Second Revised

Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD1-081

"Beatty-London 138 kV"

April 2021
Second Revision

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.

Revisions since November 2018 System Impact Study

The Network Impacts Section of this report has been updated to reflect that the AD1-081 project no longer causes an overload of the AC1-078 Tap – London 138 kV line. This was determined after reanalyzing the model with updated queue information. Therefore, the AD1-081 project is no longer dependent on PJM Network Upgrade Number n5783 (Reconductor the AC1-078 Tap-London 138 kV Line) and it has been removed from this report.

The customer name was revised to Big Plain Solar, LLC and the Commercial Operation Date proposed for the AC1-078/AD1-081 was also updated to February 28, 2023 in this report. No other changes were made to this report regarding physical interconnection. That will be addressed in the Facilities Study Report to follow.

General

Big Plain Solar, LLC, the Interconnection Customer (IC), has proposed a Solar generating facility located in Madison County, Ohio. The installed facilities will have a capability of 20 MW with 13.2 MW of this output being recognized by PJM as capacity. Note that this project is an increase to the Interconnection Customer's AC1-078 project, which will share the same property and connection point. The AC1-078 project will have a capability of 176 MW with 66 MW being recognized as capacity. The total capability of the combined AC1- 078 and AD1-081 projects will be 196 MW with 79.2 MW being recognized by PJM as capacity. The proposed Commercial Operation Date for the AC1/078AD1-081 project is February 28, 2023. **This study does not imply an ATSI commitment to this in-service date.**

Point of Interconnection

AD1-081 will interconnect with the ATSI transmission system along the Beatty-London 138kV line.

Cost Summary

The AD1-081 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$ 0
Direct Connection Network Upgrades	$ 0
Non Direct Connection Network Upgrades	$ 45,200
Allocation for New System Upgrades	$ 0
Description	**Total Cost**
Contribution for Previously Identified Upgrades	$ 0
Total Costs	**$ 45,200**

General Information

Interconnection Customer ("IC"): First Solar Development, LLC Queue Position: AD1-081

Interconnected Transmission Owner ("TO"): American Transmission Systems, Incorporated ("ATSI")

Affected TO(s) (if applicable): American Transmission Systems, Incorporated ("ATSI")

PJM Zone: ATSI

FE Operating Company or Planning Region: Ohio Edison – Southern

Customer Connection Request

Requested Backfeed Date: 10/31/2022

Requested Commercial Operation Date: 02/28/2023

This study does not imply a FirstEnergy commitment to these dates.

New Facilities		Existing Facilities	
Capacity:	13.2 MW	Capacity:	66 MW
Energy:	20 MW	Energy:	176 MW
MFO[1]:	196 MW	MFO:	176 MW
Fuel:	Solar	Prior Queue Position(s):	AC1-078

Point of Interconnection

Primary Point of Interconnection: Beatty (AEP) – London (FE) 138 kV Line

[1] Maximum Facility Output

Attachment Facilities

No Attachment Facilities are required to support this interconnection request.

Direct Connection Cost Estimate

No Direct Connection Facilities are required to support this interconnection request.

Non-Direct Connection Cost Estimate

The total preliminary cost estimate for the Non-Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Activity Cost	Tax (if applicable)	Total Cost
Modify relay settings at AD1-081 Interconnect @ AD1-081 Interconnect SS	$ 45,200	$ 5,900	$ 51,100
Total Non-Direct Connection Facility Costs	**$ 45,200**	**$ 5,900**	**$ 51,100**

Transmission Owner Scope of Work

Because AD1-081 is an increase to queue project AC1-078, no new interconnection facilities are required to accommodate the increased output. The project uprate will require direct and non-direct connection upgrades at Beatty and London substations.

Based on this scope of work, it is expected to take a minimum of 9 months after the signing of an Interconnection Construction Service Agreement (Non-Direct work will take a minimum of 13 months to complete). This includes preliminary payment that compensates FE for the first three months of the engineering design work that is related to the modifications of the AC1-078 interconnection substation. This assumes that there will be no delays in acquiring the necessary permits for network upgrades and that PJM will allow all transmission system outages when requested.

Interconnection Customer Requirements

1. An Interconnection Customer entering the New Services Queue on or after October 1, 2012 with a proposed new Customer Facility that has a Maximum Facility Output equal to or greater than 100 MW shall install and maintain, at its expense, phasor measurement units (PMUs). See Section 8.5.3 of Appendix 2 to the Interconnection Service Agreement as well as section 4.3 of PJM Manual 14D for additional information.

2. The Interconnection Customer may be required to install and/or pay for metering as necessary to properly track real time output of the facility as well as installing metering which shall be used for billing purposes. See Section 8 of Appendix 2 to the

Interconnection Service Agreement as well as Section 4 of PJM Manual 14D for additional information.

3. The Interconnection Customer seeking to interconnect a wind generation facility shall maintain meteorological data facilities as well as provide that meteorological data which is required per item 5.iv. of Schedule H to the Interconnection Service Agreement.

