Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AC1-078

Beatty-London 138kV

October 2017

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

First Solar Development, LLC, the Interconnection Customer (IC), has proposed a Solar generating facility located in Madison County, Ohio. The installed facilities will have a total capability of 176 MW with 66 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is December 31, 2019. **This study does not imply an ATSI commitment to this in-service date.**

Point of Interconnection

AC1-078 will interconnect with the ATSI transmission system along the Beatty-London 138kV line.

Cost Summary

The AC1-078 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$ 0
Direct Connection Network Upgrades	$ 5,404,007
Non Direct Connection Network Upgrades	$ 516,294
Allocation for New System Upgrades	$ 0
Contribution for Previously Identified Upgrades	$ 0
Total Costs	**$ 5,920,301**

Attachment Facilities

No Attachment Facilities are required to support this interconnection request.

Direct Connection Cost Estimate

The total preliminary cost estimate for the 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
Install a 138kV 3-breaker ring bus on the London-Beatty (AEP) line for interconnection to AC1-078. PJM Network Upgrade # n5925	$ 4,890,604	$ 651,489	$ 5,542,093
Loop the Beatty-London 138kV circuit into the proposed 3-breaker ring bus. @ Beatty-London Loop to New 3-Breaker Ring Bus. PJM Network Upgrade # n5926	$ 513,403	$ 68,459	$ 581,862
Total Direct Connection Facility Costs	**$ 5,404,007**	**$ 719,948**	**$ 6,123,955**

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
London 138kV Substation (ATSI): Remote end relay changes for AC1-078 Substation on the 138kV Beatty Line. PJM Network Upgrade # n5927	$ 266,294	$ 35,552	$ 301,845
Beatty Road 138kV Substation (AEP): Remote end relay changes for AC1-078 Substation on the 138kV London Line. PJM Network Upgrade # n5928	$ 250,000	$ 31,778	$ 281,778
Total Non-Direct Connection Facility Costs	**$ 516,294**	**$ 67,330**	**$ 583,623**

Interconnection Customer Requirements

In addition to the ATSI facilities, First Solar Development, LLC will also be responsible for meeting all criteria as specified in the applicable sections of the FE "Requirements for Transmission Connected Facilities" document including:

1. The purchase and installation of fully rated 138 kV circuit breakers on the high side of the AC1-078 step-up transformers.
2. The purchase and installation of the minimum required ATSI 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 FE Transmission System Control Center.
4. The establishment of dedicated communication circuits for SCADA to the FE Transmission System Control Center.
5. A compliance with the FE and PJM generator power factor and voltage control requirements.
6. The execution of a back-up service agreement to serve the customer load supplied from the AC1-078 generation project metering point when the units are out-of-service. This assumes the intent of First Solar 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.

Transmission Owner Scope of Work

The First Solar Development, LLC generation project (AC1-078) calls for the connection of a 176 MW (66 MW Capacity) solar generation project to the London-Beatty 138 kV line. The First Solar Development, LLC has proposed a commercial operation date of December 31, 2019.

Attachment 1 provides the proposed location of the generation facility and point of interconnection to the ATSI transmission system. The proposed facility's single line diagram connection to the ATSI transmission system, as shown in Attachment 2, will not require any network upgrades. The direct connection costs for the proposed facility is shown in on page 2.

Based on the extent of the ATSI primary direct connection required to support the AC1-078 generation project, it is expected to take a minimum of nineteen (19) months from the date of a fully executed Interconnection Construction Service Agreement to complete the installation. This includes the requirement for First Solar Development, LLC to make a preliminary payment to ATSI which funds the first three months of engineering design that is related to the construction of the Direct Connection facilities. It further assumes that First Solar Development, 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 direct connection and facility upgrades, and that all system outages will be allowed when requested.

Note that the FE findings were made from a conceptual review of this project. A more detailed review of the connection facilities and their cost will be identified in the Facilities Study. Further note that the cost estimate data contained in this document are subject to further refinement after the Facilities Study is complete. The applicant will be responsible for the actual cost of construction. The cost estimates in this document do not include the remote end work at the AEP substation Beatty. The cost of the Beatty substation remote end work will need to be obtained from AEP via a request from PJM. The applicant will be responsible for the actual cost of construction. FE herein reserves the right to return to any issues in this document and, upon appropriate justification, request additional monies to complete any reinforcements to the transmission or sub-transmission systems.

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

London-Beatty 138 kV

The primary Point of Interconnection (POI) for the AC1-078 generation project is located one span outside of the proposed ATSI ring bus switch station which will be located on the London-Beatty 138kV line. Please note that Beatty substation is an American Electric Power (AEP) owned facility. Attachments of this document illustrate the proposed location for the point of interconnection. The direct connection of AC1-078 generation project will be accomplished by utilizing a 3 breaker ring bus to connect to the London-Beatty 138 kV line. Attachment shows a conceptual one-line diagram of the proposed connection of AC1-078 generation project to the ATSI transmission system. The First Solar Development, LLC will be responsible for constructing all of the facilities on its side of the POI, including the 138 kV line extension to its generation facilities. First Solar Development, LLC may not install above ground equipment within any FirstEnergy right-of-way unless permission to do so is expressly granted by

FirstEnergy. The ATSI facilities required for the Direct Connection of the generation project and the associated cost estimate are shown in Attachments.

