Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AA2-119

Glenn Falls 138 kV

May 2016

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 Interconnected 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 Feasibility Study, but the actual allocation, if any, is included in the System Impact Study.

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 project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs associated with them will be addressed when seeking an Interconnection Agreement as outlined below. Developer will also be responsible for providing and installing metering equipment in compliance with applicable PJM and Transmission Owner standards.

General

ESC Harrison County Power, LLC ("Interconnection Customer" or "ESC Harrison") has proposed a combined-cycle natural gas generating facility located at approximately 1.5 miles southeast of Glen Falls substation in Harrison County, West Virginia.

The installed facilities will have a total capability of 550 MW with 550 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is June 1, 2020. **This study does not imply a Monongahela Power Company ("Mon Power") commitment to this in-service date.**

Point of Interconnection (POI)

For AA2-119 project, the connection from the Mon Power transmission system to ESC Harrison's facilities will be provided through a direct connection to the 138 kV bus in the Glen Falls substation. The POI location is a developer's installed dead-end structure outside the substation as shown in Appendix 2.

Transmission Owner Scope of Work and Costs Estimation

The Transmission Owner attachment facilities and network upgrades as well as related costs estimates required for this interconnection project are shown in below table. Please note that these costs do not include CIAC Tax Gross-up:

AA2-119 Project Costs Description		Cost Estimate
Attachment Facilities *Install attachment line (overhead or underground) from bus breaker to POI.*		**$ 50,000**
Direct Connection Network Upgrades		**$ 1,363,700**
*NUN**	*Description*	
n4851	*Glen Falls SS - Grade and extend fence and ground grid approx. 50' x 180'. Extend 138 kV bus and install 138 kV SF6 breaker, bus/line disconnects, foundations, control cable and associated facilities. 16' x 16' expansion of concrete control building.* ***Estimate does not include property acquisition necessary for expansion.***	
Non-Direct Connection Network Upgrades		**$ 11,397,300**
*NUN**	*Description*	
n4852	*Oak Mound SS - Upgrade Glen Falls 138 kV terminal to 1322 A LTE capacity for PJM AA2-119 feasibility study. Replace line trap, down conductors and terminal connectors. $82,300.*	
n4853	*Glen Falls SS - Upgrade Oak Mound 138 kV terminal to 1322 A LTE capacity for PJM AA2-119 feasibility study. Replace line trap, down conductors and terminal connectors. $76,300.*	
n4854	*Glen Falls SS. Replace the Buckhannon 50, Barnetts Run 406, Oak Mound 4, No. 1 & No. 4 transf. and 138 kV Bust tie breakers with 63 kA, 3000 A units. Install 3 new foundations, 4 switches, cable trench, control cable and all associated facilities. $1,915,300.*	
n4855	*Glen Falls - Oak Mound 138 kV, 2.5 Mile Rebuild. Rebuild from Glen Falls Sub to structure #13, approx. 2.5 miles, to increase conductor size. $9,323,400.*	
Contributions for Previously Identified Upgrades None.		**$ 0**
	Total Costs	**$ 12,811,000**

** NUN means Network Upgrade Number*

Interconnection Customer Requirements

ESC Harrison will be responsible for meeting all criteria as specified in the applicable sections of the Interconnected Transmission Owner "Requirements for Transmission Connected Facilities" document including:

1. The purchase and installation of fully rated 138 kV circuit breaker on the high side of the AA2-119 step-up transformer.
2. The purchase and installation of the minimum required Interconnected Transmission Owner generation interconnection relaying and control facilities. This includes over/under voltage protection, over/under frequency protection, and zero sequence voltage protection relays.
3. The purchase and installation of supervisory control and data acquisition ("SCADA") equipment.
4. The establishment of dedicated communication circuits for SCADA.
5. A compliance with the Interconnected Transmission Owner and PJM generator power factor and voltage control requirements.
6. The execution of a back-up retail service agreement with the electric distribution company to serve the customer load supplied from the AA2-119 generation project interconnection point when the units are out-of-service. This assumes the intent of ESC Harrison is to net the generation with the load.