4. The original portion of the IC's facility (AC1-078) shall retain its existing ability to maintain a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs) measured at the generator's terminals. The increase of 20 MW to the IC's facility proposed for project AD1-081 shall be designed with the ability to maintain a power factor of at least 0.95 leading to 0.95 lagging measured at the high side of the facility substation transformers.

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

ATSI Requirements

The Interconnection Customer will be required to comply with all FE 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

General Connection Requirements

The AC1-078 delivery point substation (DPS) is a 138 kV three-breaker ring bus on the London-Beatty 138 kV line. See Attachment 2.

The existing line relays at London and Beatty require replacement.

Line protection between London and AC1-078 and between Beatty and AC1-078 shall consist of two independent SEL-411L line schemes with pilot communication over power line carrier for each 138 kV line, at each terminal.

At the AC1-078 DPS, each 138 kV breaker shall have breaker failure-to-trip protection. SEL-501 relays are acceptable for this application.

Protection of the 138 kV Generator Lead Line of approximately 0.25 miles shall consist of two SEL-411L line current differential schemes with pilot communication over fiber optic cable, at each terminal.

Protection Requirements

AC1-078 138 kV Interconnecting Substation

138 kV Transmission Line Protection

- London line exit
- Primary relay: SEL-411L relay DCB over power line carrier with DTT
- Backup relay: SEL-411L relay over
- DTT over power line carrier

- Beatty line exit
- Primary relay: SEL-411L relay DCB over power line carrier with DTT
- Backup relay: SEL-411L relay over
- DTT over power line carrier

- AC1-078 generating facility
- Primary relay: SEL-411L relay with line current differential protection over fiber with DTT
- Backup relay: SEL-411L relay with line current differential protection over fiber with DTT

138 kV AC1-078 Interconnecting Station Communications

- AC1-078 Interconnecting Station to London and Beatty
- Power line carrier for use with PRI SEL-411L for DCB
- Power line carrier for DTT
- AC1-078 Interconnecting Station to AC1-078 generating facility
- Dual, independent fiber-optic cable paths with dedicated fibers for use with the SEL-411L primary and backup relaying
- Minimum of 12 fibers, separate primary and backup fiber cables

138 kV Breaker Failure to Trip Protection

- 138 kV Breaker Failure to Trip Relaying – SEL501 relay per breaker

AC1-078 Generating Station 138 kV
138 kV Transmission Line Protection @ AC1-078 generating station

- AC1-078 Interconnecting Station line exit
- Primary relay: SEL-411L relay with line current differential protection over fiber with DTT
- Backup relay: SEL-411L relay with line current differential protection over fiber with DTT

- Synch check for manual/SCADA close on the interconnecting line to be done at AC1-078 Generating Station

138 kV Breaker Failure to Trip Protection

- 138 kV Breaker Failure to Trip Relaying
- SEL-352-2 breaker failure to trip relaying on AC1-078 138 kV Generating Station breaker. The breaker failure to trip relaying on the AC1-078 Interconnecting Station line exit breaker shall initiate direct transfer trip via the SEL-411L primary and backup line relays (fiber).

138 kV Bus & GSU Transformer Protection @ AC1-078 generating station (minimum protection to meet FE requirements)

- Dual, independent transformer differential protection schemes (Transformer and Overall)
- Transformer neutral time overcurrent relay

The Connecting Party shall provide utility-grade relays for protection of the FE Transmission System. FE shall approve all relays specified for the protection of the FE Transmission System, including time delay and auxiliary relays. Relay operation for any of the listed functions that are required shall initiate immediate separation of the parallel generation from the FE Transmission System:

Relay	**Function**
Frequency	To detect underfrequency and overfrequency operation.
Overvoltage	To detect overvoltage operation.
Undervoltage	To detect undervoltage operation.
Ground Fault Detector	To detect a circuit ground on the FE Transmission System.
Phase Fault Detector	To detect phase to phase faults on the FE Transmission System.
Transfer Trip Receiver	To provide tripping logic to the generation owner for isolation of the generation upon opening of the FE supply circuits.
Directional Power	To detect, under all system conditions, a loss of FE primary source. The relay shall be sensitive enough to detect transformer magnetizing current supplied by the generation.

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

www.firstenergycorp.com/feconnect

www.pjm.com/planning/design-engineering/to-tech-standards.aspx

FE System Modifications

London Substation

138 kV Transmission Line Protection

- AC1-078 Interconnecting Station line exit Relaying
- Primary relay: SEL-411L relay DCB over power line carrier
- Backup relay: SEL-411L relay
- DTT over power line carrier

Beatty Substation

138 kV Transmission Line Protection

- AC1-078 Interconnecting Station line exit Relaying
- Primary relay: SEL-411L relay DCB over power line carrier
- Backup relay: SEL-411L relay

Settings Changes

- Settings changes are possible at remote substations.

Metering

The IC will be require to comply with all FE revenue metering requirements for generation interconnection customers which can be found in FE's "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx.

Compliance Issues and Interconnection Customer Requirements

AD1-081 is an increase in generation of 20 MW to the AC1-078 project and must meet the predefined requirements specified for AC1-078.