Power Flow Analysis

A power flow study was conducted to determine the reliability impact of the proposed AC1-078 generation project on the ATSI transmission system. This study was completed using 2020 summer peak power flow model that contains a detailed representation of the ATSI transmission network in the area of the proposed AC1-078 generation project. The findings and the recommendations from this analysis are based on a contingency review that was performed to identify the facility loadings and/or voltage conditions that violate the ReliabilityFirst, PJM, or FE Planning Criteria and are attributable to this project. Note that in accordance with PJM RTEP study procedures, the AC1-078 generation project under study and earlier active queue projects are considered to be in-service. All active queue projects after the AC1-078 project are considered not in-service.

As shown in Attachments, the AC1-078 generation project was studied with connection to the London-Beatty 138 kV line. The results of the FE analysis show that there are no transmission system network upgrades required for the deliverability of the AC1-078 generation to the ATSI transmission system on the London-Beatty 138 kV.

The AC1-078 generation facility must maintain a 0.95 leading to 0.95 lagging power factor at the generator terminals.

Short Circuit Analysis

A short circuit analysis has been performed by PJM. The results have identified the 211-B-63 breaker at the East Springfield 138kV bus has been over-dutied to 102.9% due to the AC1-078 project. FE reviewed and confirmed that the 211-B-62 breaker at East Springfield has been recently replaced with a new breaker that has a 40kA interrupting rating which mitigates the identified breaker over-duty. Therefore, no breaker upgrades are required at this time.

System Protection Analysis

An analysis was conducted to assess the impact of the London-Beatty 138 kV (AC1-078) generation project on the system protection requirements in the area.

Attachment 5 shows the specific power and protection equipment requirements for the Primary POI.

Compliance Issues

The proposed interconnection facilities must be designed in accordance with the FE "Requirements for Transmission Connected Facilities" located at:

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

First Solar Development, LLC will be responsible for following the requirements of the "FE Approved Vendors and Contractors" documents which is also located at the above link.

First Solar Development, LLC will also be required to meet all PJM, ReliabilityFirst and NERC reliability criteria and operating procedures for standards compliance. For example, First Solar Development, LLC 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 ATSI system.

ATSI Facility Upgrades and Costs

The results of the FE power flow analysis for the AC1-078 generation project show that there are no FE criteria violations that are attributable to connecting the project to the London-Beatty 138 kV line. Therefore, there are no ATSI Transmission network upgrades required at this time.

The direct connection costs for the new AC1-078 direct connect facilities, (substation, breaker, disconnects, CTs, VTs, etc.) is provided on page 2 of this report. This tax may or may not be charged based on whether or not this project meets the eligibility requirements of IRS Notice 88-129. This total cost does not include the remote end work at the AEP Beatty substation. The cost of the Beatty substation remote end work will need to be obtained from AEP via a request from PJM.

Note that all cost estimates contained in this document were produced without a detailed engineering review and are therefore subject to change. More accurate estimates will be determined as a part of the Facility Study. First Solar Development, LLC will be responsible for the actual cost of the direct connection that is implemented. In addition, First Solar Development, LLC is responsible to provide metering, disconnect switches and high-side breakers for each unit, as First Solar Development, LLC will own this equipment. FE herein reserves the right to return to any issues in this document and, upon appropriate justification, request additional monies to complete any reinforcements to the transmission or sub-transmission systems.

Network Impacts

The Queue Project AC1-078 was evaluated as a 176.0 MW (Capacity 66.0 MW) injection into the Beatty – London 139 kV line substation in the ATSI area. Project AC1-078 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-078 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2020

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).

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)

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

(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)

None. See Attachment 4

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.

Note: Only the most severely overloaded conditions are listed below. 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 shall study all overload conditions associated with the overloaded element(s) identified

None.

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO Impacts:

MISO Impacts to be determined during later study phases (as applicable).

Duke, Progress & TVA Impacts:

