Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AB1-149

Baker 138 kV

September 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 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 will be deferred until the System Impact Study is performed.

The System Impact 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 may be included in the study.

General

Invenergy Wind Development LLC – Interconnection Customer – has proposed a wind generating facility located approximately 1 mile from the existing 138 kV Baker Substation in Hardy County, West Virginia. The installed facilities will have a total capability of 121.6 MW with 15.8 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is December 31, 2018. **This study does not imply a Potomac Edison ("Transmission Owner") commitment to this in-service date.**

Point of Interconnection

AB1-149 will interconnect with the Potomac Edison transmission system through direct injection into Baker substation 138 kV bus. Please refer to the one-line diagram in Appendix 2 for system configuration.

Cost Summary

Interconnected Transmission Owner facilities, network upgrades and related costs required for this interconnection project are listed below. Contributions in Aid of Construction (CIAC) tax gross-up is not included.

(a.) Attachment Facilities: $ 0 (None)

(b.) Direct Connection Network Upgrades:

Estimated time to complete: 34 Months.
Estimated costs: **$ 14,401,500**, detailed as follows:

(b.1) Baker Substation - construct 138kV ring bus.
Estimated cost: **$ 2,563,600** (Network Upgrade Number: tbd at the facilities study stage.)

(b.2) Loop the existing Baker-Hardy 138 kV circuit into the new Short Mountain Substation. Existing horizontal circuit to be maintained on singel-circuit structures. At Baker-Hardy 138 kV loop to Short Mountain.
Estimated cost: **$ 922,300** (Network Upgrade Number: tbd at the facilities study stage.)

(b.3) Albright Substation - Construct a 138 kV breaker and half substation with 5 strings.
Estimated cost: **$ 10,915,600** (N4655; same NUN for c.2 and c.2)

(c.) Non-Direct Connection Network Upgrades

Estimated time to complete: 34 Months.
Estimated costs: **$ 4,771,700**, detailed as follows:

(c.1) Hardy Substation - Install 1-2000A 138 kV wave trap, 1-138 kV CVT, structures and foundations, tuner, transfer trip transmitter and associated facilities. Revise relay settings as required.
Estimated cost: **$ 165,800** (Network Upgrade Number: tbd at the facilities study stage.)

(c.2) Relocate (9) 138 kV transmission lines to a new breaker-and-a-half substation adjacent to the abandoned Albright PS.
Estimated cost: **$ 4,477,100** (N4655; same NUN for b.3 and c.3)

(c.3) Adjust Remote Relay and Metering Settings at Multiple Substations.
Estimated cost: **$ 128,800** (N4655; same NUN for c.2 and b.3)

(d.) Direct Connection Local Upgrades: $ 0 (None)

(e.) Non-Direct Connection Local Upgrades: $ 0 (None)

(f.) Contributions for Previously Identified Upgrades: $ 0 (None)

(g.) Baseline Upgrades: $ 0 (None)

(h.) Option to Build Upgrades: $ 0 (None)

Total costs (a.) to (h.): $ 19,173,200

Interconnection Customer Requirements

In addition to the Potomac Edison and FirstEnergy affiliated facilities, Invenergy Wind Development, LLC will also be responsible for meeting all criteria as specified in the applicable sections of the FirstEnergy "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 (AB1-149) step-up transformer.
2. The purchase and installation of the minimum required FirstEnergy 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 a revenue class meter for each unit to measure the power delivered in compliance with the FirstEnergy standards.
4. The purchase and installation of supervisory control and data acquisition ("SCADA") equipment to provide information in a compatible format to the FirstEnergy Transmission System Control Center.
5. The establishment of dedicated communication circuits for SCADA to the FirstEnergy Transmission System Control Center.
6. A compliance with the FirstEnergy and PJM generator power factor and voltage control requirements.
7. The execution of a back-up service agreement to serve the customer load supplied from the (AB1-149) generation project interconnection point when the units are out-of-service. This assumes the intent of Invenergy Wind Development, LLC is to net the generation with the load.