Power Factor Requirements

The existing non-synchronous 176 MW portion of the Customer Facility shall retain the ability to maintain a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs) measured at the Generator's Terminals. The increase of 20 MW to the non-synchronous Customer Facility associated with AD1-081 project shall be designed 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 to the FE transmission system.

Network Impacts

Summer Peak Analysis - 2021

The Queue Project AD1-081 was evaluated as a 20.0 MW (Capacity 13.2 MW) injection into the AC1-078 Tap 138 kV substation (which is tap of the London – Beatty 138 kV line) in the ATSI area. Project AD1-081 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD1-081 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Contingency Descriptions

The following contingencies resulted in overloads: None

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

None.

Light Load Analysis

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

None.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)

None.

Short Circuit

(Summary of impacted circuit breakers)

PJM performed a short circuit analysis and the results were verified by FE. The connection of AD1-081 project to the system does not result in any newly overdutied circuit breakers on the FE transmission system and does not have a significant fault current contribution to existing overdutied circuit breakers.

Short Circuit Values

The 138 kV fault values for the AC1-078 interconnection location with all new generation out of service are:

Three Phase = 10.4kA
Single Line to Ground = 8.7kA

Z1= (0.92+ j 3.91) %
Z0= (2.23 + j 5.96) %

Impedances are given on a 100 MVA and 138 kV base. The faults provided are bolted, symmetrical values for normal system conditions. Future increases in fault currents are possible and it is the customer's responsibility to upgrade their equipment and/or protective equipment coordination when necessary.

Steady-State Voltage Requirements

(Summary of the VAR requirements based upon the results of the steady-state voltage studies)

None.

Stability and Reactive Power Requirement for Low Voltage Ride Through

(Summary of the VAR requirements based upon the results of the dynamic studies)

See Attachment 5 for analysis

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

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO Impacts:

None

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

None

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

Potential Congestion due to Local Energy Deliverability

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.

None

Network Impacts
Winter Peak Analysis - 2021

The Queue Project AD1-081 was evaluated as a 20.0 MW (Capacity 13.2 MW) uprate to the AC1-078 Queue Project which is tapping the Beatty to London 138kV line in the AEP area. Project AD1-081 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD1-081 was studied with a commercial probability of 100%. Potential network impacts were 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)

None

Steady-State Voltage Requirements

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

None

Winter 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

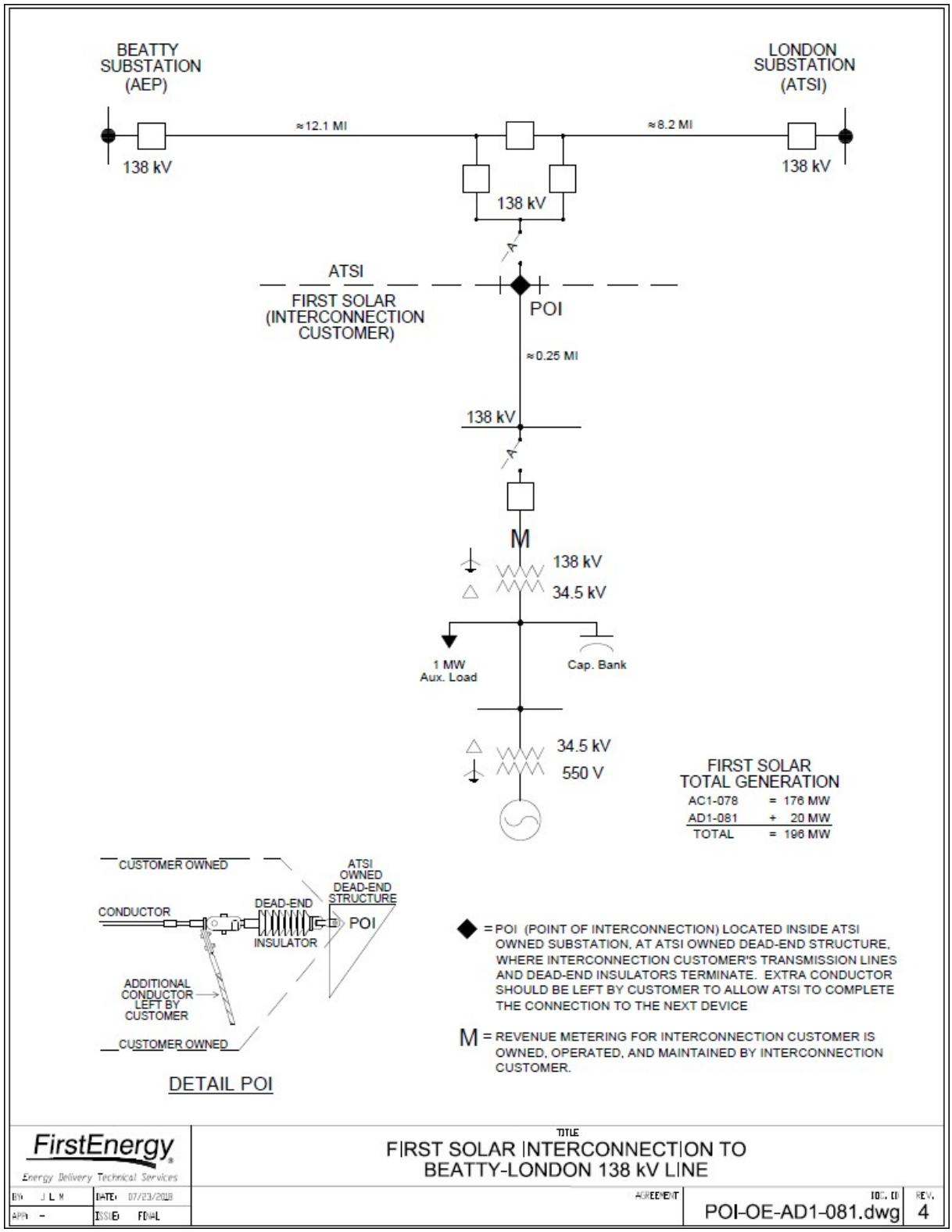
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

