Revised

Generation Interconnection

System Impact Study Report

for

Queue Project AE1-132

MCCONNELLSBURG 138 KV

51 MW Capacity / 85 MW Energy

May 2021

Revision 1

Table of Contents

1 Introduction

This Feasibility Study has been prepared in accordance with the PJM Open Access Transmission Tariff, 36.2, as well as the Feasibility Study Agreement between **Keystone State Renewables, LLC**, the Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Allegheny Power Systems (APS).

2 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.

The Interconnection Customer seeking to interconnect a wind or solar generation facility shall maintain meteorological data facilities as well as provide that meteorological data which is required per Schedule H to the Interconnection Service Agreement and Section 8 of Manual 14D.

3 Revisions since August 2019 System Impact Study Report

The AE1-132 System Impact Study has been revised from August 2019 to include the Stability Analysis and Reactive Power Assessment results.

The reactive power assessment for this project reveals that the project does meet the reactive power requirements at the high side of the main transformer. Therefore, this project does not need to have additional reactive power capabilities to fulfill the power factor requirement.

4 General

The Interconnection Customer (IC) has proposed a Solar generating facility located in Fulton County, McConnellsburg, Pennsylvania. The installed facilities will have a total capability of **85 MW** with **51 MW** of this output being recognized by PJM as Capacity. The proposed in-service date for this project is **December 31, 2021.** This study does not imply a TO commitment to this in-service date.

Queue Number	**AE1-132**
Project Name	MCCONNELLSBURG 138 KV
Interconnection Customer	Keystone State Renewables, LLC
State	PA
County	Fulton
Transmission Owner	APS
MFO	85
MWE	85
MWC	51
Fuel	Solar
Basecase Study Year	2022

4.1 Point of Interconnection

The interconnection of the project will be accomplished by installing a new 138 kV breaker at McConnellsburg substation. Attachment 1 shows a one-line diagram of the proposed primary direct connection facilities for the AE1-132 generation project to connect to the FirstEnergy ("FE") transmission system. Attachment 2 provides the proposed location for the point of interconnection. The IC will be responsible for constructing the facilities on its side of the POI.

4.2 Cost Summary

The AE1-132 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$0
Direct Connection Network Upgrade	$254,000
Non Direct Connection Network Upgrades	$2,744,000
New System Upgrades	$0
Contribution to Previously Identified Upgrades	$0
Total Costs	$2,998,000

The costs provided above exclude the Contribution in Aid of Construction ("CIAC") Federal Income Tax Gross Up charge. If, at a future date, it is determined that the CIAC Federal Income Tax Gross charge is required, the Transmission Owner shall be reimbursed by the Interconnection Customer for such taxes.

The required Attachment Facilities and Direct and Non-Direct Connection work for the interconnection of the AE1-132 generation project to the FE Transmission System is detailed in the following sections. The associated one-line with the generation project Attachment Facilities and the Primary Direct and Non-Direct Connection facilities are shown in Attachment 1.

5 Transmission Owner Scope of Work

5.1 Attachment Facilities

There is no Attachment Facility scope of work required for this project.

5.2 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	Total Cost
Project Management and Commissioning	$176,200
Review customer drawings and provide equipment nameplates at customer substation.	$77,800
Total Non-Direct Connection Facility Costs	$254,000

5.3 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	Total Cost
McConnellsburg Substation: Install new 138 kV breaker and associated equipment for a new line terminal	$1,180,000
McConnellsburg Substation: Install disconnect switch and pull-off structure	$296,400
Upgrade SCADA at McConnellsburg, Guilford and Cherry Run Substations	$169,700
Guildford Substation: Upgrade relaying	$ 536,800
Cherry Run Substation: Upgrade relaying	$ 561,100
Total Non-Direct Connection Facility Costs	$2,744,000

6 Schedule

Based on the extent of the FE interconnection work required to support this project, it is expected to take a minimum of **twenty-four (24) months** from the date of a fully executed Interconnection Construction Service Agreement to complete the installation required for the AE1-132 Project. This includes the requirement for IC to make a preliminary payment to FE which funds the cost of the non-direct connection work identified. It further assumes that IC 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 connection work, and that all system outages will be allowed when requested.

7 Transmission Owner Analysis

7.1 Power Flow Analysis

FE performed an analysis of its underlying transmission <100 kV system. The AE1-132 project did not contribute to any overloads on the FE transmission <100 kV system.

8 Interconnection Customer Requirements

8.1 System Protection

The IC must design its Customer Facilities in accordance with all applicable standards, including the standards in FE's "Requirements for Transmission Connected Facilities" document located at: http://www.pjm.com/planning/design-engineering/to-tech-standards/private-firstenergy.aspx.