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

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.

Interconnected Transmission Owner Requirements

The Interconnection Customer will be required to comply with all FirstEnergy Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the "FirstEnergy Requirements for Transmission Connected Facilities" document located at the following links:

http://www.firstenergycorp.com/feconnect
http://www.pjm.com/planning/design-engineering/to-tech-standards.aspx

Schedule

Based on the scope of Network Upgrades required to support this generation project, it is expected to take a minimum of thirty four (34) months from the date of a fully executed Interconnection Construction Service Agreement to complete the installation. This assumes that Interconnection Customer will provide all rights-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 Network upgrades and that all system outages will be allowed when requested.

Network Impacts

The Queue Project AB1-149 was evaluated as a 121.6 MW (Capacity 15.8 MW) injection into the Baker 138 kV substation in the APS area. Project AB1-149 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-149 was stu12died 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 01PARSNS-01LOUGHL 138 kV line (from bus 235385 to bus 235362 ckt 1F) loads from 93.97% to 111.46% (AC power flow) of its emergency rating (179 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_411'. This project contributes approximately 29.47 MW to the thermal violation.

```
CONTINGENCY 'AP_SB_411'                 / ALBRIGHT BREAKER FAILURE - TIE BREAKER
  OPEN BUS 235120
  OPEN BUS 235564
  OPEN BUS 235565
  OPEN BUS 235566
  END
```

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

2. (AP - AP) The 01PARSNS-01LOUGHL 138 kV line (from bus 235385 to bus 235362 ckt 1F) loads from 87.98% to 102.74% (AC power flow) of its emergency rating (179 MVA) for the bus fault outage of 'AP_C1_73'. This project contributes approximately 24.97 MW to the thermal violation.

```
CONTINGENCY 'AP_C1_73'                                    / ALBRIGHT_138_NORTH
  OPEN BRANCH FROM BUS 235120 TO BUS 235566 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235356 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235398 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235304 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235485 CKT 1F
  END
```

3. (AP - AP) The 01WILLIM-01PARSNS 138 kV line (from bus 235427 to bus 235385 ckt 1F) loads from 98.38% to 115.92% (AC power flow) of its emergency rating (179 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_411'. This project contributes approximately 29.47 MW to the thermal violation.

```
CONTINGENCY 'AP_SB_411'                    / ALBRIGHT BREAKER FAILURE - TIE BREAKER
  OPEN BUS 235120
  OPEN BUS 235564
  OPEN BUS 235565
  OPEN BUS 235566
  END
```

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

4. (AP - AP) The 01WILLIM-01PARSNS 138 kV line (from bus 235427 to bus 235385 ckt 1F) loads from 92.38% to 107.17% (AC power flow) of its emergency rating (179 MVA) for the bus fault outage of 'AP_C1_73'. This project contributes approximately 24.97 MW to the thermal violation.

```
CONTINGENCY 'AP_C1_73'                                / ALBRIGHT_138_NORTH
  OPEN BRANCH FROM BUS 235120 TO BUS 235566 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235356 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235398 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235304 CKT 1
  OPEN BRANCH FROM BUS 235120 TO BUS 235485 CKT 1F
  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

(Results of the steady-state voltage studies should be inserted here)

None

Short Circuit

(Summary of impacted circuit breakers)

None

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. (AP - AP) The 01BLACKO 500/138 kV transformer (from bus 235446 to bus 235103 ckt 3) loads from 91.72% to 100.33% (AC power flow) of its emergency rating (549 MVA) for the single line contingency outage of '01HATFLD _01BLACKO _058'. This project contributes approximately 43.91 MW to the thermal violation.

