Revised
Generation Interconnection
System Impact Study Report

For

PJM Generation Interconnection Request
Queue Position AD2-062

"Roxbury-Greene 138 kV"

October 2021

June 2022

Introduction

This System Impact Study has been prepared in accordance with the PJM Open Access Transmission Tariff, 205, as well as the System Impact Study Agreement between Beaver Creek Solar, LLC, the Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Mid-Atlantic Interstate Transmission (MAIT).

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

Revisions since December 2019 System Impact Study

The AD2-062 System Impact Study has been revised to reflect the results from a recent retool analysis. No other changes were made. Updates to the physical interconnection scope and cost will be reflected in the Facilities Study Report.

General

Beaver Creek Solar, LLC, the Interconnection Customer (IC), has proposed a solar generating facility located in Franklin County, Pennsylvania. The installed facilities will have a total capability of 80.3 MW with 53.4 MW of this output being recognized by PJM as capacity.

Queue Number	**AD2-062**
Project Name	Roxbury-Greene 138 KV
Interconnection Customer	Beaver Creek Solar, LLC
State	Pennsylvania
County	Franklin
Transmission Owner	MAIT (Penelec)
MFO	80.3
MWE	80.3
MWC	53.4
Fuel	Solar
Basecase Study Year	2021

The proposed in-service date for the AD2-062 project is June 1, 2020. **This study does not imply a Mid-Atlantic Interstate Transmission (MAIT) commitment to this in-service date.**

Point of Interconnection (POI)

AD2-062 will interconnect with the MAIT transmission system through a new 138 kV interconnection switchyard along the Grand Point-Roxbury 138 kV line, between Roxbury and Greene substations. See One Line diagram in Attachment 1. The physical POI will be where the customer's generator lead line terminates onto the deadend structure within the new interconnection switchyard.

Cost Summary

The AD2-062 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$596,200
Direct Connection Network Upgrades	$5,472,900
Non-Direct Connection Network Upgrades	$782,700
Allocation for New System Upgrades	$0[1]
Contribution for Previously Identified Upgrades	$0[1]
Total Costs	**$6,851,800**

[1] Though the customer does not have cost responsibility for any network upgrades, they may need the RTEP baseline projects below to be in-service in order to be deliverable to the PJM system. If Queue Project AD2-062 desires to come into service prior to the completion of these upgrades, they will need an interim deliverability study. (b2743.6, ,2743.6.1, b2743.7, b2743.8, b2970.1, b2970.2, b2970.3, b2970.4, b2970.5)

The transmission and substation costs given above exclude the Contribution in Aid of Construction ("CIAC") Federal Income Tax Gross up charge. If at a future date Federal CIAC taxes are deemed necessary by the IRS for this project, MAIT shall be reimbursed by the Interconnection Customer for such taxes. MAIT estimates this tax, if needed, would be approximately $1,393,100.

The required Attachment Facilities, Direct Connection and Non-Direct Connection work for the interconnection of the AD2-062 generation project to the MAIT System is detailed in the following sections. The associated one-line with the generation project is shown in Attachment 1.

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 a future study phase. Further note that the cost estimate data contained in this document should be considered high level estimates since it was produced without a detailed engineering review. 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 systems.

Transmission Owner Scope of Work

The interconnection of the project at the Primary POI will be accomplished by constructing a new 138 kV three (3) breaker ring bus and looping the Grand Point – Roxbury 138 kV line into the new station. The new substation will be located approximately 2.25 miles from Roxbury substation. The IC will be responsible for acquiring all easements, properties, and permits that may be required to construct both the new interconnection switching station and the associated attachment facilities. The IC will also be responsible for the rough grade of the property and an access road to the proposed three breaker ring bus site. The project will also require non-direct connection upgrades at Roxbury and Grand Point substations.