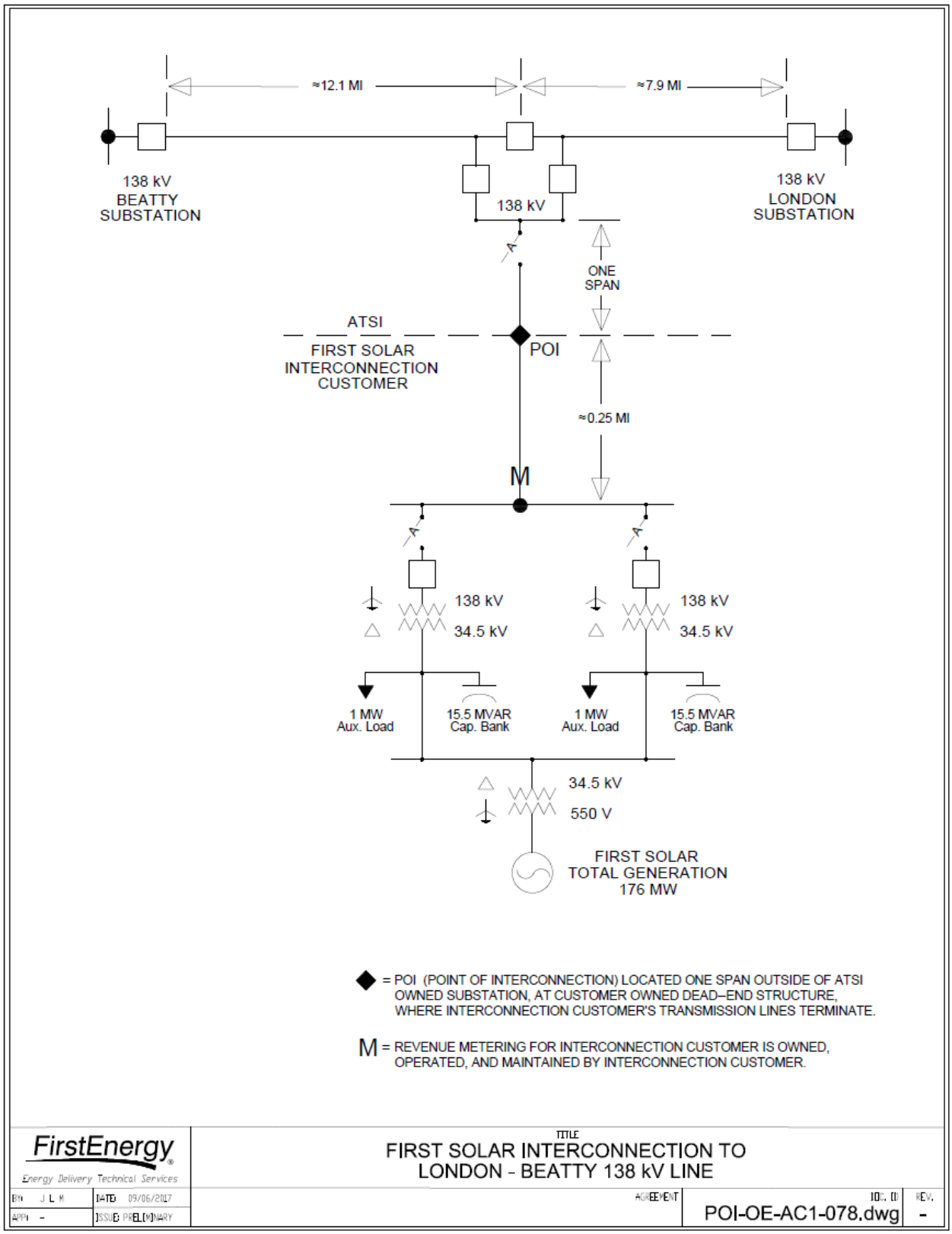
None

OVEC Impacts:

OVEC Impacts to be determined during later study phases (as applicable).

Attachment 1. Project Location

Attachment 2. Single Line Diagram



Attachment 3. Protection Requirements

PJM AC1-078 Preliminary Short Circuit Duties & Protection Requirements

(8-15-2017)

Short Circuit Analysis

Short Circuit Values

The 138kV 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 100 MVA and 138kV bases. 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.

General Connection Requirements

The AC1-078 delivery point substation (DPS) is a 138kV three-breaker ring bus on the London-Beatty 138kV 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 138kV line, at each terminal.

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

Protection of the 138kV 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 138kV Interconnecting Substation

138kV 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

138kV 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

138kV Breaker Failure to Trip Protection

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

AC1-078 Generating Station 138kV

138kV 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

138kV Breaker Failure to Trip Protection

- 138kV Breaker Failure to Trip Relaying
  - SEL-352-2 breaker failure to trip relaying on AC1-078 138kV 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).

138kV 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

138kV 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

138kV 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.

Attachment 4. Dynamic Simulation Analysis

TABLE OF CONTENTS

Executive Summary

Generator Interconnection Request AC1-078 is for a 176 MW Maximum Facility Output (MFO) solar generation plant. AC1-078 consists of 3830 x 0.05 MVA HUAWEI SUN2000HA-45KTL 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 AC1-078 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 Summer Peak case, modified to include applicable queue projects. AC1-078 has been dispatched online at maximum power output, with POI voltage of (1.01 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 AC1-078 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 AC1-078 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.

1. Introduction

Generator Interconnection Request AC1-078 is for a 176 MW Maximum Facility Output (MFO) solar generation plant. AC1-078 consists of 3830 x 0.05 MVA HUAWEI SUN2000HA-45KTL 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 AC1-078 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AC1-078 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 AC1-078 is for a 176 MW Maximum Facility Output (MFO) solar generation plant. AC1-078 consists of 3830 x 0.05 MVA HUAWEI SUN2000HA-45KTL inverters with a Point of Interconnection (POI) tapped into London – Beatty Road 138kV line in the ATSI transmission system, Madison county, OH. The AC1-078 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 AC1-078 loadflow models.

The dynamic model for the AC1-078 plant is based on the model data supplied by the Developer.