Attachment 1. Project Location

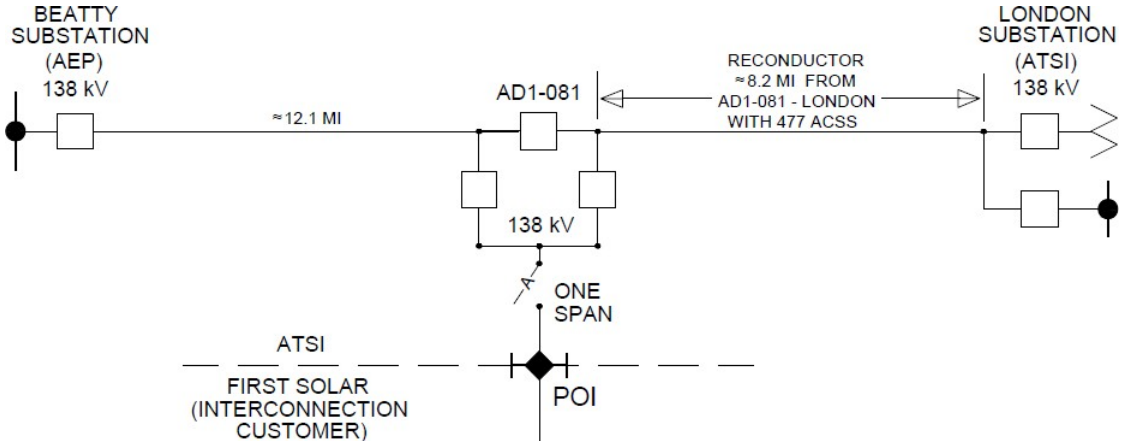
Attachment 2. Single Line Diagram



Attachment 3. Network Upgrades Single Line Diagram

Network Upgrades:

- Reconductor ~8 miles of transmission line from the AC1-078/AD1-081 Gen Queue project - London 138 kV substation with 477 ACSS due to a thermal overload.



Attachment 4. Flowgate Details

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. All New Service Queue Requests, through the end of the Queue under study, that are contributors to a flowgate will be listed in the Appendices. Please note that there may be contributors that are subsequently queued after the queue under study that are not listed in the Appendices. Although this information is not used "as is" for cost allocation purposes, it can be used to gage the impact of other projects/generators.

It should be noted the project/generator MW contributions presented in the body of the report and appendices sections are full contributions, whereas the loading percentages reported in the body of the report, take into consideration the commercial probability of each project as well as the ramping impact of "Adder" contributions.

None

Attachment 5. Dynamic Simulation Analysis

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Executive Summary

Generator Interconnection Request AD1-081 is for a 20MW uprate to AC1-078. After the uprate, AD1-081 is a 196 MW Maximum Facility Output (MFO) solar generation plant. AD1-081 consists of 4215 x 0.05 MVA HUAWEI SUN2000HA-45KTL-US-HV inverters with a Point of Interconnection (POI) tapped into London – Beatty Road 138kV line in the ATSI transmission system, Madison county, OH.

This report describes a dynamic simulation analysis of AD1-081 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. AD1-081 has been dispatched online at maximum power output, with regulating POI voltage of (1.011 p.u.), consistent with the default generator reference voltage specified in PJM Manual 03 Transmission Operations Section 3.3.3 for generator connections to the PJM 138 kV system.

The AD1-081 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-001 faults 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 covered by P1 and P4 contingencies.

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.

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

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.

For the remaining fault contingencies tested on the 2020 Summer Peak case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 4% for local modes and 3% for inter-area modes.

b) The AD1-081 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.

This project is reactive deficient as the +/- 0.95 Power Factor requirement can not be met at the Point of Interconnection. Additional Capacitive reactive compensation is required.

1. Introduction

Generator Interconnection Request AD1-081 is for a 20MW uprate to AC1-078. After the uprate, AD1-081 is a 196 MW Maximum Facility Output (MFO) solar generation plant. AD1-081 consists of 4215 x 0.05 MVA HUAWEI SUN2000HA-45KTL-US-HV inverters with a Point of Interconnection (POI) tapped into London – Beatty Road 138kV line in the ATSI transmission system, Madison County, OH.

