Generation Interconnection
System Impact Study Report

For

PJM Generation Interconnection Request
Queue Position AD1-083

Page - Bethel 138 kV

October 2018

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

Urban Grid Solar Projects, LLC ("Interconnection Customer") has proposed a new solar generation facility located approximately 1.2 miles from Page substation in Page County, Virginia. GPS coordinates are 38.6800000, -78.4500000. The installed facilities will have capability of 100 MW with 60.1 MW of this output being recognized by PJM as capacity. The proposed in-service date is December 31, 2019. This study does not imply a **Potomac Edison ("Transmission Owner") commitment to this in-service date.**

Point of Interconnection (POI)

The AD1-083 project will interconnect with the Potomac Edison transmission system by tapping the Page – Riverton 138 kV line at a point located approximately 1.2 miles from Page substation. To facilitate the tap interconnection, Potomac Edison will construct a new 138 kV three (3) breaker ring bus station and loop the Page-Riverton 138 kV line into the new station. The Point of Interconnection will be located at the new substation's exist side to solar plant. Please refer to Appendix 2 for one-line diagram of system configuration.

Schedule

Based on the extent of the Potomac Edison direct connection and network upgrades required to support the (AD1-083) generation project, it is expected to take a minimum of eighteen (18) months from the date of a fully executed Interconnection Construction Service Agreement to complete the installation. This includes the requirement for Urban Grid Solar Projects, LLC to make a preliminary payment to FirstEnergy (via PJM) which funds the first three months of engineering design that is related to the construction of the Direct Connection facilities. It is assumed that Urban Grid Solar Projects, LLC 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.

Transmission Owner Scope of Work and Cost Summary

The following upgrades are required to support AD1-083 interconnection. Please Note: The estimated costs shown below do not include Contribution in Aid of Construction (CIAC) Federal Income Tax Gross Up charge The total tax is $1,225,800 may or may not be charged to this project based on whether or not this project meets the eligibility requirements of the latest IRS Notice 88-129 provisions for non-taxable status. Total cost with tax: $9,619,300. All costs are in 2018 Dollars. All Network Upgrade Numbers will be determined during the facilities study stage.

(a) Attachment Facilities: None.

(b) Direct Connection Network Upgrades:

(b1) PJM Network Upgrade Number: tbd.
New 138-kV three (3) breaker ring bus. **$5,566,400**

(b2) PJM Network Upgrade Number: tbd.
Loop the Page-Riverton 138kV line into the new Hawksbill substation **$1,724,800**

(b3) PJM Network Upgrade Number: None.
Project management, commissioning, environmental, forestry, Right of Way, and Scada. **$570,600**

(b4) PJM Network Upgrade Number: None.
Nameplates and drawing updates for line name change at the new generation substation. **$28,600**

(b5) PJM Network Upgrade Number: None.
Customer-owned 138 kV revenue metering inside Customer Facility **$2,300**

(c) Non-Direct Network Upgrades:

(c1) PJM Network Upgrade Number: tbd.
Replace Riverton line tuner and line relaying at Page substation **$250,400**

(c2) PJM Network Upgrade Number: tbd.
Replace Page line tuner and line relaying at with carrier set at Riverton substation. **$250,400**

(d) Direct Local Network Upgrades: None.

(e) Non-Direct Local Network Upgrades: None.

(f) Option to Build Upgrades: None.

Estimated Total Costs (a) to (f): $8,393,500

Interconnection Customer Requirements

The proposed Customer Facilities must be designed in accordance with FirstEnergy's "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx. In particular, Interconnection Customer is responsible for the following:

1. The purchase and installation of fully rated 138 kV circuit breaker on the high side of the AD1-083 step-up transformer. A single breaker must be used to protect this line; individual GSU transformer breakers cannot be used to protect this line.
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 supervisory control and data acquisition (SCADA) equipment to provide information in a compatible format to the FirstEnergy Transmission System Control Center.
4. The compliance with the FirstEnergy and PJM generator power factor and voltage control requirements. Interconnection Customer shall design its non-synchronous Customer Facility with the ability to maintain a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs) measured at the high-side of the facility substation transformer(s) connected with the FirstEnergy transmission system.
5. The execution of a back-up service agreement to serve the customer load supplied from the AD1-083 generation project metering point when the units are out-of-service. This assumes the intent of Interconnection Customer is to net the generation with the load.
6. Interconnection Customer must meet all PJM, ReliabilityFirst and NERC reliability criteria and operating procedures required for standards compliance. For example, Interconnection Customer will need to properly locate and report the over and under-voltage and over and under-frequency system protection elements for its units as well as the submission of the generator model and protection data required to satisfy the PJM and ReliabilityFirst audits. Failure to comply with these requirements may result in a disconnection of service if the violation is found to compromise the reliability of the FirstEnergy system.
7. Interconnection Customer will be responsible for acquiring all easements, properties, and permits that may be required to construct both the new interconnection switching station and the associated attachment facilities. Interconnection Customer will also be responsible for the rough grade of the property and an access road to the proposed three breaker ring bus site. The project will also require non-direct connection upgrades at Page and Riverton substations.
8. Revenue Metering and Scada Requirements:
   7.1 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.
   7.2 First Energy 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.pjm.com/planning/design-engineering/to-tech-standards.aspx

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

Network Impacts

The Queue Project AD1-083 was evaluated as a 100.0 MW (Capacity 60.1 MW) injection tapping Page to Bethel 138kV line in the APS area. Project AD1-083 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD1-083 was studied with a commercial probability of 53%. Potential network impacts were as follows:

Summer Peak Analysis - 2021

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)

None

Steady-State Voltage Requirements

To be determined during later study phase

Short Circuit

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.