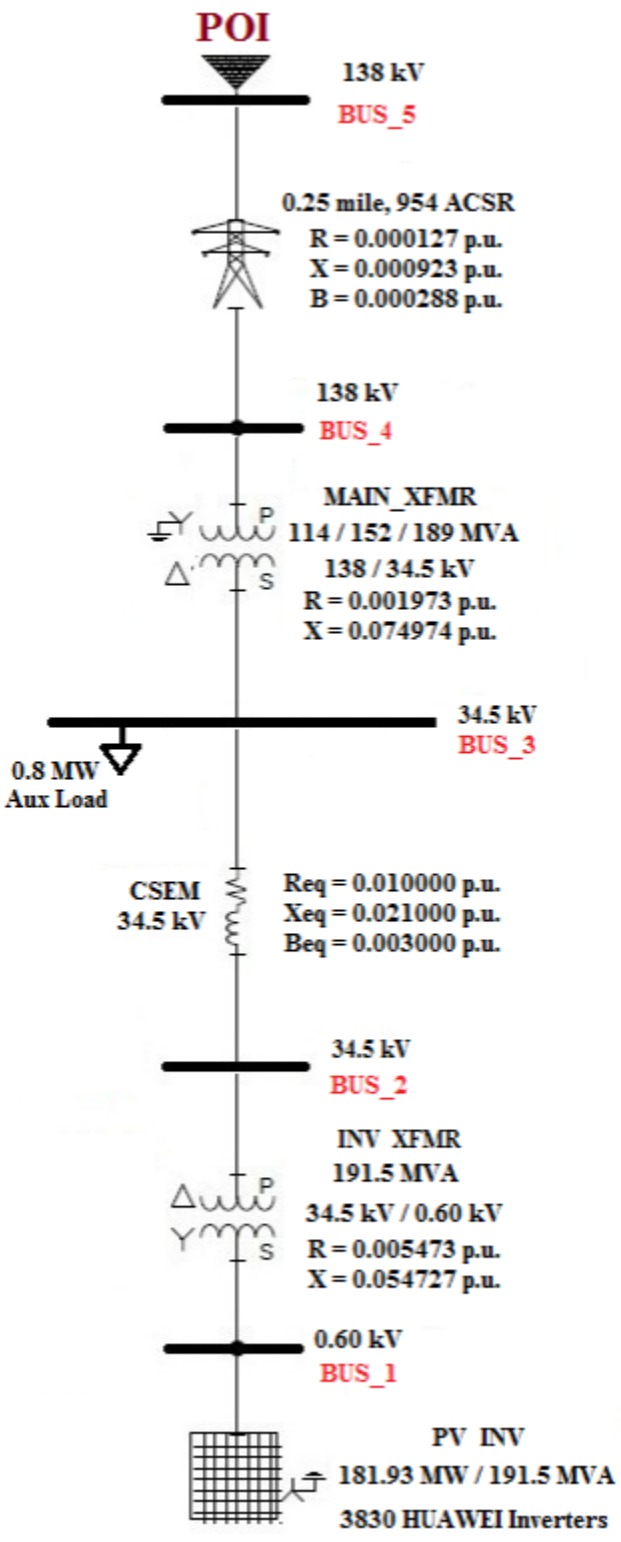


Figure 1: AC1-078 Plant Model

Table 1: AC1-078 Plant Model

	Impact Study Data	Model
Inverters	3830 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 3830 HUAWEI SUN2000HA-45KTL 0.05MVA inverters Pgen 181.93 MW Pmax 181.93 MW Pmin 0 MW Qmax 21.5 MVAr Qmin -21.5 MVAr Mbase 70.2 MVA Zsorce j1.000 pu @ Mbase
Inverter Transformers	Lumped equivalent representing 3830 GSUs Rating = 114/152/189 MVA Transformer base = 191.5 MVA Impedances: High – Low = 0.005473+ j 0.054727 @ MVA base Number of taps = 33 Tap step size = 0.00625 Nominal Tap = 17	Lumped equivalent representing 3830 GSUs Rating = 114/152/189 MVA Transformer base = 191.5 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 = 0.01 X = 0.021 B = 0.003 @100MVA	R = 0.01 X = 0.021 B = 0.003 @100MVA
Collector transformer	138/34.5/13.8 kV three winding transformer Rating = 114/152/189 MVA Transformer base = 114 MVA Impedances: High – Low = 0.001973 + j0.074974 High – Ter = 0.001294 + j0.049182 Low – Ter = 0.003662 + j0.139152 @ MVA base Number of taps = N/A Tap step size = N/A Nominal Tap = N/A	138/34.5 kV two winding transformer Rating = 114/152/189 MVA Transformer base = 114 MVA Impedances: High – Low = 0.001973 + j0.074974 @ MVA base Number of taps = 33 Tap step size = 0.00625 Nominal Tap = 19

Auxiliary load	0.8 MW + 0.0 MVAR	0.8 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[1].

The selected load flow scenario is the RTEP 2020 Summer Peak case with the following modifications:

a) Addition of all applicable queue projects prior to AC1-078.

b) Addition of AC1-078 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AC1-078.

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

The AC1-078 initial conditions are listed in Table 2, indicating maximum power output, with AC1-078 regulating to unity power factor at the generator bus.

Table 2: AC1-078 machine initial conditions

Bus	Name	Unit	PGEN (MW)	QGEN (MVAR)	ETERM (p.u.)	POI Voltage (p.u.)
926014	AC1-078 GEN 0.6000	1	191.93	26.7	1.0282	1.011

Generation within the vicinity of AC1-078 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AC1-078 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.

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 AC1-078, 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 AC1-078 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 4% for local modes and 3% for inter-area modes.

b) The AC1-078 is able to ride through faults (except for faults where protective action trips AC1-078).

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 4% for local modes and 3% for inter-area modes.

b) The AC1-078 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 @ AC1-078 Main – AC1-078 POI 138kV line, normal clear loss of AC1-078	6	Stable
P1.01	3ph @ AC1-078 POI – Beatty Road 138kV line, normal clear	6	Stable
P1.02	3ph @ AC1-078 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
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
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

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
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 – AC1-078 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