This analysis is effectively a screening study to determine whether the addition of AD1-081 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AD1-081 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.

2. Description of Project

Generator Interconnection Request AD1-081 is for a 20MW uprate to AC1-078. After the uprate, AD1-081 is a 196 MW Maximum Facility Output (MFO) solar generation plant. AD1-081 consists of 4215 x 0.05 MVA HUAWEI SUN2000HA-45KTL-US-HV inverters with a Point of Interconnection (POI) tapped into London – Beatty Road 138kV line in the ATSI transmission system, Madison county, OH. The AD1-081 Point of Interconnection (POI) is as shown in Figure 1.

Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AD1-081 loadflow models.

The dynamic model for the AD1-081 plant is based on the model data supplied by the Developer.

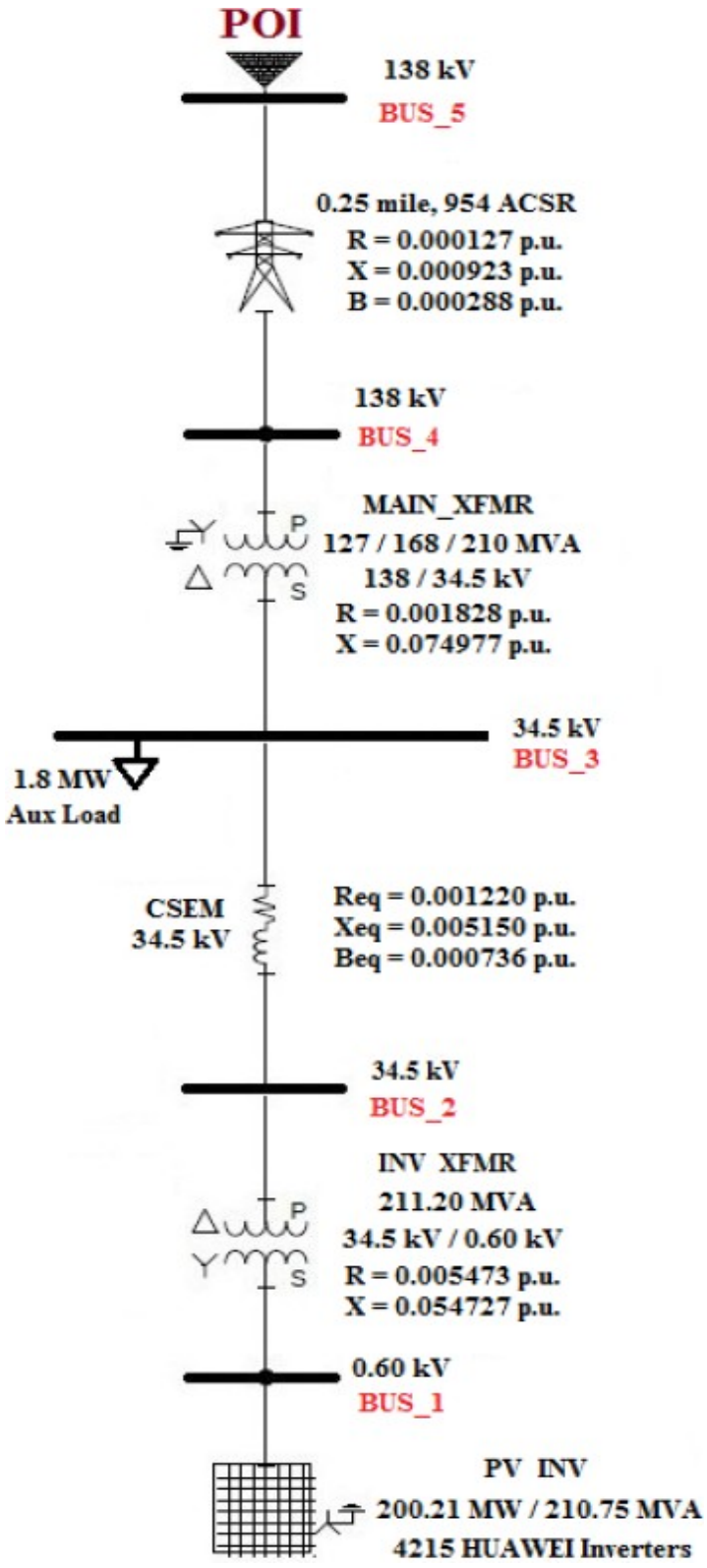

Figure 1: AD1-081 Plant Model

Table 1: AD1-081 Plant Model

	Impact Study Data	Model
Inverters	4215 HUAWEI SUN2000HA-45KTL 0.05MVA inverters MVA base = 0.05 MVA Vt = 0.6 kV Unsaturated sub-transient reactance = j99999 pu @ MVA base	Lumped equivalent representing 4215 HUAWEI SUN2000HA-45KTL 0.05MVA inverters Pgen 200.21 MW Pmax 200.21 MW Pmin 0 MW Qmax 65.81 MVAr Qmin -65.81 MVAr Mbase 210.75 MVA Zsorce j1.000 pu @ Mbase
Inverter Transformers	Lumped equivalent representing 96X2.2MVA GSUs Rating = 211.2 MVA Transformer base = 211.2 MVA Impedances: High – Low = 0.005473+ j 0.054727 @ MVA base Number of taps = N/A Tap step size = N/A Nominal Tap = N/A	Lumped equivalent representing 96X2.2MVA GSUs Rating = 211.2 MVA Transformer base = 211.2 MVA Impedances: High – Low = 0.005473+ j 0.054727 @ MVA base Number of taps = 33 Tap step size = 0.00625 Nominal Tap = 17
Collector System Equivalent	R = 0.001220 X = 0.005150 B = 0.000736 @100MVA	R = 0.001220 X = 0.005150 B = 0.000736 @100MVA
Collector transformer	138/34.5/13.8 kV three winding transformer Rating = 127/168/210 MVA Transformer base = 127 MVA Impedances: High – Low = 0.001828 + j0.074974 High – Ter = 0.003394+ j0.139158 Low – Ter = 0.001199 + j0.049185 @ MVA base Number of taps = N/A Tap step size = N/A Nominal Tap = N/A	138/34.5 kV two winding transformer Rating = 127/168/210 MVA Transformer base = 127 MVA Impedances: High – Low = 0.001828 + j0.074974 @ MVA base Number of taps = 33 Tap step size = 0.00625 Nominal Tap = 17

Auxiliary load	1.8 MW + 0.0 MVAR	1.8 MW + 0.0 MVAR at low voltage side of main transformer
Station load	0.0 MW + 0.0 MVAR	0.0 MW + 0.0 MVAR
Transmission line	R = 0.000127 X = 0.000923 B = 0.000288 @100MVA	R = 0.000127 X = 0.000923 B = 0.000288 @100MVA

3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.

The load flow scenario and fault cases for this study are based on PJM's Regional Transmission Planning Process[2].

The selected load flow scenario is the RTEP 2021 Summer Peak case with the following modifications:

a) Addition of all applicable queue projects prior to AD1-081.

b) Addition of AD1-081 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AD1-081.

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