None

Light Load Analysis - 2021

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

To be determined during later study phases

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)

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

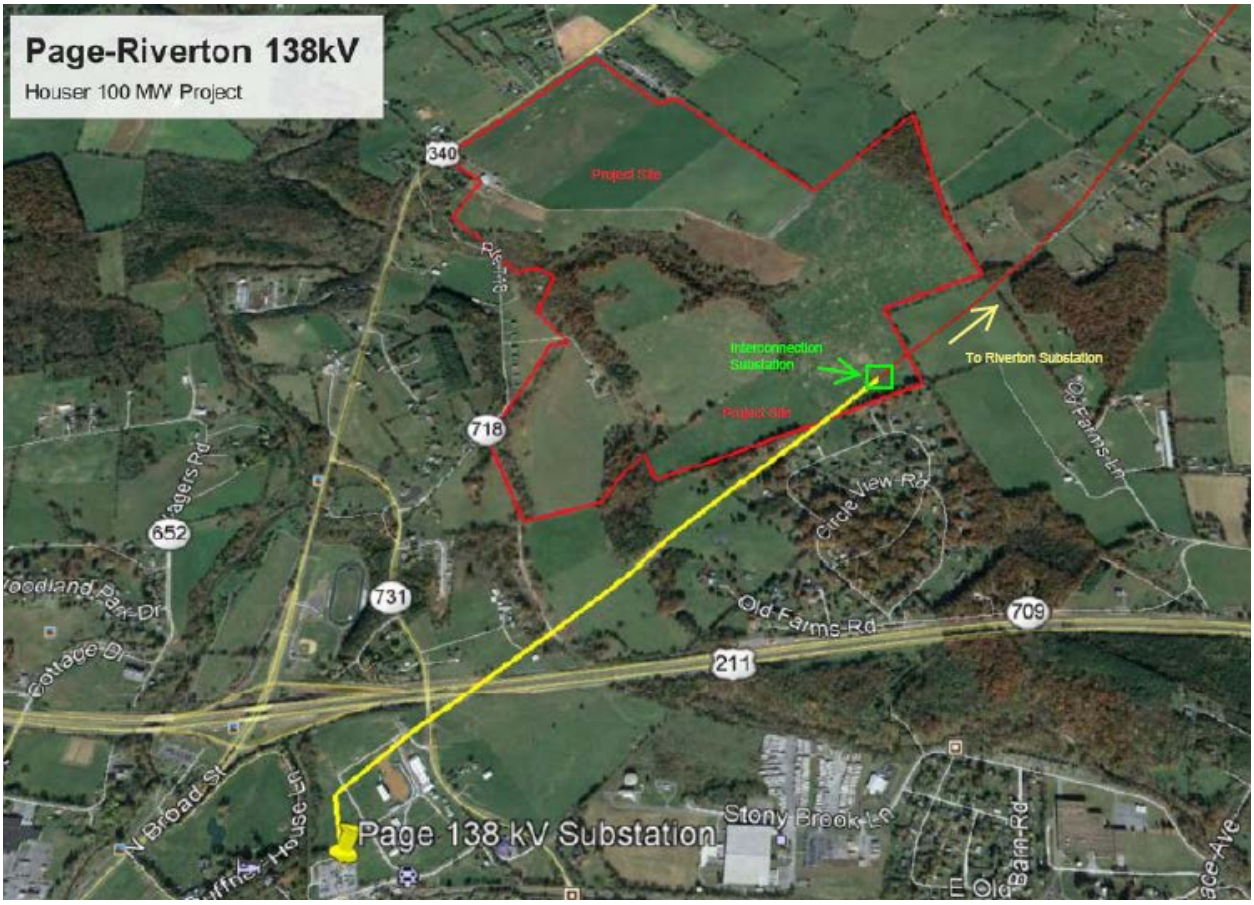
Contribution to Previously Identified System Reinforcements