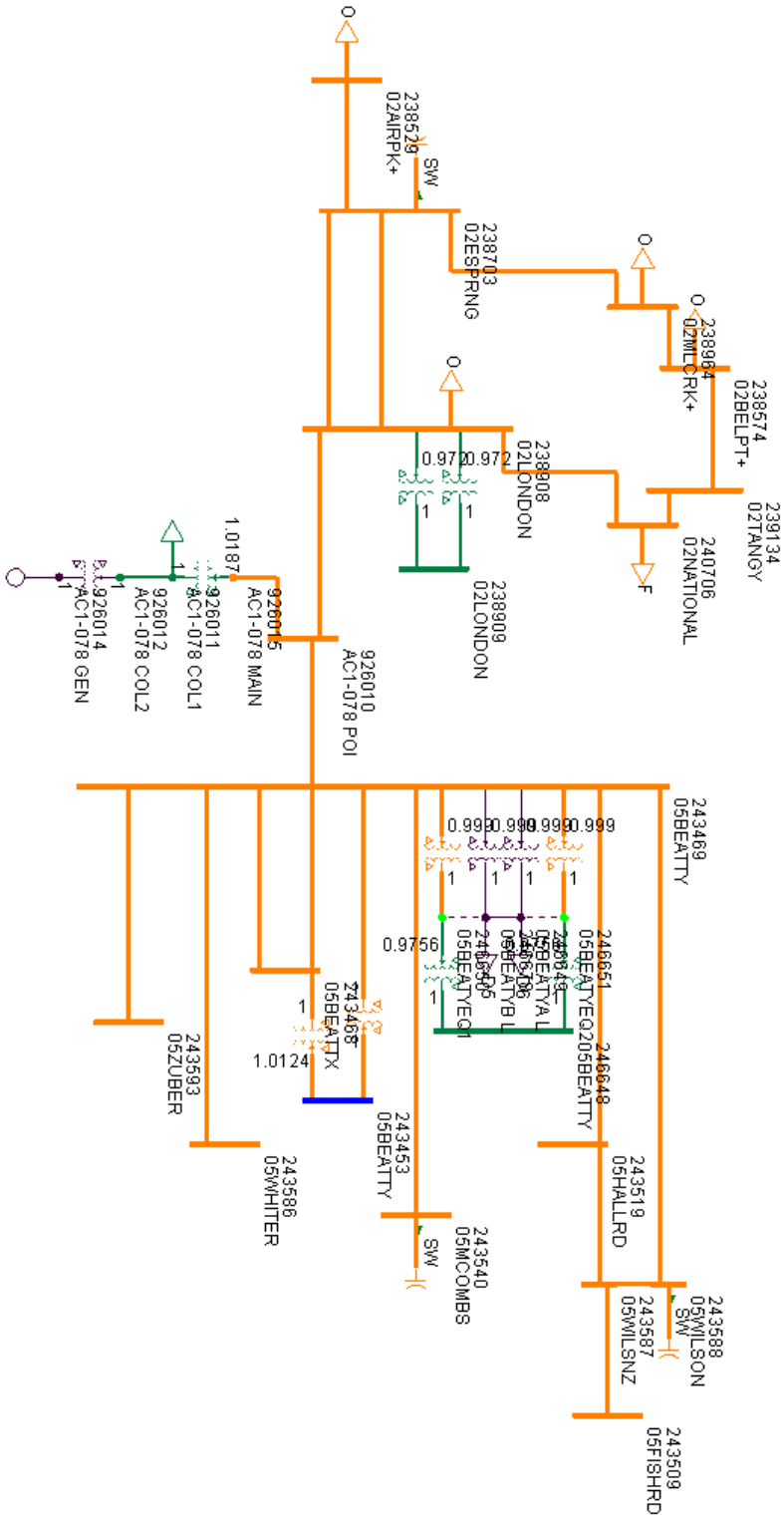
Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P5.01	SLG at 80% of AC1-087 – London 138kV line, delayed clear.	6 / 60	Stable
P5.02	SLG at 80% of London – AC1-087 138kV line, delayed clear.	6 / 60	Stable
P5.03	SLG at 80% of AC1-087 – Beatty Rd 138kV line, delayed clear.	6 / 60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

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. AC1-078 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,-0.313,1.1,0.9,0.0,0.0,0.0,0.0,0.0,0.00,0.5,-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 0.0000 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 1 '1 ' 0.8800 10.000 20.0000 0.00000 /
92601402 'VTGDCAT' 926010 1 '1 ' 0.7000 10.000 10.0000 0.00000 /
92601403 'VTGDCAT' 926010 1 '1 ' 0.5000 10.000 1.00000 0.00000 /
92601404 'VTGDCAT' 926010 1 '1 ' 0.0000 10.000 0.0200 0.00000 /
92601405 'VTGDCAT' 926010 1 '1 ' 0.0000 1.3500 0.0200 0.00000 /
92601406 'VTGDCAT' 926010 1 '1 ' 0.0000 1.2000 0.1600 0.00000 /
92601407 'VTGDCAT' 926010 1 '1 ' 0.0000 1.1000 12.0000 0.00000/
92601409 'FRQDCAT' 926010 1 '1 ' 58.500 100.00 299.00 0.00000 /
92601410 'FRQDCAT' 926010 1 '1 ' 50.000 100.00 0.0200 0.00000 /
92601411 'FRQDCAT' 926010 1 '1 ' 0.0000 64.000 0.0200 0.00000 /
92601413 'FRQDCAT' 926010 1 '1 ' 0.0000 60.500 299.00 0.00000 /