The above requirements are in addition to any metering or other requirements required by PJM.

Schedule of Work

Based on the scope of interconnection attachment facilities, direct and non-direct system upgrades, it is expected to take a minimum of twenty three (23) months from the date of a fully executed Interconnection Construction Service Agreement to complete the installation. This includes a preliminary payment that compensates the Interconnected Transmission Owner for the first three months of the engineering design work that is related to the interconnection facilities of the Project. It also assumes that the Interconnection Customer will provide the property for the Project direct connection facilities and all right-of-way, permits, easements, etc. that will be needed. A further assumption is that there will be no environmental issues with any of the new properties associated with this project, that there will be no delays in acquiring the necessary permits for implementing the defined direct connection facilities and that transmission system outages will be possible when requested.

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 Interconnection

Customer's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

Transmission Owner Requirements

The Interconnection Customer will be required to comply with all First Energy revenue metering requirements for generation interconnection customers. The Interconnected Transmission Owner revenue metering requirements may be found in the Interconnected Transmission Owner "Requirements for Transmission Connected Facilities" document located at the following links:

https://www.firstenergycorp.com/content/dam/feconnect/files/wholesale/Requirements-for-Transmission-Connected-Facilities.pdf

http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx

Network Impacts

The Queue Project AA2-119 was evaluated as a 550.0 MW (Capacity 550.0 MW) injection into the Glen Falls 138 kV substation in the APS area. Project AA2-119 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AA2-119 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2019

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)

1. (AP - AP) The 01GLENFL-01OAKMND 138 kV line (from bus 235334 to bus 235380 ckt 1) loads from 9.36% to 131.26% (AC power flow) of its emergency rating (192 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_54'. This project contributes approximately 236.72 MW to the thermal violation.

CONTINGENCY 'AP_SB_54' / GLEN FALLS-HARRISON TAP STK BKR AT GLEN FALLS
  OPEN BUS 235349
  OPEN BUS 235347
  OPEN BUS 235396
  OPEN BRANCH FROM BUS 235334 TO BUS 235442 CKT 1
  OPEN BRANCH FROM BUS 235334 TO BUS 235375 CKT 1

END

Please refer to Appendix 3 for a table containing the generators having contribution to this flowgate.

2. (AP - AP) The 01GLENFL-01OAKMND 138 kV line (from bus 235334 to bus 235380 ckt 1) loads from 9.34% to 131.24% (AC power flow) of its emergency rating (192 MVA) for the bus fault outage of 'AP_C1_88'. This project contributes approximately 236.72 MW to the thermal violation.

CONTINGENCY 'AP_C1_88' /GLEN_FALLS_138_EAST
OPEN BRANCH FROM BUS 235334 TO BUS 235375 CKT 1
OPEN BRANCH FROM BUS 235334 TO BUS 235349 CKT 1
OPEN BRANCH FROM BUS 235334 TO BUS 235442 CKT 1
END

3. (AP - AP) The 01GLENFL-01OAKMND 138 kV line (from bus 235334 to bus 235380 ckt 1) loads from 9.34% to 131.24% (AC power flow) of its emergency rating (192 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_53'. This project contributes approximately 236.72 MW to the thermal violation.

CONTINGENCY 'AP_SB_53' / GLEN FALLS-MCALPIN STK BKR AT GLEN FALLS
OPEN BRANCH FROM BUS 235334 TO BUS 235349 CKT 1
OPEN BRANCH FROM BUS 235334 TO BUS 235375 CKT 1
OPEN BRANCH FROM BUS 235334 TO BUS 235442 CKT 1
END

4. (AP - AP) The 01GLENFL-01OAKMND 138 kV line (from bus 235334 to bus 235380 ckt 1) loads from 31.6% to 110.61% (AC power flow) of its emergency rating (192 MVA) for the tower line contingency outage of 'AP_C5_130'. This project contributes approximately 153.35 MW to the thermal violation.