Preliminary Protection requirements will be provided as part of the Facilities Study. Detailed Protection Requirements will be provided once the project enters the construction phase.

The IC has requested a non-standard GSU transformer winding configuration. This transformer is in violation of section 14.2.6 of FE's "Requirements for Transmission Connected Facilities" document and will not be accepted. The GSU transformer must have a grounded wye connection on the high (utility) side and a delta connection on the low (generator) side.

8.2 Compliance Issues and Interconnection Customer Requirements

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

1. The purchase and installation of a fully rated 138 kV circuit breaker to protect the AE1-132 generator lead line. A single circuit breaker must be used to protect this line; if the project has several GSU transformers, the individual GSU transformer breakers cannot be used to protect this line.

2. The purchase and installation of the minimum required FE 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. Compliance with the FE and PJM generator power factor and voltage control requirements.

5. The execution of a back-up service agreement to serve the customer load supplied from the AE1-132 generation project metering point when the units are out-of-service. This assumes the intent of the IC is to net the generation with the load.

The IC will also be required to meet all PJM, ReliabilityFirst, and NERC reliability criteria and operating procedures for standards compliance. For example, the IC 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 FE system.

8.3 Power Factor Requirements

The IC shall design its [non-synchronous] Customer Facility with the ability to maintain a power factor of at least 0.95 leading (absorbing VARs) to 0.95 lagging (supplying VARs) measured at the high-side of the facility substation transformer(s) connected to the FE transmission system

9 Revenue Metering and SCADA Requirements

9.1 PJM Requirements

The Interconnection Customer will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for IC's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Section 8 of Attachment O.

9.2 Meteorological Data Reporting Requirement

The solar generation facility shall provide the Transmission Provider with site-specific meteorological data including:

- Temperature (degrees Fahrenheit)
- Atmospheric pressure (hectopascals)
- Irradiance
- Forced outage data

9.3 FE Requirements

The IC will be required 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

10 Network Impacts

The Queue Project AE1-132 was evaluated as a 85.0 MW (Capacity 51.0 MW) injection at McConnellsburg 138kV substation in the APS area. Project AE1-132 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AE1-132 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Load Flow

11 Generation Deliverability

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

None

12 Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies for the full energy output)

None

13 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)

ID	FROM BUS#	FROM BUS	FROM BUS AREA	TO BUS#	TO BUS	TO BUS AREA	CKT ID	CONT NAME	Type	Rating MVA	PRE PROJECT LOADING %	POST PROJECT LOADING %	AC|DC	MW IMPACT
403997	200532	26ROXBURY	PENELEC	200520	26ROXBURY	PENELEC	2	ME_P4-500-002H	breaker	150.0	114.38	121.0	AC	10.23

14 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.

ID	FROM BUS#	FROM BUS	FROM BUS AREA	TO BUS#	TO BUS	TO BUS AREA	CKT ID	CONT NAME	Type	Rating MVA	PRE PROJECT LOADING %	POST PROJECT LOADING %	AC|DC	MW IMPACT
404923	200532	26ROXBURY	PENELEC	200520	26ROXBURY	PENELEC	2	Base Case	operation	124.0	101.03	108.68	AC	9.94
4283356	200532	26ROXBURY	PENELEC	200520	26ROXBURY	PENELEC	2	AP-P1-2-WP-138-109	operation	150.0	95.28	105.58	AC	16.0

15 System Reinforcements

ID	Index	Facility	Upgrade Description	Cost
403997	1	**26ROXBURY 138.0 kV - 26ROXBURY 115.0 kV Ckt 2**	To Relieve the ROXBURY 138/115 kV transformer overload (ckt 2) Existing PJM Supplemental Upgrade S1643 - Replace the existing Roxbury 100 MVA 138/115 kV transformer with a 224 MVA unit. Convert Roxbury 115 kV substation into a four (4) breaker ring bus. IS Date: 12/31/2019 Note: AE1-132 does not have cost responsibility for this upgrade. AE1-132 will need this upgrade in-service to be deliverable to the PJM system. If AE1-132 intends to come into service prior to completion of the upgrade, they will need an interim study.	$0
			TOTAL COST	**$0**

16 Flow Gate Details

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. Although this information is not used "as is" for cost allocation purposes, it can be used to gage other generators impact. It should be noted the generator contributions presented in the appendices sections are full contributions, whereas in the body of the report, those contributions take into consideration the commercial probability of each project.