(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

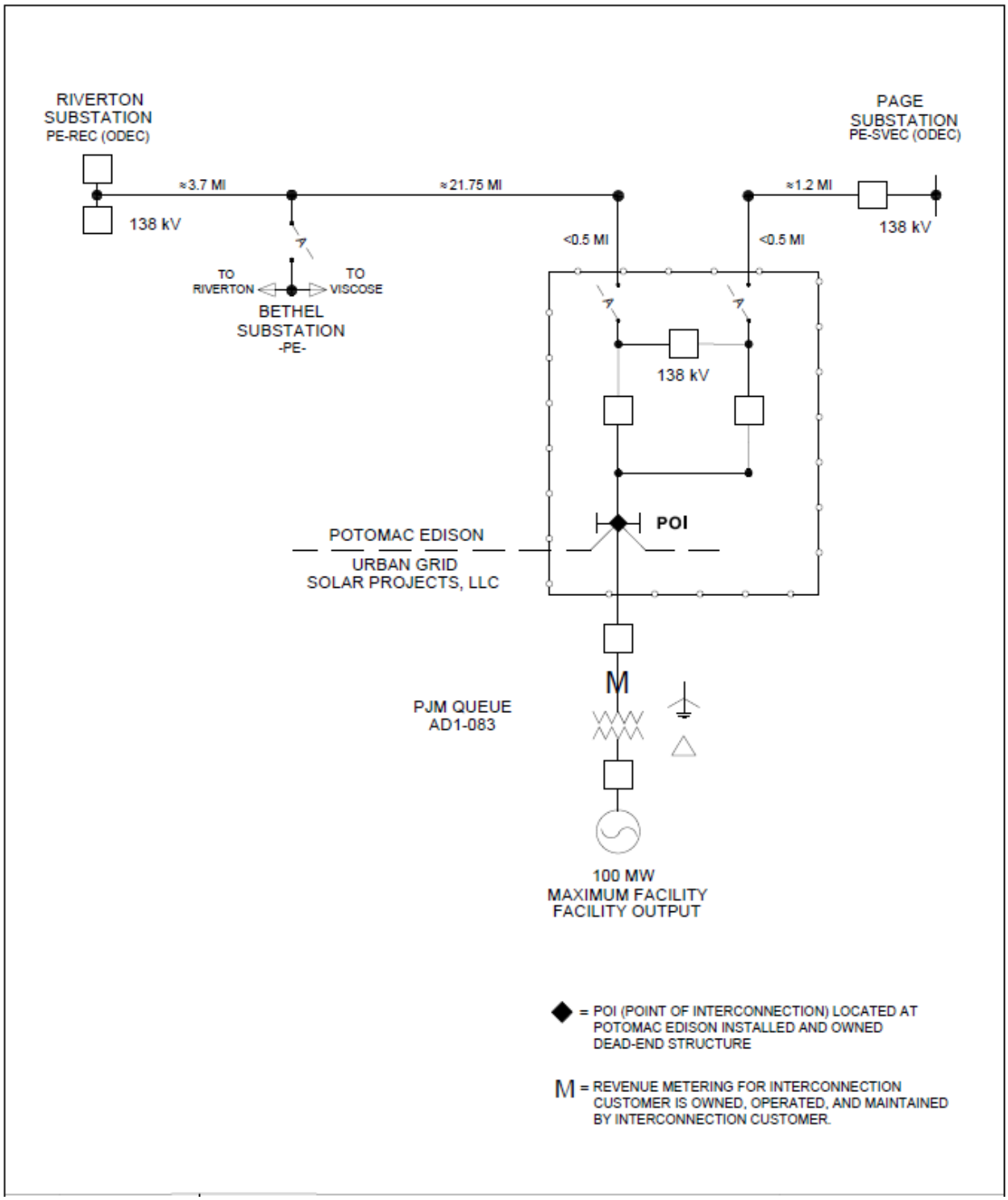
Appendix 1

Facility Location
PJM Queue Position: AD1-083



Appendix 2

Interconnection One-Line Diagram
PJM Queue Position: AD1-083



Appendix 3

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-155

Executive Summary

Generator Interconnection Request AD1-083 project is for a 100 MW Maximum Facility Output (MFO) solar powered generating facility with a Point of Interconnection (POI) on Page – Bethel 138 kV line in the APS system, Page County, Virginia.

This report describes a dynamic simulation analysis of AD1-083 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2021 summer peak case, modified to include applicable queue projects. AD1-083 has been dispatched online at maximum power output, with approximately unity power factor at the POI.

The AD1-083 queue project was tested for compliance with NERC, PJM and other applicable criteria. The range of contingencies evaluated was limited to that necessary to assess compliance and each was limited to a 20-second simulation time period.

Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Operating of a line section w/o a fault, Single-line-to-ground (slg) on Bus Section and Breaker. (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis. In this study, P2 contingencies are not applicable.

Other applicable criteria tested include:

1. Transmission Owner (TO) specific criteria
2. Other criteria

The system was tested for a system intact condition and the fault types listed above. Specific fault descriptions and breaker clearing times used for this study are provided in the result table.

Relevant High Speed Reclosing (HSR) contingencies were identified in the P1 contingency list table. 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.

AD1-083 tripping was observed for P5.01, P5.02 and P5.03 faults, the generator could ride through the faults with the updated LVRT settings provided by the Developer.

For the fault contingencies tested on the 2021 summer peak case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3%.
b) The AD1-083 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).
c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).
d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

No mitigations were found to be required.

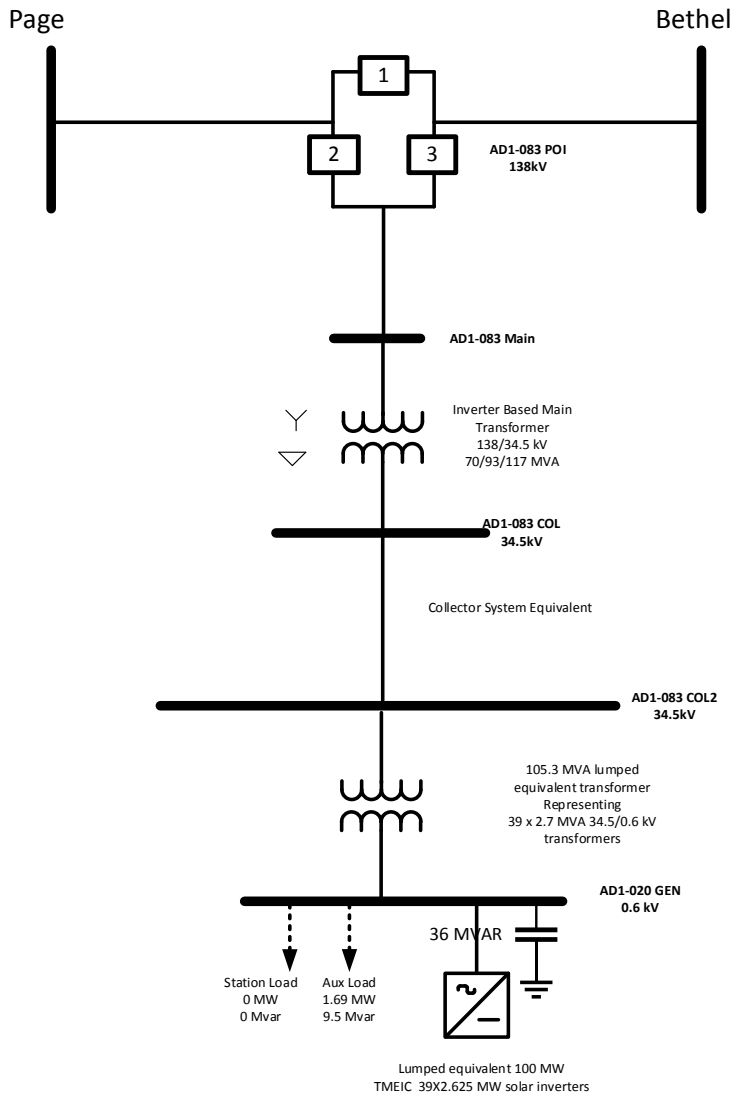
Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