CONTINGENCY 'AP_C5_130' /GLF-WUN_GLF-MRG
OPEN BUS 235349
OPEN BUS 235417
OPEN BUS 235347
OPEN BUS 235396
END

5. (AP - AP) The 01GLENFL-01OAKMND 138 kV line (from bus 235334 to bus 235380 ckt 1) loads from 4.05% to 101.4% (AC power flow) of its emergency rating (192 MVA) for the tower line contingency outage of 'AP_C5_120'. This project contributes approximately 191.54 MW to the thermal violation.

CONTINGENCY 'AP_C5_120' /GLF-BPH_GLF-BKH
OPEN BRANCH FROM BUS 235306 TO BUS 235334 CKT 1
OPEN BUS 235375
END

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

Steady-State Voltage Requirements

None

Short Circuit
(Summary of impacted circuit breakers)

PJM identified five (5) overdutied breakers. See Appendix 4 for details.

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.

Not Applicable

Light Load Analysis - 2019
None.

System Reinforcements

Short Circuit and Dynamic (Stability and Reactive Power) System Requirement

Criteria for Short Circuit and Dynamic System Requirement were not met.

Short Circuit study identified five (5) overdutied breakers and the Dynamic Study identified seven three-phase fault contingencies (3N.02-3N.08) due to the unanticipated tripping of AA2-119 assuming the use of electro-mechanical negative sequence directional ground relays (12 cycles clearing time).

Replacing the five breakers identified in the Short Circuit study with faster 3 cycle gas breakers at Glen Falls would ensure that protection would operate within the required time of 6 cycles.

Breaker identifiers are provided in Appendix 5.

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)

1. To relieve the Glen Falls – Oak Mound 138 kV line overloads identified: Rebuild 2.5 miles of line and upgrade terminal equipment at both Glen Falls & Oak Mound substations. New expected SE rating of Glen Falls – Oak Mound 138 kV line to be 316 MVA. Cost estimate is $9,482,000. PJM Network Upgrades N4852, N4853 and N4855.

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

Light Load 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)