The AD1-081 initial conditions are listed in Table 2, indicating maximum power output, with regulating POI voltage of (1.011 p.u.), consistent with the default generator reference voltage specified in PJM Manual 03 Transmission Operations Section 3.3.3 for generator connections to the PJM 138 kV system..

Table 2: AD1-081 machine initial conditions

Bus	Name	Unit	PGEN (MW)	QGEN (MVAR)	ETERM (p.u.)	POI Voltage (p.u.)
926014	AD1-081 GEN 0.6000	1	200.21	34.8	1.012	1.011

Generation within the vicinity of AD1-081 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AD1-081 is given in Attachment 3.

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

4. 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-001 faults 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 covered by P1 and P4 contingencies.

The system was tested for a system intact condition and the fault types listed above. No relevant High Speed Reclosing (HSR) contingencies were studied.

5. Evaluation Criteria

This study is focused on AD1-081, 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 AD1-081 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

b) The AD1-081 is able to ride through faults (except for faults where protective action trips AD1-081).

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.

6. Summary of Results

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

The frequency protection was disabled due to the PSSE deficiency in calculating frequencies for 3ph fault at POIs.

For the fault contingencies tested in this study:

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

b) The AD1-081 generator was able to withstand all contingencies.

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.

7. Mitigations

No Mitigations were found to be required.

Table 3: Fault list

P0: Steady State

Fault ID	Duration
P0.00	Steady State 20 sec run

P1: Three Phase Faults with normal clearing

Fault ID	Fault description	Clearing Time Normal (Cycles)	Results
P1.00	3ph @ AD1-081 Main – AD1-081 POI 138kV line, normal clear loss of AD1-081	6	Stable
P1.01	3ph @ AD1-081 POI – Beatty Road 138kV line, normal clear	6	Stable
P1.02	3ph @ AD1-081 POI – London 138kV line, normal clear	6	Stable
P1.03	3ph @ London – East Springfield 138kV line #1, normal clear	6	Stable
P1.04	3ph @ London – East Springfield 138kV line #2, normal clear	6	Stable
P1.05	3ph @ London – National – Tangy 138kV line, normal clear	6	Stable
P1.06	3ph @ London 138/69kV TF #3, normal clear	6	Stable
P1.07	3ph @ London 138/69kV TF #4, normal clear	6	Stable
P1.08	3ph @ Beatty Road – Hall 138kV line, normal clear	6	Stable
P1.09	3ph @ Beatty Road – Wilson Rd 138kV line, normal clear	6	Stable
P1.10	3ph @ Beatty Road – McComb 138kV line, normal clear loss of Beatty Road 138/13.8kV TF #6	6	Stable

Fault ID	Fault description	Clearing Time Normal (Cycles)	Results
P1.11	3ph @ Beatty Road – White Road 138kV line, normal clear	6	Stable
P1.12	3ph @ Beatty Road – Zuber – Harrison 138kV line, normal clear	6	Stable
P1.13	3ph @ Beatty Road 138/345kV TF #3, normal clear	6	Stable
P1.14	3ph @ Beatty Road 138/345kV TF #4, normal clear	6	Stable
P1.15	3ph @ Beatty Road 138/69kV TF#1, normal clear loss of Beatty Road 138/69kV TF #2	6	Stable
P1.16	3ph @ Beatty Road 138/13.8kV TF #5, normal clear	6	Stable