1. Description of the Project

Generator Interconnection Request AD1-083 project is for a 100 MW Maximum Facility Output (MFO) solar powered generating facility with a Point of Interconnection (POI) on Page – Bethel 138 kV line in the Allegheny Power System (APS), Page County, Virginia. This analysis is effectively a screening study to determine whether the addition of AD1-083 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards. In this report the AD1-083 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided. Figure 1 shows the simplified one-line diagram of the AD1-083 loadflow model. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AD1-083 loadflow model. The dynamic model for AD1-083 is based on standard PSS/E models.

Figure 1: AD1-083 Plant Model



Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Table 1: AD1-083 Plant Model

	Impact Study Data	Model
Generators	39 x 2.625 MW generators MVA base = 2.7 MVA Vt = 0.6 kV Unsaturated sub-transient reactance = j99999 pu @ MVA base	2 x 2.625 MW generators Pgen 102.375 MW Pmax 102.375 MW Pmin 0 MW Qgen 33.78 MVAr Qmax 33.78 MVAr Qmin -33.78 MVAr Mbase 2.7 MVA Zsorce j99999 pu @ Mbase
GSU transformer	1x 34.5/0.6 kV transformer Rating = 2.7 MVA Transformer base = 2.7 MVA Impedance = 0.00713 + j0.05704 pu @ MVA base Number of taps = NA Tap step size = NA	1x 34.5/0.6 kV two winding transformer Rating = 105.3 MVA Transformer base = 2.7 MVA Impedance = 0.00713 + j0.05704 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %
MAIN transformer	1x 138/34.5 kV transformer Rating = 70/93/117 MVA (OA/F1/F2) Transformer base = 70 MVA Impedance = 0.00333 + j0.0999 pu @ MVA base Number of taps = NA Tap step size = NA	1x 138/34.5 kV two winding transformer Rating = 70/93/117 MVA Transformer base = 70 MVA Impedance = 0.00333 + j0.0999 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %
Auxiliary load	1.69 MW + 9.65 MVAr at LV side of GSU	1.69 MW + 9.65 MVAr at LV side of GSU
Station Load	0.6 MW + 18.2 MVAr (Not modelled)	0.6 MW + 18.2 MVAr (Not modelled)
Shunt Capacitor Bank	3x12 MVAR	3 x 12 MVAR
Transmission line	Impedance=0.00003 + j 0.000011 pu; Charging Susceptance = 0.00004 pu @ 100 MVA, 138 kV base. Line length = 0.03 miles	Impedance=0.00003 + j 0.000011 pu; Charging Susceptance = 0.00004 pu @ 100 MVA, 138 kV base. Line length = 0.03 miles

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

2. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.0.

The load flow scenarios and fault cases for this study are based on PJM's Regional Transmission Planning Process[1] and discussions with PJM.

The selected load flow scenarios were the RTEP 2021 Summer peak load case with the following modifications:

a) Addition of all applicable queue projects prior to AD1-083.

b) Addition of AD1-083 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AD1-083.

d) Dispatch of units in the PJM system in order to maintain slack generators within limits.

The AD1-083 initial conditions are listed in Table 2, indicating maximum power output with regulating to unity power factor at the POI bus.

Table 2: AD1-083 initial conditions

Bus	Name	Unit	PGEN (MW)	QGEN (MVAr)	ETERM (pu)	POI Voltage (pu)
934584	AD1-083 GEN 0.600	1	102	-23.3	1.003	1.0047

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AD1-083 was dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AD1-083 is given in Attachment 3.

[1] Manual 14B: PJM Region Transmission Planning Process, Rev 33, May 5 2016, Attachment G : PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

3. Fault Cases

Tables 3 listed the contingencies and results that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 20 second simulation time interval.

Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Operating of a line section w/o a fault, Single-line-to-ground (slg) on Bus Section and Breaker. (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis. In this study, P2 contingencies are not applicable.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

4. Evaluation Criteria

This study is focused on AD1-083, along with the rest of the PJM system, maintaining synchronism and having all states return to an acceptable new condition following the disturbance. The recovery criteria applicable to this study are as per PJM's Regional Transmission Planning Process and Transmission Owner criteria:

a) The system with AD1-083 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%

b) The AD1-083 is able to ride through faults (except for faults where protective action trips AD1-083).

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

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

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

5. Summary of Results

Plots from the dynamic simulations are provided in Attachment 4, with results summarized in Table 3.