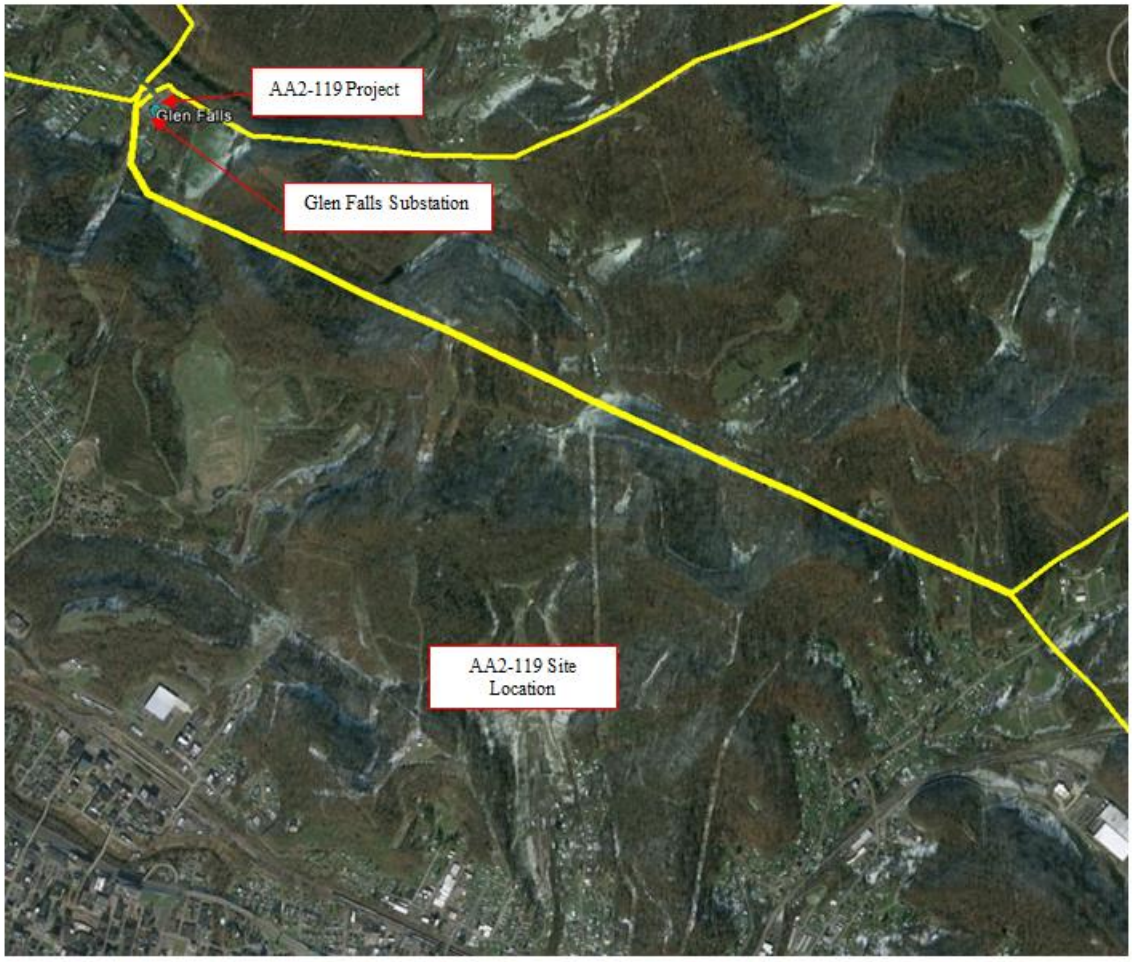
None

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)

None

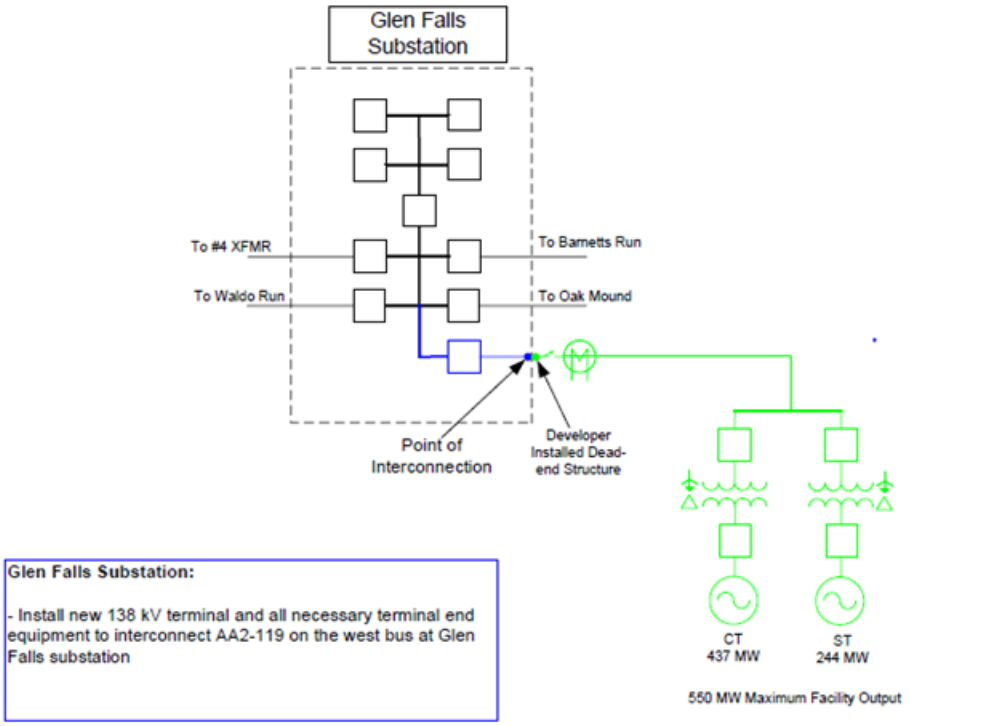
Appendix 1

AA2-119 Project Location



Appendix 2

Interconnection Single Line Diagram



Appendix 3

Flowgate Contributions

The purpose of this appendix is to provide information about 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.