```
CONTINGENCY '01HATFLD _01BLACKO _058'
  DISCONNECT BRANCH FROM BUS 235108 TO BUS 235103 CKT 1   /* 500/500KV, AREA 201/201.
  END
```

Light Load Analysis - 2019

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

System Reinforcements

Short Circuit

None

Stability and Reactive Power Requirement

None. Please refer to Appendix 5 for more dynamic study summary.

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 resolve the Parsons – Loughs Lane 138 kV line overloads and the William – Parsons 138 kV line overloads: Reconfigure the Albright 138 kV bus to a breaker and a half configuration at an estimated cost of $15.5215 M. PJM Network Upgrade N4655. AB1-149 will be responsible for this cost.

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

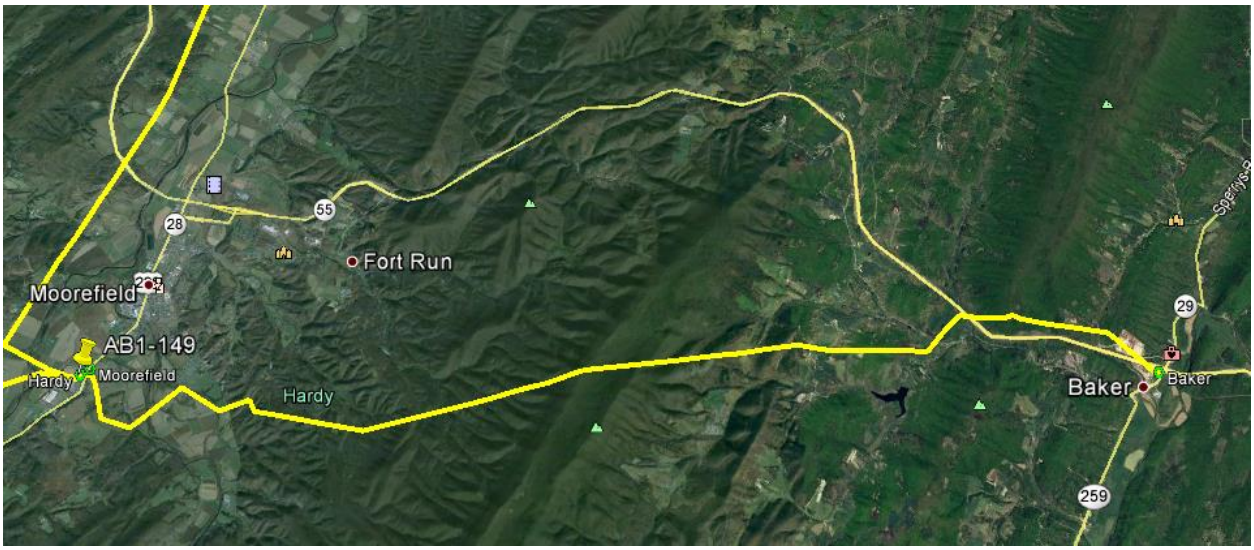
Contribution to Previously Identified System Reinforcements
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

None

Appendix 1

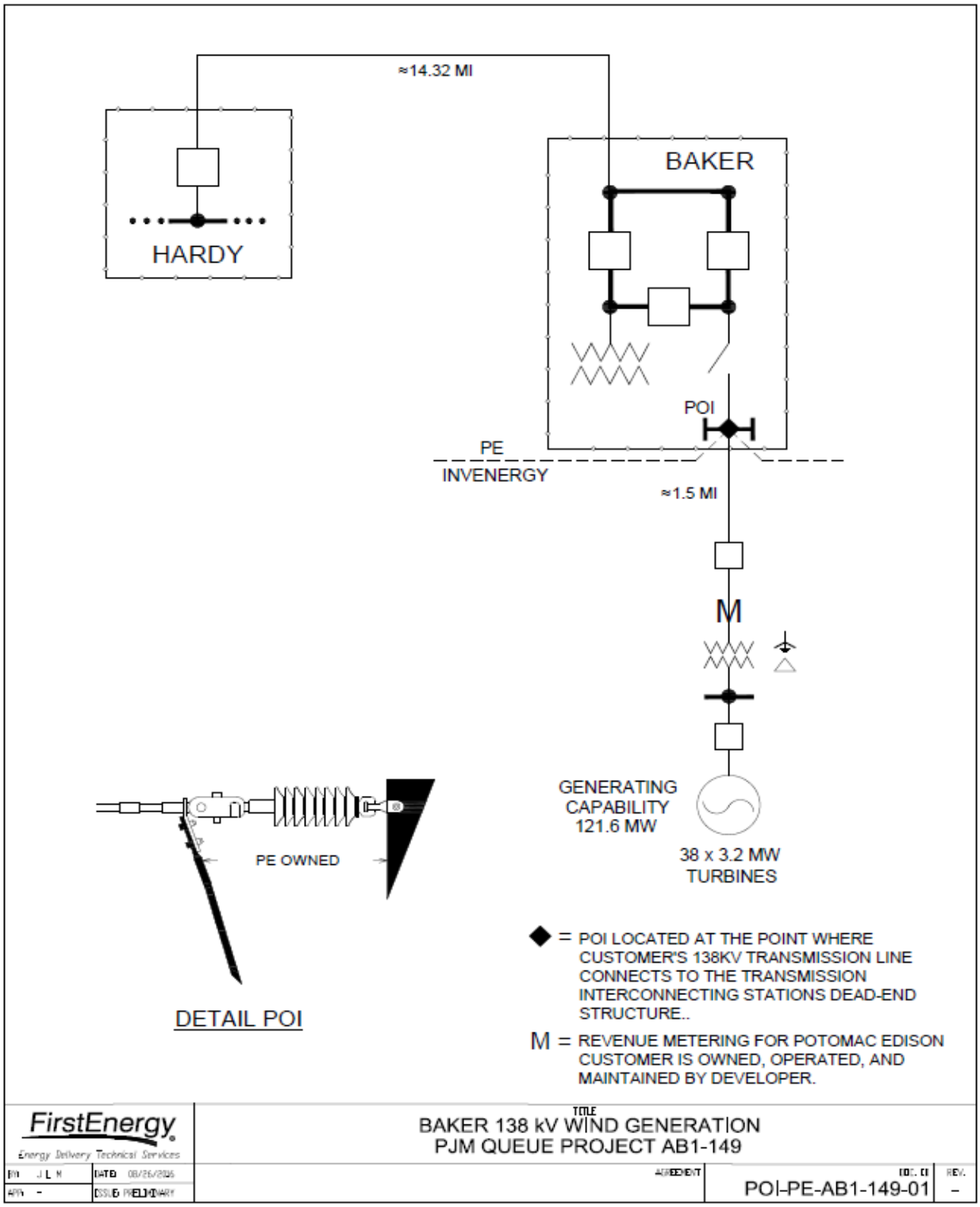
Facility Location

PJM Queue Position: AB1-149



Appendix 2

Interconnection One-Line Diagram
PJM Queue Position: AB1-149



Appendix 3

Flowgate Contingency 1
PJM Queue Position: AB1-149

This appendix contains additional information about flowgate in question presented in the body of the report. A description of the flowgate and its contingency is included for convenience. However, the intent of this appendix 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.

(AP - AP) The 01PARSNS-01LOUGHL 138 kV line (from bus 235385 to bus 235362 ckt 1F) loads from 93.97% to 111.46% (AC power flow) of its emergency rating (179 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_411'. This project contributes approximately 29.47 MW to the thermal violation.