Attachment 3. AC1-078 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	141.29	247	-162
243623	05CVG5 24.000	5	1	405	405	160	141.29	202	-81
243624	05CVG6 24.000	6	1	405	405	160	141.29	205	-36
248005	06KYGER 345.00	1	1	72.594	72.594	22.2	1.9685	20.276	-22.64
248005	06KYGER 345.00	2	1	72.594	72.594	22.2	1.9685	20.276	-22.64
248005	06KYGER 345.00	3	1	72.594	72.594	22.2	1.9685	20.276	-22.64
248005	06KYGER 345.00	4	1	72.594	72.594	22.2	1.9685	20.276	-22.64
248005	06KYGER 345.00	5	1	72.594	72.594	22.2	1.9685	20.276	-22.64
248005	06KYGER 345.00	6	1	123.61	123.61	37.8	3.3517	34.524	-38.56
248005	06KYGER 345.00	7	1	123.61	123.61	37.8	3.3517	34.524	-38.56
248005	06KYGER 345.00	8	1	123.61	123.61	37.8	3.3517	34.524	-38.56
248005	06KYGER 345.00	9	1	123.61	123.61	37.8	3.3517	34.524	-38.56
248005	06KYGER 345.00	A	1	123.61	123.61	37.8	3.3517	34.524	-38.56
253038	09KILLEN 345.00	2	1	612	612	230	154.08	199	-63
253038	09KILLEN 345.00	3	1	18	18	15.66	4.5319	18	-10.2
253077	09STUART 345.00	1	1	580.6	580.6	300	-17	280	-17
253077	09STUART 345.00	2	1	580	580	300	-30	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	-30	280	-30
253077	09STUART 345.00	5	1	9.2	9.2	0	-5.2	8.8	-5.2
253110	09ADKINS 345.00	1	1	82	82	38	-13.03	24	-15
253110	09ADKINS 345.00	2	1	82	82	38	-13.03	22	-16
253110	09ADKINS 345.00	3	1	81	81	38	-12.87	22	-13
253110	09ADKINS 345.00	4	1	80	80	38	-12.71	22	-14
253110	09ADKINS 345.00	5	1	82	82	38	-13	27	-13
253110	09ADKINS 345.00	6	1	79	79	38	-12.55	25	-14
926014	AC1-078 GEN 0.6000	1	1	181.93	181.93	0	26.77	59.8	-59.8

Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD1-081

Beatty-London 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

First Solar Development, 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 in-service date for the AD1-081 project is June 1, 2020. **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: 02/01/2020 Requested Commercial Operation Date: 06/01/2020

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:

Contingency Name	Description
AEP_P7-1_#468	CONTINGENCY 'AEP_P7-1_#468' OPEN BRANCH FROM BUS 239133 TO BUS 243458 CKT 1 / 239133 02TANGY 345 243458 05HYATT 345 1 OPEN BRANCH FROM BUS 239133 TO BUS 242939 CKT 1 / 239133 02TANGY 345 242939 05MARYSV 345 1 END
ATSI-P7-1-OES-345-68T	CONTINGENCY 'ATSI-P7-1-OES-345-68T' /* TANGY-HYATT & TANGY-MARYSVILLE COMMON TOWER DISCONNECT BRANCH FROM BUS 239133 TO BUS 243458 CKT 1 /* 02TANGY 345 05HYATT 345 DISCONNECT BRANCH FROM BUS 239133 TO BUS 242939 CKT 1 /* 02TANGY 345 05MARYSV 345 DISCONNECT BRANCH FROM BUS 239133 TO BUS 239134 CKT 3 /* 02TANGY 345 02TANGY 138 DISCONNECT BRANCH FROM BUS 239133 TO BUS 239134 CKT 4 /* 02TANGY 345 02TANGY 138 DISCONNECT BRANCH FROM BUS 239133 TO BUS 239134 CKT 5 /* 02TANGY 345 02TANGY 138 DISCONNECT BUS 239133 /* 02TANGY 345 END

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)

#	Contingency Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Ref
1	DCTL	AEP_P7-1_#468	FE	AC1-078 TAP-02LONDON 138 kV line	926010	238908	1	AC	104.15	107.21	ER	242	7.38	1
2	DCTL	ATSI-P7-1-OES-345-68T	FE	AC1-078 TAP-02LONDON 138 kV line	926010	238908	1	AC	104.15	107.21	ER	242	7.38	

Affected System Analysis & Mitigation

LGEE Impacts:

LGEE Impacts to be determined during later study phases (as applicable).

MISO Impacts:

MISO Impacts to be determined during later study phases (as applicable).

Duke, Progress & TVA Impacts:

Duke Carolina, Progress, & TVA Impacts to be determined during later study phases (as applicable).

OVEC Impacts:

OVEC Impacts to be determined during later study phases (as applicable).

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)

Violation #	Overloaded Facility	Upgrade Description	Network Upgrade Number	Upgrade Cost	AD1-081 Allocation
1, 2	AC1-078 Tap – London 138 kV line	In order to mitigate the overloads of facilities above, the following reinforcements are required: Reconductor 8 miles of transmission line from the AC1-078 Tap location to London substation with 477 ACSS conductor. Cost estimate is $3.9079 M. PJM Network Upgrade N5783. Queue Project AD1-081 presently does not receive cost allocation for this upgrade. Note 1: as changes to the interconnection process occur, such as prior queued projects withdrawing from the queue, reducing in size, etc, Queue Project AD1-081 could receive cost allocation. Note 2: Although Queue Project AD1-081 may not have cost responsibility for this upgrade, Queue Project AD1-081 may need this upgrade in-service to be deliverable to the PJM system. If Queue Project AD1-081 comes into service prior to completion of the upgrade, Queue Project AD1-081 will need an interim study.	N5777	**$ 3,907,900**	**$ 0**
				Total New Network Upgrades	**$ 0**