P4: SLG Stuck Breaker (SB) Faults at Backup Clearing

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P4.01	SLG @ London – East Springfield 138kV line #1, SB @ London 138kV, delayed clear loss of London 138kV bus	6 / 20	Stable
P4.02	SLG @ London – East Springfield 138kV line #2, SB @ London 138kV, delayed clear loss of London 138kV bus	6 / 20	Stable
P4.03	SLG @ London – National – Tangy 138kV line, SB @ London 138kV, delayed clear loss of London 138kV bus	6 / 20	Stable
P4.04	SLG @ London 138/69kV TF #3, SB @ London 138kV, delayed clear loss of London 138kV bus	6 / 20	Stable
P4.05	SLG @ London 138/69kV TF #4, SB @ London 138kV, delayed clear loss of London 138kV bus	6 / 20	Stable
P4.06	SLG @ Beatty Road 138/345kV TF #3, SB @ Beatty Road 138kV, delayed clear loss of Beatty Road – AC1-087 138kV line	6 / 20	Stable
P4.07	SLG @ Beatty Road – Hall 138kV line, SB @ Beatty Road, delayed clear loss of Beatty Road – Zuber – Harrison 138kV line	6 / 20	Stable

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P4.08	SLG @ Beatty Road – Wilson Rd 138kV line, SB @ Beatty Road, delayed clear loss of Beatty Road – White Road 138kV line	6 / 20	Stable
P4.09	SLG @ Beatty Road 138/345kV TF #4, SB @ Beatty Road 138kV, delayed clear loss of Beatty Road 138/69kV TF#1 and Beatty Road 138/69kV TF #2	6 / 20	Stable
P4.10	SLG @ Beatty 138kV East Bus, normal clear loss of Beatty Road – McComb 138kV line, Beatty Road 138/13.8kV TF #6, SB @ Beatty Road, delayed clear loss of Beatty Road – White Road 138kV line	6 / 20	Stable
P4.11	SLG @ Beatty 138kV East Bus, normal clear loss of Beatty Road – McComb 138kV line, Beatty Road 138/13.8kV TF #6, SB @ Beatty Road, delayed clear loss of Beatty Road – Zuber – Harrison 138kV line	6 / 20	Stable
P4.12	SLG @ Beatty 138kV East Bus, normal clear loss of Beatty Road – McComb 138kV line, Beatty Road 138/13.8kV TF #6, SB @ Beatty Road, delayed clear loss of Beatty Road 138/345kV TF #3	6 / 20	Stable
P4.13	SLG @ Beatty 138kV East Bus, normal clear loss of Beatty Road – McComb 138kV line, Beatty Road 138/13.8kV TF #6, SB @ Beatty Road, delayed clear loss of Beatty Road 138/345kV TF #4	6 / 20	Stable
P4.14	SLG @ Beatty Road 138kV West bus, normal clear loss of Beatty Road 138/13.8kV TF #5, SB @ Beatty Road 138kV, delayed clear loss of Beatty Road – AD1-081 POI 138kV line	6 / 20	Stable
P4.15	SLG @ Beatty Road 138kV West bus, normal clear loss of Beatty Road 138/13.8kV TF #5, SB @ Beatty Road 138kV, delayed clear loss of Beatty Road 138/69kV TF#1 and Beatty Road 138/69kV TF #2	6 / 20	Stable
P4.16	SLG @ Beatty Road 138kV West bus, normal clear loss of Beatty Road 138/13.8kV TF #5, SB @ Beatty Road 138kV, delayed clear loss of Beatty Road – Hall 138kV line	6 / 20	Stable
P4.17	SLG @ Beatty Road 138kV West bus, normal clear loss of Beatty Road 138/13.8kV TF #5, SB @ Beatty Road 138kV, delayed clear loss of Beatty Road – Wilson 138kV line	6 / 20	Stable

P5: SLG Fault with Delayed (Zone 2) Clearing

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P5.01	SLG at 80% of AC1-087 – London 138kV line, delayed clear.	6 / 60	Stable
P5.02	SLG at 80% of London – AC1-087 138kV line, delayed clear.	6 / 60	Stable
P5.03	SLG at 80% of AC1-087 – Beatty Rd 138kV line, delayed clear.	6 / 60	Stable
P5.04	SLG at 80% of Beatty Rd – AC1-087 138kV line, delayed clear.	6 / 60	Stable

P7: Common Structure

Fault ID	Fault description	Clearing Time (Cycles)	Results
P7.01	CONTINGENCY 'C5-TWL-SR066A' SLG @ London – East Springfield 138kV #1, tower failure normal clear loss of London – East Springfield 138kV #2	6	Stable
P7.02	CONTINGENCY '8123' 3ph @ Beatty – Adkins 345kV line, tower failure normal clear loss of Beatty – Greene 345kV line, Beatty 345/138kV TF #3	6	Stable