```
CONTINGENCY 'AP_SB_411'              / ALBRIGHT BREAKER FAILURE - TIE BREAKER
  OPEN BUS 235120
  OPEN BUS 235564
  OPEN BUS 235565
  OPEN BUS 235566
  END
```

Bus Number	*Bus Name*	*Full Contribution*
235625	*01BACKB*	*31.54*
237512	*01ROTHROCK*	*0.45*
292310	*K-019*	*0.9*
292400	*K-028 C*	*0.42*
292401	*K-028 E*	*14.78*
885641	*T-016 C*	*0.13*
885642	*T-016 E*	*4.42*
237519	*U2-061 E*	*25.99*
918471	*AA1-062 C*	*17.32*
918472	*AA1-062 E*	*116.49*
920072	*AA2-103 E*	*11.95*
931001	*AB1-149 C OP*	*3.83*
931002	*AB1-149 E OP*	*25.64*

Appendix 4

Flowgate Contingency 2
PJM Queue Position: AB1-149

This appendix contains additional information about flowgate in question presented in the body of the report. A description of the flowgate and its contingency is included for convenience. However, the intent of this appendix 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.

(AP - AP) The 01WILLIM-01PARSNS 138 kV line (from bus 235427 to bus 235385 ckt 1F) loads from 98.38% to 115.92% (AC power flow) of its emergency rating (179 MVA) for the line fault with failed breaker contingency outage of 'AP_SB_411'. This project contributes approximately 29.47 MW to the thermal violation.