AD1-083 tripping was observed for P5.01, P5.02 and P5.03 faults, the generator could ride through the fault with the updated LVRT settings provided by the Developer.

For the studied fault contingencies tested on the 2021 summer peak case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 3%.

b) The AD1-083 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

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

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

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

6. System Reinforcement Requirements

No mitigations were found to be required.

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Table 2: Steady State Operation

Fault ID	Duration	Result No Mitigation
P0.00	Steady state 20 sec	Stable

Table 3: Three-Phase Faults with Normal Clearning

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
P1.01	Fault at AD1-083 138 kV on Bethel circuit, trips Bethel-Riverton 138kV	8	Stable
P1.02	Fault at AD1-083 138 kV on Page circuit	8	Stable
P1.03	Fault at Riverton on Bethel circuit, trips Riverton-Bethel-AD1-083 138kV	8	Stable
P1.04	Fault at Riverton 138 kV on Bethel circuit via Viscose, resulting in loss of load at Viscose 138 kV	8	Stable
P1.05	Fault at Riverton 138 kV on Double Toll Gate circuit	8	Stable
P1.06	Fault at Riverton 138 kV on Klines Mill circuit	8	Stable
P1.07	Fault at Riverton 138 kV on Riverton Cap circuit, resulting in loss of cap at Riverton 138kV	8	Stable
P1.08	Fault at Page 138 kV on Sperryville circuit, resulting in loss of load at Sperryville 138 kV	8	Stable
P1.09	Fault at Page 138 kV on AD1-083 circuit	8	Stable
P1.10	Fault at Page 138 kV on Page Cap circuit, resulting in loss of cap at Page 138kV	8	Stable
P1.11	Fault at Page 138 kV on N.Shenandoah circuit, resulting in loss of cap at Page 138kV	8	Stable
P1.12	Fault at Sperryville 138kV on Page, trips Sperryville-Page 138kV, resulting in loss of load at Sperryville 138kV	8	Stable
P1.13	Fault at N.Shenandoah 138kV to Page, resulting in loss of cap and load ‘R2’ at Page 138kV	8	Stable
P1.14	Fault at N.Shenandoah 138kV on transformer	8	Stable
P1.15	Fault at N.Shenandoah 115kV on Endless Caverns (Dominion) L118, resulting in loss of N.Shenandoah-Merck 115kV and 39.6 MVAR cap bank at Merck 5 115kV station.	8	Stable
P1.16	Fault at EndlessCaverns 115kV on Transformer #3 H357 (230/115kV)	5.5	Stable
P1.17	Fault at EndlessCaverns 115kV on Transformer #4 H457 (230/115kV)	5.5	Stable
P1.18	Fault at EndlessCaverns 115kV on Transformer #5 H557 (230/115kV)	5.5	Stable
P1.19	Fault at EndlessCaverns 115kV on Mt.Jackson - Edinburg circuit, resulting in loss of AC2-074 unit	5.5	Stable
P1.20	Fault at EndlessCaverns 115kV on N.Shenandoah circuit	5.5	Stable
P1.21	Fault at EndlessCaverns 115kV on Timberville DP circuit	5.5	Stable
P1.22	Fault at Merck 115kV on N.Shenandoah circuit, resulting in loss of N Shenandoah – Endless Caverns 115 kV circuit	5.5	Stable
P1.23	Fault at Merck 115kV on ElktonDP, resulting in loss of ElktonDP - Grottoes 115kV circuit	5.5	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Table 4: Single-phase Bus Faults with Normal Clearing Time

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result No Mitigation
P2.01	Fault at Page 138 kV on Bus B. Fault cleared with loss of Page – N Shenandoah 138 kV, Page 138 kV Cap. CONTINGENCY 'AP-P2-2-PE-138-019' /* 39 DISCONNECT BRANCH FROM BUS 235496 TO BUS 235500 CKT 1 /* 01NSHEND 138 01PAGE 138 DISCONNECT BRANCH FROM BUS 235500 TO BUS 237035 CKT ZB /* 01PAGE 138 01PAGE CAP 138 END	5.5	Stable
P2.02	Fault at Riverton 138 kV on Bus A. Fault cleared with loss of Riverton-Klines Mill 138 kV line, Riverton-Bethel 138 kV line, Bethel-AD1-083 138 kV Tap, Riverton 138 kV Cap CONTINGENCY 'AP-P2-2-PE-138-023' /* 47 DISCONNECT BRANCH FROM BUS 235507 TO BUS 235548 CKT 1 /* 01RIVERT 138 01KLINEM 138 DISCONNECT BRANCH FROM BUS 934580 TO BUS 235523 CKT 1 /* AD1-083 TAP 138 01BETHEL+ 138 DISCONNECT BRANCH FROM BUS 235507 TO BUS 235523 CKT 1 /* 01RIVERT 138 01BETHEL+ 138 DISCONNECT BRANCH FROM BUS 235507 TO BUS 237038 CKT ZB /* 01RIVERT 138 01RIVERT CAP138 END	5.5	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Table 5: Single Line to Ground Faults with Stuck Breaker