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

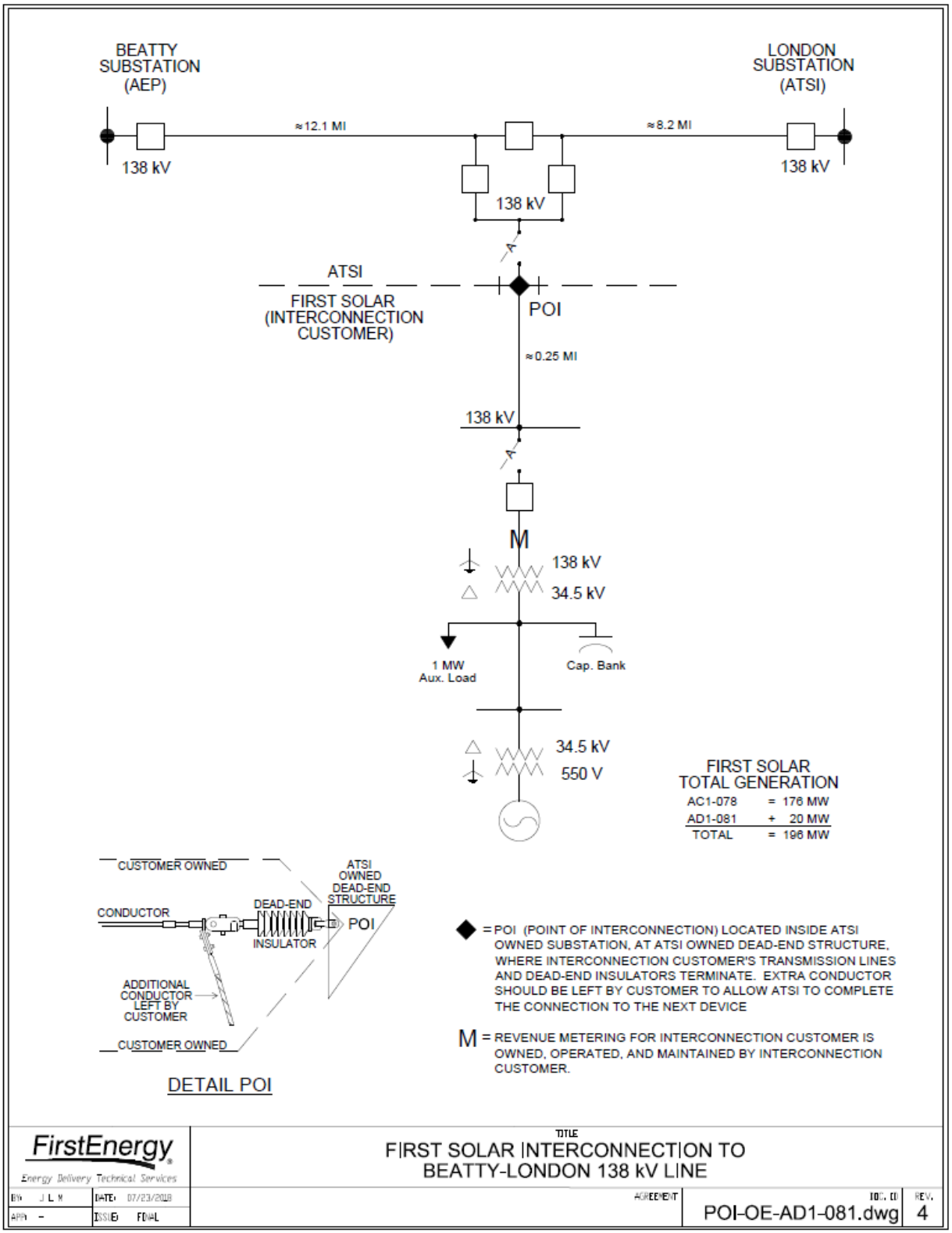
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

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

None

Attachment 1. Project Location

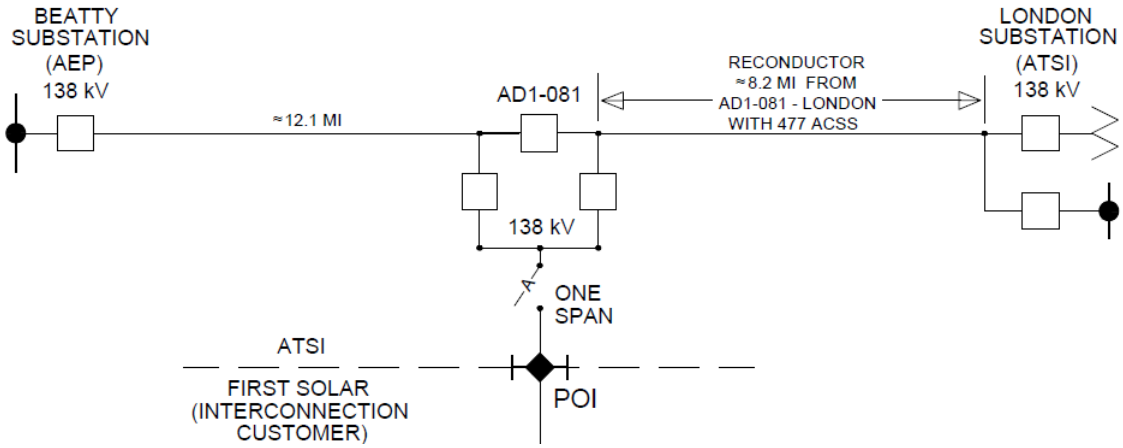
Attachment 2. Single Line Diagram



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.