16.1 Index 1

ID	FROM BUS#	FROM BUS	FROM BUS AREA	TO BUS#	TO BUS	TO BUS AREA	CKT ID	CONT NAME	Type	Rating MVA	PRE PROJECT LOADING %	POST PROJECT LOADING %	AC|DC	MW IMPACT
403997	200532	26ROXBURY	PENELEC	200520	26ROXBURY	PENELEC	2	ME_P4-500-002H	breaker	150.0	114.38	121.0	AC	10.23

Bus #	Bus	MW Impact
235723	01GUILF1	0.96
235724	01GUILF2	0.96
237329	01CHBRG_I12	0.89
905554	W4-102 E	0.64
918731	AA1-092 C	0.52
918732	AA1-092 E	0.26
918761	AA1-095 C	0.36
918762	AA1-095 E	0.18
923871	AB2-027 C	0.17
923872	AB2-027 E	0.29
924482	AB2-097 E	0.61
930781	AB1-123 C O1	0.38
930782	AB1-123 E O1	0.62
930821	AB1-127 C	1.01
930822	AB1-127 E	1.66
930831	AB1-128 C	1.01
930832	AB1-128 E	1.66
933251	AC2-136 C	0.32
933252	AC2-136 E	0.36
933974	AD1-020 EBAT	1.13
934362	AD1-060 E	0.85
934371	AD1-061 C	0.85
934372	AD1-061 E	1.39
936061	AD2-009 C	5.79
936062	AD2-009 E	2.64
936471	AD2-062 C O1	20.79
936472	AD2-062 E O1	10.41
936871	AD2-110	1.85
938751	AE1-101 C	13.53
938752	AE1-101 E	6.67
939031	AE1-132 C O1	6.14
939032	AE1-132 E O1	4.09
939591	AE1-188 C	1.55
939592	AE1-188 E	0.91
CARR	CARR	0.45
CBM-S1	CBM-S1	1.74
CBM-S2	CBM-S2	1.07
CBM-W1	CBM-W1	2.66
CBM-W2	CBM-W2	12.29
CIN	CIN	1.19
CPLE	CPLE	0.46

Bus #	Bus	MW Impact
G-007	G-007	1.26
IPL	IPL	0.76
LGEE	LGEE	0.35
MEC	MEC	2.28
MECS	MECS	1.42
O-066	O-066	8.27
RENSSELAER	RENSSELAER	0.35
WEC	WEC	0.32

Affected Systems

17 Affected Systems

17.1 LG&E

None.

17.2 MISO

None.

17.3 TVA

None.

17.4 Duke Energy Progress

None.

17.5 NYISO

None.

18 Contingency Definitions

Contingency Name	Contingency Definition
Base Case	
AP-P1-2-WP-138-109	CONTINGENCY 'AP-P1-2-WP-138-109' /* GUILFORD - REID 138KV DISCONNECT BRANCH FROM BUS 235189 TO BUS 235136 CKT 1 /* 01GUILFD 138 01ANTRIM 138 DISCONNECT BRANCH FROM BUS 235136 TO BUS 235503 CKT 1 /* 01ANTRIM 138 01REID 138 REMOVE LOAD 1 FROM BUS 235136 /* 01ANTRIM 138 END
ME_P4-500-002H	CONTINGENCY 'ME_P4-500-002H' /* HUNTERSTOWN 500 KV STUCK CB - CBB11392 DISCONNECT BRANCH FROM BUS 200026 TO BUS 200004 CKT 1 /* HUNTERTN 500 CNASTONE 500 DISCONNECT BRANCH FROM BUS 200026 TO BUS 204501 CKT 1 /* HUNTERTN 500 27HUNTRSTN 230 END

Short Circuit

19 Short Circuit

The following Breakers are overduty:

None

Stability

20 Stability Analysis

20.1 Executive Summary

Generator Interconnection Request AE1-132 is for an 85 MW Maximum Facility Output (MFO) Solar Energy facility. AE1-132 consists of 30 x 2.865 MW Power Electronics HEM FS3350M inverters with a Point of Interconnection (POI) directly connecting to the McConnellsburg 138 kV substation in Fulton County, Pennsylvania, in the First Energy (FE) transmission system.

The power flow scenario for the analysis was based on the RTEP 2022 summer peak case, modified to include applicable queue projects. AE1-089 has been dispatched online at maximum facility output, with approximately unity power factor at the high-side of the station transformer.

AE1-132 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. For this study, 92 contingencies were simulated, each with a 20 second simulation time period. Studied faults included:

- Steady-state operation (20 second simulation)
- Three-phase faults with normal clearing time
- Single-phase bus faults with normal clearing time
- Single-phase faults with a stuck breaker
- Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at remote line end because of primary communications/relaying failure
- Three-phase faults with loss of multiple circuits caused by a common tower contingency

The 61 fault contingencies tested on the 2022 summer peak case met the recovery criteria:

- The AE1-132 generators were able to ride through the faults except for faults where protective actions trip one or more generator(s).
- All generators maintained synchronism and any post-contingency oscillations are positively damped with a damping margin of at least 3%.