P4.01	Fault on Page-AD1-083 138kV circuit, SB @ AD1-083, delayed clear loss of AD1-083 – Bethel – Riverton 138 kV line and AD1-083 unit	8/20	Stable
P4.02	Fault on Riverton-Bethel 138kV circuit, SB 'RLU' @ Riverton 138kV, normal clear loss of AD1-083-Bethel-Riverton 138kV line, delayed clear loss of Riverton – KlinesMill - Meadowbrook 138kV circuit, followed by loss of load1 and 31.2 MVAR Cap at Riverton and loss of load 1 at Klines Mill 138 kV	8/20	Stable
P4.03	Fault on Riverton-KlinesMill 138kV circuit, SB 'MRV' @ Riverton 138kV, normal clear loss of MeadowBrook-KlinesMill-Riverton 138kV with a loss of load 1 at KlinesMill 138kV, delayed clear loss of Bethel-Riverton –AD1-083 138kV followed loss of Load 1 at Riverton 138kV	8/20	Stable
P4.04	Fault on Riverton-Bethel 138kV circuit, SB 'RVF' @Riverton 138kV, normal clear loss of Viscose-Bethel-Riverton 138kV, loss of load 2 and 4 at Riverton 138kV and load at Viscose, delayed clear loss of Riverton-Double Toll Gate 138kV circuit	8/20	Stable
P4.05	Fault on DoubleTollGate-Riverton 138kV, SB 'RDT' @Riverton, normal clear loss of DoubleTollGate-Riverton 138kV, loss of load 2 and 4 at Riverton 138kV, delayed clear loss of Riverton-Bethel-Viscose 138kV and load at Viscose.	8/20	Stable
P4.06	Fault on Page-Sperryville 138kV, SB @ Page, normal clear loss of load 2 at Sperryville, delayed clear loss of Page-AD1-083 138kV, loss of Load 1 and 3 at Page.	8/20	Stable
P4.07	Fault on Page-AD1-083 138kV circuit, SB @ Page, delayed clear loss Page-Sperryville 138kV followed by loss of load 1 and 3 at Page 138kV	8/20	Stable
P4.08	Fault on Page 138kV – Page Cap bank, SB @Cap bank, normal clear loss of Page 30.8MVAR Cap bank, with loss of load 2 at Page, delayed clear loss of Page-N.Shenandoah 138kV	8/20	Stable
P4.09	Fault on N.Shenandoah-Page 138kV, SB @ N.Shenandoah 138kV, normal clear loss of load 1 at N.Shenandoah 138kV, loss of load 2 @Page 138kV, delayed clear loss of Page 138kV Cap bank	8/20	Stable
P4.10	Fault on N.Shenandoah 138/115kV transformer, SB @N.Shenandoah 138kV, normal clear loss of of load 2 at N.Shenandoah 138kV.	8/20	
P4.11	Fault on N.Shenandoah 138/115kV transformer, SB 'B' @N.Shenandoah 115kV, delayed clear loss of N.Shenandoah-Merck 5 115kV, followed by loss of N.Shenandoah – Endless Caverns, and loss of 39.6MVAR cap bank at Merck 138kV	8/20	
P4.12	Fault on EndlessCaverns 230/115kV transformer H457M, SB 'XT118' @EndlessCaverns, delayed clear loss of N.Shenandoah-Merck 115kV and N.Shenandoah –Endless Caverns 138kV, loss of 39.6MVAR cap bank at Merck 5 115 kV station.	5.5/26	
P4.13	Fault on EndlessCaverns 230/115kV transformer H557M, SB 'L5T11B' @EndlessCaverns, delayed clear loss of N.Shenandoah-Merck 115kV and N.Shenandoah –Endless Caverns 138kV, followed by loss of 39.6MVAR cap bank at Merck 5 115 kVstation.	5.5/26	
P4.14	Fault on EndlessCaverns 230/115kV transformer H357M, SB '13152' @EndlessCaverns, normal clear loss of loss of 39.6 MVAR cap @EndlessCaverns 115kV, delayed clear loss of EndlessCaverns-Timberville 115kV	5.5/26	
P4.15	Fault on EndlessCaverns 230/115kV transformer H357M, SB '12852' @EndlessCaverns, normal clear loss of 39.6 MVAR cap @EndlessCaverns 115kV, delayed clear loss of EndlessCaverns-Mt.Jackson 115kV	5.5/26	
P4.16	Fault on EndlessCaverns 230/115 kV transformer H457M, SB 'XT131' @EndlessCaverns, delayed clear loss of EndlessCaverns-Timberville 115kV circuit	5.5/26	
P4.17	Fault on EndlessCaverns 230/115kV H557M transformer, SB 'L5T128' @EndlessCaverns, delayed clear loss of EndlessCaverns-Mt.Jackson DP – Edinburg 115kV circuit, followed by loss of AC2-074 unit	5.5/26	
P4.18	Fault on Merck 5 115kV – N Shenandoah 115 kV circuit, SB @'11802', with a normal clear loss of N.Shenandoah - Endless Caverns 115kV circuit.	5.5/26	

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Table 6: Single-phase With Delayed (Zone 2) Clearing at Line End Closest to AD1-083 POI

Fault ID	Fault description	Clearing Time (Cycles)	Results
P5.01	Fault at 80% of line from AD1-083 138 kV on AD1-083-Bethel-Riverton 138kV circuit. Delayed clearing at AD1-083.	8/36	Stable
P5.02	Fault at 80% of line from AD1-083 138 kV on AD1-083-Page 138kV circuit. Delayed clearing at AD1-083.	8/36	Stable
P5.03	Fault at 80% of line from Page 138 kV on Page-Sperryville 138kV. Delayed clearing at Page.	8/36	Stable
P5.04	Fault at 80% of line from Riverton 138 kV on Riverton-Bethel (Via Viscose). Delayed clearing at Riverton 115kV.	8/36	Stable
P5.05	Fault at 80% of line from Riverton 138 kV on Riverton-KlinesMill-Meadowbrook. Delayed clearing at Riverton.	8/36	Stable
P5.06	Fault at 80% of line from Riverton 138 kV on Double Toll Gate circuit. Delayed clearing at Riverton.	8/36	Stable
P5.07	Fault at 80% of line from Page 138 kV on N.Shenandoah circuit. Delayed clearing at Page.	8/36	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