```
CONTINGENCY 'AP_SB_411'              / ALBRIGHT BREAKER FAILURE - TIE BREAKER
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  OPEN BUS 235564
  OPEN BUS 235565
  OPEN BUS 235566
  END
```

Bus Number	*Bus Name*	*Full Contribution*
235625	*01BACKB*	*31.54*
237512	*01ROTHROCK*	*0.45*
292310	*K-019*	*0.9*
292400	*K-028 C*	*0.42*
292401	*K-028 E*	*14.78*
885641	*T-016 C*	*0.13*
885642	*T-016 E*	*4.42*
237519	*U2-061 E*	*25.99*
918471	*AA1-062 C*	*17.32*
918472	*AA1-062 E*	*116.49*
920072	*AA2-103 E*	*11.95*
931001	*AB1-149 C OP*	*3.83*
931002	*AB1-149 E OP*	*25.64*

Appendix 3

Dynamic Simulation Analysis – Executive Summary
PJM Queue Project Number: AB1-049

Generator Interconnection Request AB1-149 is for a 121.6 MW Maximum Facility Output (MFO) wind generating facility consisting of 38 GE 3.2MW wind turbines. AB1-149 has a Point of Interconnection (POI) at Baker 138 kV substation in the Potomac Edison (PE) transmission system, Hardy County, West Virginia.

This report describes a dynamic simulation analysis of AB1-149 as part of the overall system impact study. The load flow scenario for the analysis was based on the RTEP 2019 summer peak case, modified to include applicable queue projects. AB1-149 has been dispatched online at maximum power output and unity power factor at the generator bus.

AB1-149 was tested for compliance with NERC, PJM and other applicable criteria. 48 contingencies was studied, each with a 10 second simulation time period. Contingencies studied include:

a) Steady state operation (20 second);

b) Three phase faults with normal clearing time;

c) Single phase faults with stuck breaker;

d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from the fault due to primary communications/relay failure.

e) Single phase bus faults with normal clearing time.

f) Single-phase faults with loss of multiple circuit tower line.

No relevant Bus or High Speed Reclosing (HSR) contingencies were identified.

For all, excepting one, fault contingencies tested on the 2019 summer peak case:

a) The system with AB1-149 included is transiently stable and post-contingency oscillations were positively damped with a damping margin of at least 3%.

b) The AB1-149 generator was able to ride through all faults (except for faults where protective action tripped a generator(s)).

c) Following fault clearing, all bus voltages recovered to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element tripped, other than those either directly connected or designed to trip as a consequence of that fault.

Instability was observed for the stuck breaker fault 1B.10. Network non-convergence at AB1-149 was observed and AB1-149 tripped off due to voltage collapse in the surrounding network. The unusual dynamic response was due to the network being unable to converge as a result of voltage collapse and thus the dynamic response was considered invalid. The issue was resolved by turning off the 34.5 kV capacitor banks at Frenchs Mill and Junction thereby indicating that a model issue may be the cause of the instability.

The Warrior Run generator exhibited low amplitude insufficiently damped (< 3%) oscillations for contingencies 3N.09 to 3N.13. The insufficient damping was present in a pre-project case for these contingencies and is therefore not attributable to AB1-149.

No mitigations were found to be required.