- All bus voltages recover to 0.7 p.u. within 2.5 seconds and the final voltage is within the range of 0.92 p.u. to 1.05 p.u. for buses other than 500 kV . The final voltages for 500 kV buses should be within 1.02 p.u. to 1.08 p.u.
- No transmission element trips, other than those either directly connected or designated to trip as a consequence of the fault.

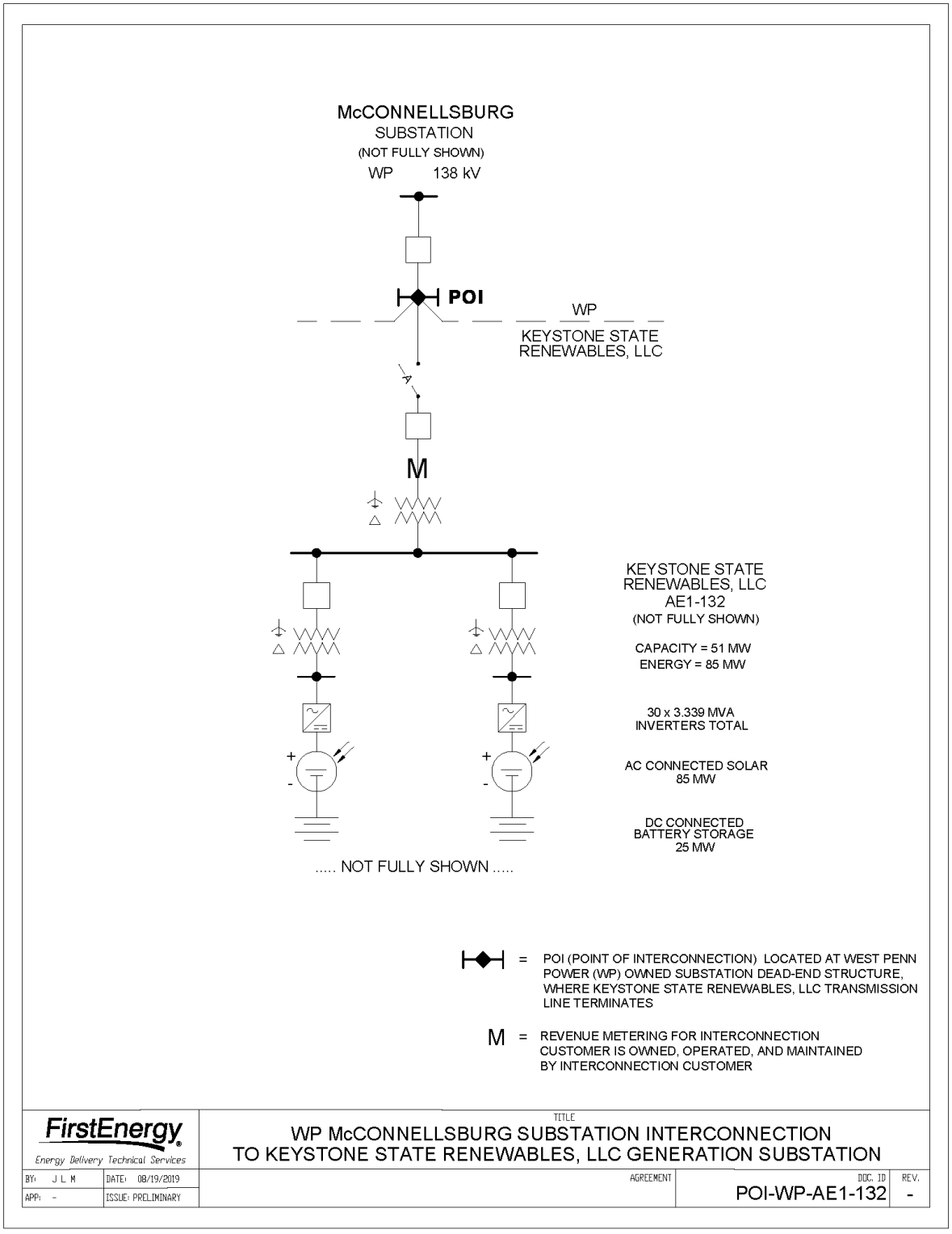
The queue project, AE1-132, met both the 0.95 leading and 0.95 lagging power factor requirement.

Light Load

21 Light Load Analysis

No impacts.

22 Attachment 1: One Line



23 Attachment 2: Site Plan