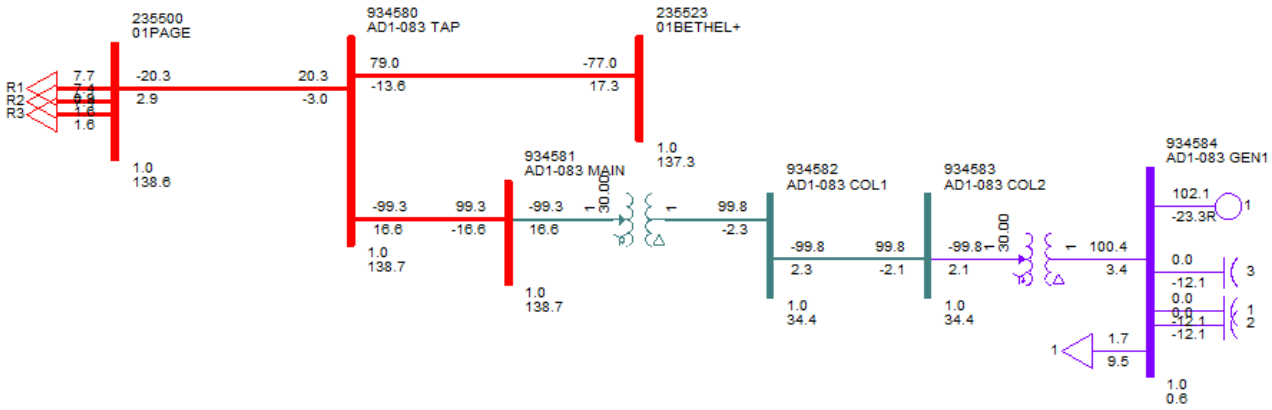
Table 7: Single Line to Ground Fault with Common Structure Failure

Fault ID	Fault description	Clearing Time (Cycles)	Results
P7.01	SLG fault at Page – Sperryville 138 kV, Common Structure failure loss of Page – North Shenandoah 138 kV line CONTINGENCY 'AP-P7-1-PE-138-021' /* PAG-N SHENANDOAH PAG-SPV DISCONNECT BRANCH FROM BUS 235500 TO BUS 235510 CKT 1 /* 01PAGE 138 01SPERYV 138 DISCONNECT BRANCH FROM BUS 235500 TO BUS 235496 CKT 1 /* 01PAGE 138 01NSHEND 138 END	5.5	Stable

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Attachment 1. PSS/E Model One Line Diagram



Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Attachment 2. AD1-083 PSS/E Dynamic Model

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/*****************************************************
/*** Project: AD1-083 - 100 MW MFO
/*** POI: Tap into
/*** Inverter:  TMEIC L2700GR inverters
/*** Size: 10 x 2.625 MW  Solar PV
/*** PSSE Version 33
/*****************************************************