Appendix 1

(AEP - FE) The AC1-078 TAP-02LONDON 138 kV line (from bus 926010 to bus 238908 ckt 1) loads from 104.15% to 107.21% (AC power flow) of its emergency rating (242 MVA) for the tower line contingency outage of 'AEP_P7-1_#468'. This project contributes approximately 7.38 MW to the thermal violation.

Bus Number	Bus Name	Full Contribution
934561	AD1-081 C	4.87
934562	AD1-081 E	2.51
LTF	AMIL	0.04
LTF	BAYOU	0.06
LTF	BIG_CAJUN1	0.09
LTF	BIG_CAJUN2	0.17
LTF	BLUEG	0.34
LTF	CANNELTON	0.05
LTF	CBM-N	< 0.01
LTF	CBM-S2	0.15
LTF	CHOCTAW	0.05
LTF	CLIFTY	0.18
LTF	COTTONWOOD	0.25
LTF	CPLE	0.05
LTF	DEARBORN	0.49
LTF	EDWARDS	0.08
LTF	ELMERSMITH	0.13
LTF	FARMERCITY	0.05
LTF	G-007A	0.15
LTF	GIBSON	0.11
LTF	MORGAN	0.07
LTF	NEWTON	0.2
LTF	NYISO	0.02
LTF	O-066A	0.07
LTF	PRAIRIE	0.33
LTF	SMITHLAND	0.02
LTF	TATANKA	0.09
LTF	TILTON	0.11
LTF	TRIMBLE	0.07
LTF	TVA	0.03
LTF	VFT	0.41
926011	AC1-078 C	24.35
926012	AC1-078 E	40.59

Attachment 5. Dynamic Simulation Analysis

TABLE OF CONTENTS

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.

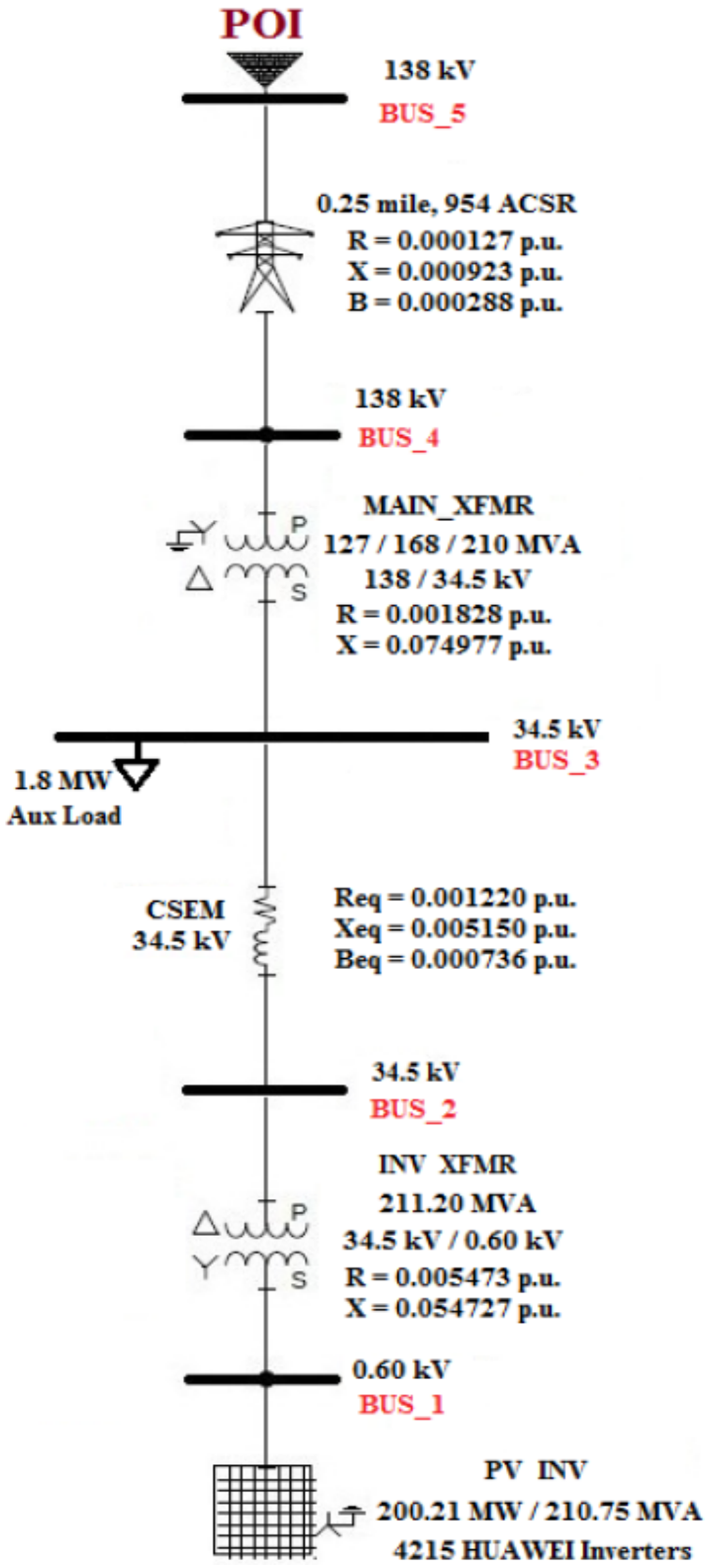


Figure 1: AD1-081 Plant Model

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,-0.313,1.1,0.9,0.0,0.0,0.0,0.0,0.0,0.00,0.5,-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)

Summary: Application Exhibit M electronically filed by Mr. Michael J. Settineri on behalf of Big Plain Solar, LLC