(AP - AP) The 01GLENFL-01OAKMND 138 kV line (from bus 235334 to bus 235380 ckt 1) loads from 9.36% to 131.26% (AC power flow) of its emergency rating (192 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_54'. This project contributes approximately 236.72 MW to the thermal violation.

CONTINGENCY 'AP_SB_54' / GLEN FALLS-HARRISON TAP STK BKR AT GLEN FALLS
OPEN BUS 235349
OPEN BUS 235347
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OPEN BRANCH FROM BUS 235334 TO BUS 235375 CKT 1
END

Bus Number	*Bus Name*	*Full Contribution*
920231	*AA2-119*	*236.72*

Appendix 4

Overdutied Breakers Identified by PJM Short Circuity Screening

Bus Name	BREAKER	Rating Type	Breaker Capacity (Amps)	Duty Percent With AA2-119_APS	Duty Percent Without AA2-119_APS	Duty Percent Difference
GLEN FALLS 138.kV	BUCKHANN 50	T	19703	176.07%	87.43%	88.64%
GLEN FALLS 138.kV	BarnetR406	T	20189.2	171.83%	85.32%	86.50%
GLEN FALLS 138.kV	OAK MOUND 4	T	20335	170.59%	84.71%	85.88%
GLEN FALLS 138.kV	1 & 4 XFMRS	T	20918.5	165.84%	82.35%	83.49%
GLEN FALLS 138.kV	138 BUS TIE	S	19777.8	146.17%	85.02%	61.15%

Appendix 5

Dynamic Analysis

AA2-119 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 84 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation (20 second run);
b) Three-phase faults with normal clearing time;
c) Single-phase faults with single phase stuck breaker;
d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at remote end due to primary communications/relaying failure;
e) Single-phase bus faults with normal clearing time;
f) Single-phase faults with loss of multiple-circuit tower line.

For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.

The results indicate that for 77 of the 84 fault contingencies tested on the RTEP 2019 light load case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3%.
b) AA2-119 generators were able to ride through faults (except for faults where protective action trips AA2-119).

The stability criteria was not met for seven three-phase fault contingencies (3N.02-3N.08) due to the unanticipated tripping of AA2-119 assuming the use of electro-mechanical negative sequence directional ground relays (12 cycles clearing time). Replacing the five breakers with faster 3 cycle gas breakers at Glen Falls would ensure that protection would operate within the required time of 6 cycles. These breakers were also identified as overdutied in the Short Circuit Analysis conducted by PJM. Breaker identifiers are provided in the results section.

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in **Error! Reference source not found.** through **Error! Reference source not found.**.

The results indicate that for 77 of the 84 fault contingencies tested on the RTEP 2019 light load case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3%.
b) AA2-119 generators were able to ride through faults (except for faults where protective action trips AA2-119).

The stability criteria was not met for seven three-phase fault contingencies (3N.02-3N.08) due to the unanticipated tripping of AA2-119. These faults clearing times of 12 cycles are assuming the use of electro-mechanical negative sequence directional ground relays.

Additional testing showed that using typical clearing time at this kV level (a reduction in the fault clearing time from 12.0 cycles to 6.0 cycles) mitigates the unanticipated tripping of AA2-119.

Replacing the five breakers with faster 3 cycle gas breakers at Glen Falls would ensure that protection would operate within the required time of 6 cycles. These breakers were also identified as overdutied in the Short Circuit Analysis conducted by PJM. Full list of breaker that need to be replaced is shown below.

Bus Number	Bus Name	BREAKER
20064	GLEN FALLS 138.kV	BUCKHANN 50
20064	GLEN FALLS 138.kV	BarnetR406
20064	GLEN FALLS 138.kV	OAK MOUND 4
20064	GLEN FALLS 138.kV	1 & 4 XFMRS
20064	GLEN FALLS 138.kV	138 BUS TIE