000
Approximate Total Cost with 15% Contingency			$15,479,000

The estimated time to complete this work is **36-48 months** after receipt of a fully executed interconnection agreement

Additional Operating Requirements

1. The Company 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 the Company requires directly to PJM. The Interconnection Customer will grant permission for PJM to send the Company the following telemetry that the Interconnection Customer sends to PJM: real time MW, MVAR, volts, amperes, generator breaker status or inverter 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 Company 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 Company Distribution Engineering.

5. Company 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 Company.

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.

Protective relaying and metering design and installation must comply with PHI's applicable standards. The IC is also required to provide revenue metering and real-time telemetering data to PJM in conformance with the requirements contained in PJM Manuals M-01 and M-14 and the PJM Tariff.

The IC 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. Each meter will be equipped with load profile, telemetry, and form-c pulse outputs. The ownership of metering equipment purchased or installed by the IC shall be transferred to the Transmission Owner at Commercial Operation, unless the IC asserts its right to install, own and operate the metering system.

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. It is the responsibility of the owner to secure the inverter from any unauthorized access (including physical and remote access) which could alter settings or adversely affect the inverter's ability to operate as required. Security measures should include utilizing secure password settings and/or physical locks on cabinet doors.

Equipment Requirements

Any transformers on the Interconnection Customer's side must be Wye grounded on the utility side or alternatively 3 phase potential transformers and a relay capable of detecting over/under voltage shall

be installed to detect an undesirable condition on the high side of the Interconnection Customer's transformer.

High Voltage Warning
Voltage received at the meter from the utility can 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.

Summer Peak Analysis - 2019

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. (DP&L - DP&L) The MILF_230-STEELE 230 kV line (from bus 232004 to bus 232000 ckt 1) loads from 123.51% to 125.79% (DC power flow) of its emergency rating (551 MVA) for the tower line contingency outage of 'DBL_4NC'. This project contributes approximately 12.55 MW to the thermal violation.

   CONTINGENCY 'DBL_4NC'/* RED LION-CEDAR CREEK 230;RED LION-CARTANZA 230
   OPEN LINE FROM BUS 231004 TO BUS 232002 CKT 1
   OPEN LINE FROM BUS 231004 TO BUS 232003 CKT 1
   END

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

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 Impact Study)

1. To mitigate the (DP&L - DP&L) MILF_230-STEELE 230 kV line (from bus 232004 to bus 232000 ckt 1) overload will require increasing the emergency rating of the Milford Substation – Steele Substation 230 kV line by rebuilding the circuit. The estimate to perform this work is **$23,000,000** and will take **24-30** months to complete.

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

To be determined in later study phases.

Short Circuit
(Summary of impacted circuit breakers)

Not required.

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

To be determined in later study phases.

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

Light Load Analysis - 2019

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 Facilities Study)

The estimated time for PJM to issue a Facilities Study Report is 8 months. The deposit required for the AB1-137 project will be $50,000.

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

(DP&L - DP&L) The MILF_230-STEELE 230 kV line (from bus 232004 to bus 232000 ckt 1) loads from 123.51% to 125.79% (**DC power flow**) of its emergency rating (551 MVA) for the tower line contingency outage of 'DBL_4NC'. This project contributes approximately 12.55 MW to the thermal violation.

CONTINGENCY 'DBL_4NC'/* RED LION-CEDAR CREEK 230;RED LION-CARTANZA 230
OPEN LINE FROM BUS 231004 TO BUS 232002 CKT 1
OPEN LINE FROM BUS 231004 TO BUS 232003 CKT 1
END

Bus Number	*Bus Name*	*Full Contribution*
232900	*DEMECSMY*	*2.6*
232851	*DUP-SFR1*	*0.49*
232616	*GEN FOOD*	*0.95*
232920	*IR10*	*0.86*
232904	*IR4*	*23.22*
232923	*MR1*	*12.53*
232924	*MR2*	*12.53*
232922	*MR3*	*6.39*
232901	*NORTHST*	*2.44*
232911	*NRG_G2*	*1.84*
292089	*T-011*	*0.23*

297076	*V2-028 C*	*0.78*
297077	*V2-028 E*	*1.28*
904212	*V4-022 E*	*1.52*
232813	*VAUGHN*	*0.18*
901004	*W1-003 E*	*2.22*
901014	*W1-004 E*	*2.22*
901024	*W1-005 E*	*2.22*
901034	*W1-006 E*	*2.22*
901411	*W1-062*	*2.87*
903511	*W3-032A*	*19.34*
904791	*W3-160 C*	*0.2*
904792	*W3-160 E*	*3.76*
907052	*X1-032 E*	*1.89*
907324	*X1-096 E*	*42.96*
910572	*X3-008 E*	*3.3*
910591	*X3-015 C*	*2.32*
910592	*X3-015 E*	*3.79*
913412	*Y1-080 E*	*0.67*
915522	*Y3-054 E*	*8.31*
915542	*Y3-058 E*	*4.1*
916231	*Z1-076 C*	*2.64*
916232	*Z1-076 E*	*4.3*
916241	*Z1-077 C*	*1.88*
916242	*Z1-077 E*	*3.07*
916431	*Z1-099*	*0.44*
916471	*Z1-103*	*2.04*
917081	*Z2-012 C*	*3.73*
917082	*Z2-012 E*	*6.09*
917431	*Z2-076 C*	*2.42*
917432	*Z2-076 E*	*1.22*
917441	*Z2-077 C*	*2.42*
917442	*Z2-077 E*	*1.22*
918111	*AA1-025*	*1.81*
918121	*AA1-026*	*1.81*
918161	*AA1-027*	*1.81*
918171	*AA1-028*	*1.81*
918441	*AA1-059 C*	*1.99*
918442	*AA1-059 E*	*0.79*
918461	*AA1-061 C*	*3.7*
918462	*AA1-061 E*	*1.82*
918831	*AA1-102*	*17.32*
919161	*AA1-140 C*	*4.6*
919162	*AA1-140 E*	*7.51*
919171	*AA1-141 C*	*2.84*
919172	*AA1-141 E*	*4.63*

919831	*AA2-069*	*332.42*
920312	*AA2-129 E*	*9.83*
920321	*AA2-130*	*0.92*
920461	*AA2-144 C*	*1.86*
920462	*AA2-144 E*	*0.87*
920491	*AA2-147 C*	*0.72*
920492	*AA2-147 E*	*0.35*
930201	*AB1-056 C OP*	*41.91*
930202	*AB1-056 E OP*	*119.36*
930211	*AB1-057 C*	*42.56*
930212	*AB1-057 E*	*121.31*
930691	*AB1-113 C*	*1.04*
930692	*AB1-113 E*	*1.69*
930881	*AB1-137 C*	*8.78*
930882	*AB1-137 E*	*3.76*