934584,'USRMDL', 1, 'REGCAU1', 101, 1, 1, 14, 3, 4, 1, 0.2, 10.0, 0.75,-10.0, 0.23, 2.0, 0.1, 0.0, -0.377,
0.02, 0.0, 10.0, -10.0, 0.0/
/*  IBUS,'USRMDL',ID, 'REGCAU1', 101, 1, 1, 14, 3, 4,LV,  Tg,Rrpwr,Brkpt, Zrox,Lvpl1,Volm,Lvpt,Lvp0,
Iolim,Tfltr, Khv,Iqrmx,Iqrmin,Accl/
934584,'USRMDL', 1, 'REECBU1', 102, 0, 5, 25, 6, 4, 0, 0, 0, 0, 0, 0, 0.0, 2.0, 0.0, -0.1, 0.1, 0.0, 0.377, -
0.377, 0.0, 0.05, 0.377, -0.377, 1.1, 0.9, 0.0, 0.0, 0.0, 0.0, 0.02, 2.0, -2.0, 0.972, 0.0, 1.00, 0.02/
/*  IBUS,'USRMDL',ID, 'REECBU1', 102, 0, 5, 25, 6, 4,Vb,PF,VF,QF,PQ,Vdip, Vup, Trv, dbd1,dbd2, Kqv,
iqh1,  iql1,Vrf0,  Tp,  QMax,  QMin,Vmax,Vmin, Kqp, Kqi, Kvp, Kvi,  Tiq,dPmx,dPmin,  Pmax,PMin,
imax, Tprd/
934584,'USRMDL', 1, 'REPCAU1', 107, 0, 7, 27, 7, 9, 934580, 0, 0, 0, 0, 1, 0, 0.02, 18, 5, 0, 0.15, -1, 0, 0,
0, 999, -999,-0.02, 0.02, 0.377, -0.377, 10, 1, 0.02, -99.0, 99.0, 999, -999, 0.972, 0, 20, 20, 20/
/*  IBUS,'USRMDL',ID, 'REPCAU1', 107, 0, 7, 27, 7, 9,     Vb,FB,Tb,ID,VF,RF,FF,Tfltr, Kp,Ki,Tf,
Tfv,Vfz,Rc,Xc,Kc,emax, emin,  d1,  d2,  Qmax,  Qmin, Kp,Kg,  Tp, fdbd1,Fdbd2,fmax, fmin,  Pmax,Pm,
Tg,Ddn,Dup/
9345841, 'VTGTPAT', 934580, 934584, 1, -1, 1.200, 0, 0.0/
/*mn,'VTGTPAT',Vmonbus, Genbus,ID, VL,   VU,TP,  TB/
9345842, 'VTGTPAT', 934580, 934584, 1, -1, 1.175, 0.2, 0.0/
/*mn,'VTGTPAT',Vmonbus, Genbus,ID, VL,   VU,  TP,  TB/
9345843, 'VTGTPAT', 934580, 934584, 1, -1, 1.15, 0.5, 0.0/
/*mn,'VTGTPAT',Vmonbus, Genbus,ID, VL,  VU,  TP,  TB/
9345844, 'VTGTPAT', 934580, 934584, 1, -1, 1.10, 1.0, 0.0/
9345845, 'VTGTPAT', 934580, 934584, 1, 0.45, 5, 0.80, 0.0/
/*mn,'VTGTPAT',Vmonbus, Genbus,ID,  VL,VU,  TP,  TB/
9345846, 'VTGTPAT', 934580, 934584, 1, 0.65, 5, 0.80, 0.0/
/*mn,'VTGTPAT',Vmonbus, Genbus,ID,  VL,VU,  TP,  TB/
9345847, 'VTGTPAT', 934580, 934584, 1, 0.75, 5, 2, 0.0/
9345848, 'VTGTPAT', 934580, 934584, 1, 0.90, 5, 3, 0.0/
/*mn,'VTGTPAT',Vmonbus, Genbus,ID,  VL,VU,TP,  TB/
9345849, 'FRQTPAT', 934580, 934584, 1, -100, 61.8, 0, 0.0/
/*mn,'FRQTPAT',Fmonbus, Genbus,ID,  FL,  FU,TP,  TB/
93458410, 'FRQTPAT', 934580, 934584, 1, -100, 60.5, 600.66, 0.0/
/*mn,'FRQTPAT', Fmonbus, Genbus,ID,  FL,  FU,    TP,  TB/
93458412, 'FRQTPAT', 934580, 934584, 1, 57.8, 100, 0, 0.0/
/*mn, 'FRQTPAT',Fmonbus, Genbus,ID,  FL,  FU,TP,  TB/
93458413, 'FRQTPAT', 934580, 934584, 1, 59.5, 100, 1792.049, 0.0/
/*mn, 'FRQTPAT',Fmonbus, Genbus,ID,  FL,  FU,      TP,  TB/
```

Appendix 3 (Continued)

Dynamic Simulation Analysis (Stability Study)
PJM Queue Position: AD1-083

Attachment 3. AD1-083 PSS/E Case Dispatch

Bus Number	Bus Name	Id	In Service	Pgen (MW)	Pmax (MW)	Pmin (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)
235838	01GRNGAP 0.6900	W1	1	30.056	300	0	-6.1031	6.1031	-6.1031
236001	01WARRIOR RN18.000	1	1	72.166	180	72	50.8204	87	-40
237044	01MB CAP 500.00	SV	1	0	0	0	340.7694	600	-165
237315	01FLF_U1-044138.00	1	1	1.565	2	0	2	2	-2
315251	1MT STM1 22.000	H1	1	110.254	293	110	-29.5	102.5	-29.5
315251	1MT STM1 22.000	L1	1	110.254	292	110	-29.5	102.5	-29.5
315252	1MT STM2 22.000	H2	1	110.254	293	110	-55.5	103.5	-55.5
315252	1MT STM2 22.000	L2	1	110.254	292	110	-55.5	103.5	-55.5
315253	1MT STM3 24.000	3	1	220.509	573	220	-127.9508	149	-128
315254	1MT STMG 13.800	1	1	9.313	11.9	0	-0.707	2.03	-2.03
315270	1FRNT RYL G121.000	G1	1	91.248	311	0	-55.3599	155	-75
315271	1FRNT RYL G221.000	G2	1	91.248	311	0	-55.3599	155	-75
315272	1FRNT RYL G321.000	G3	1	91.248	311	0	-55.3599	155	-75
315273	1FRNT RYL S123.500	S1	1	171.04	553	0	-55.3599	275.7	-140.2
916551	Z1-113 C 138.00	1	1	3.914	5	0	0	0	0
916552	Z1-113 E 138.00	1	0	0	7	0	0	3.36	-2.31
917161	Z2-030 C 138.00	1	1	5.95	7.6	0	0	0	0
917162	Z2-030 E 138.00	1	0	0	12.4	0	0	0	0
917241	Z2-039 1 138.00	1	0	0	0.972	0	0	0.466	-0.32
917251	Z2-039 2 138.00	1	0	0	1.373	0	0	0.48	-0.452
917261	Z2-039 3 138.00	1	0	0	0.456	0	0	0.219	-0.15
917291	Z2-040 3 138.00	1	1	1.656	2.115	0	0.888	0.888	-0.611
918812	AA1-100 E 138.00	1	0	0	11	0	0	0	0
932541	AC2-074 C 115.00	1	1	10.4	10.4	0	4.992	4.992	-3.432
932542	AC2-074 E 115.00	1	1	5.25	5.25	0	2.52	2.52	-1.732
932571	AC2-174 C 138.00	1	1	3.8	3.8	0	1.824	1.824	-1.254
932572	AC2-174 E 138.00	1	1	6.2	6.2	0	2.976	2.976	-2.046
934584	AD1-083 GEN10.6000	1	1	102.4	102.4	0	-6.0521	24.65	-24.65

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