Attachment 1. PSS/E Model One Line Diagram

Attachment 2. AD1-081 PSS/E Dynamic Model

926014 'USRMDL' 1 'REGCAU1' 101,1,1,14,3,4,1,0.02,99,0.9,-10,0.21,1.05,0.01,0.0,-0.21,0.01,0.3,99,-99,0.9/
926014 'USRMDL' 1 'REECBU1' 102,0,5,25,6,4,0,0,1,0,0,0.9,2,0.01,-0.0,0.0,2.0,1,-0.21,1.0,0.1,0.313,-0.313,1.1,0.9,0.0,0.0,0.0,0.0,0.00,0.5,-0.5,1.0,0,1.2,0.01 /
926014 'USRMDL' 1 'REPCAU1' 107 0 7 27 7 9 0 0 0 0 1 1 0
6 0.5 0.001 0.0000 0.05 0.900 0.0000 0.0000 0.0000 0.05000 -0.050000 0.000 0.0000 0.313 -0.313 0.30000 0.05 0.250000 -0.0006 0.0006 999.00 -999.00 1.00 0.00 0.70000 20.000 20.0000 /

92601401 'VTGDCAT' 926010 926014 '1 ' 0.8800 10.000 20.0000 0.00000 /
92601402 'VTGDCAT' 926010 926014 '1 ' 0.7000 10.000 10.0000 0.00000 /
92601403 'VTGDCAT' 926010 926014 '1 ' 0.5000 10.000 1.00000 0.00000 /
92601404 'VTGDCAT' 926010 926014 '1 ' 0.0000 10.000 0.0200 0.00000 /
92601405 'VTGDCAT' 926010 926014 '1 ' 0.0000 1.3500 0.0200 0.00000 /
92601406 'VTGDCAT' 926010 926014 '1 ' 0.0000 1.2000 0.1600 0.00000 /
92601407 'VTGDCAT' 926010 926014 '1 ' 0.0000 1.1000 12.0000 0.00000/
92601409 'FRQDCAT' 926010 926014 '1 ' 58.500 100.00 299.00 0.00000 /
92601410 'FRQDCAT' 926010 926014 '1 ' 50.000 100.00 0.0200 0.00000 /
92601411 'FRQDCAT' 926010 926014 '1 ' 0.0000 64.000 0.0200 0.00000 /
92601413 'FRQDCAT' 926010 926014 '1 ' 0.0000 60.500 299.00 0.00000 /

Attachment 3. AD1-081 PSS/E Case Dispatch

Bus Number	Bus Name	Id	In Service	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
243622	05CVG4 26.000	4	1	780	780	350	126.7	247	-75
243623	05CVG5 24.000	5	1	404	405	160	126.7	202	-50
243624	05CVG6 24.000	6	1	404	405	160	126.7	205	-36
248005	06KYGER 345.00	1	1	72.59	72.59	22.2	4.604	20.28	-22.6
248005	06KYGER 345.00	2	1	72.59	72.59	22.2	4.604	20.28	-22.6
248005	06KYGER 345.00	3	1	72.59	72.59	22.2	4.604	20.28	-22.6
248005	06KYGER 345.00	4	1	72.59	72.59	22.2	4.604	20.28	-22.6
248005	06KYGER 345.00	5	1	72.59	72.59	22.2	4.604	20.28	-22.6
248005	06KYGER 345.00	6	1	123.6	123.6	37.8	7.839	34.52	-38.6
248005	06KYGER 345.00	7	1	123.6	123.6	37.8	7.839	34.52	-38.6
248005	06KYGER 345.00	8	1	123.6	123.6	37.8	7.839	34.52	-38.6
248005	06KYGER 345.00	9	1	123.6	123.6	37.8	7.839	34.52	-38.6
248005	06KYGER 345.00	A	1	123.6	123.6	37.8	7.839	34.52	-38.6
253038	09KILLEN 345.00	2	1	612	612	230	199	199	-63
253038	09KILLEN 345.00	3	1	18	18	15.66	18	18	-10.2
253077	09STUART 345.00	1	1	580.6	580.6	300	-4.13	280	-17
253077	09STUART 345.00	2	1	580	580	300	-4.13	280	-30
253077	09STUART 345.00	3	1	580.4	580.4	300	8	280	8
253077	09STUART 345.00	4	1	577	577	300	-4.11	280	-30
253077	09STUART 345.00	5	1	9.2	9.2	0	-0.07	8.8	-5.2
253110	09ADKINS 345.00	1	1	94	94	38	-1.58	32	-15
253110	09ADKINS 345.00	2	1	94	94	38	-1.58	30	-16
253110	09ADKINS 345.00	3	1	94	94	38	-1.58	23	-13
253110	09ADKINS 345.00	4	1	94	94	38	-1.58	26	-14
253110	09ADKINS 345.00	5	1	94	94	38	-1.58	27	-13
253110	09ADKINS 345.00	6	1	94	94	38	-1.58	24	-14
926014	AD1-081 GEN 0.6000	1	1	200.2	200.2	0	34.85	65.81	-65.8

Attachment 4. Plots from Dynamic Simulations (See separated .PDF file)