Attachment Facilities

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

Description	Total Cost
AD2-062 New Line Terminal Equipment - Install radial equipment from ring bus terminal to the point of interconnection.	$408,000
Fiber- ADSS fiber installation between AD2-062 interconnection substation and Roxbury Substation	$185,600
Metering – FE engineering oversight of specification and design of new customer owned revenue metering.	$2,600
Total Attachment Facility Costs	**$596,200**

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
AD2-062 Interconnection Switchyard - Design, furnish and construct a new three (3) breaker 138 kV ring bus interconnection switchyard.	$3,902,800
Project Management, Commissioning, Environmental, Forestry, and Real Estate	1,309,100
SCADA - Install SCADA and associated equipment at AD2-062 interconnection switchyard.	229,300
Review drawings and provide nameplates at AD2-062 generation site.	31,700
Total Direct Connection Facility Costs	**$5,472,900**

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
Loop the Grand Point-Roxbury 138 kV line into the new AD2-062 substation.	$565,800
Roxbury Substation - Install anti-islanding scheme at Roxbury Substation	$93,200
Greene Substation - Modify drawings and nameplates for new line name at Greene Substation.	$87,000
Letterkenny Substation - Modify drawings and nameplates for new line name at Letterkenny Substation	$36,700
Total Non-Direct Connection Facility Costs	**$782,700**

Schedule

Based on the scope of work for the Attachment Facilities and the Direct and Non-Direct Connection facilities, it is expected to take a minimum of **14 months** after the signing of an Interconnection Construction Service Agreement to complete the installation. This includes the requirement for the IC to make a preliminary payment that compensates FE for the Non-Direct Connection work and a portion of the Attachment Facility/Direct Connection work. This assumes 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 network upgrades, and that PJM will allow all transmission system outages when requested.

This project does require network upgrades which are currently covered by a number of RTEP baseline projects. The projected in-service dates for these baseline projects can be found in the System Reinforcements section of the Network Impacts below.

Transmission Owner Analysis

Power Flow Analysis

PJM performed a power flow analysis of the transmission system using a 2021 summer peak load flow model and the results were verified by FE. Additionally, FE performed an analysis of its underlying transmission <100 kV system. The AD2-062 project did not contribute to any overloads on the FE transmission system <100 kV.

At the Primary POI, the AD2-062 project does cause and contribute to overloads on the FE transmission system as shown in the Network Impact section of this report. There are currently baseline RTEP projects which will alleviate these overloads as identified in the System Reinforcements section below.

Short Circuit Analysis

PJM performed a short circuit analysis and the results were verified by FE. The connection of the AD2-062 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.

Stability Analysis

A dynamic stability analysis was completed by PJM and the results were reviewed by FE. The results of the stability analysis are in the Network Impacts section of this report. Also see Attachment 4.

Interconnection Customer Requirements

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.

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 AD2-062 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 AD2-062 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.

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.

PJM's reactive power assessment indicates that the AD2-062 project will meet its requirements. See Attachment 5 for a summary of the analysis.

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 Section 8 of Attachment O.

MAIT 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

Network Impacts

The Queue Project AD2-062 was evaluated as a 80.3 MW (Capacity 53.5 MW) injection into Roxbury-Greene 138kV substation in the PenElec area. Project AD2-062 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD2-062 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2021

Contingencies

None

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

Short Circuit

(Summary of impacted circuit breakers)

None

Affected System Analysis & Mitigation

NYISO Impacts:

None

Delivery of Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed, which will study all overload conditions associated with the overloaded element(s) identified.

None

Light Load Analysis - 2021

Light load analysis was not required for this queue position.

System Reinforcements

Short Circuit

(Summary form of Cost allocation for breakers will be inserted here if any)

None

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

- Stability: No mitigations were found to be required. (See Attachment 4 for the Executive Summary of the Stability analysis results).

- Reactive Power Requirement: AD2-062 project is found to meet their reactive power requirements of 0.95 leading to 0.95 lagging. (See Attachment 5)

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)

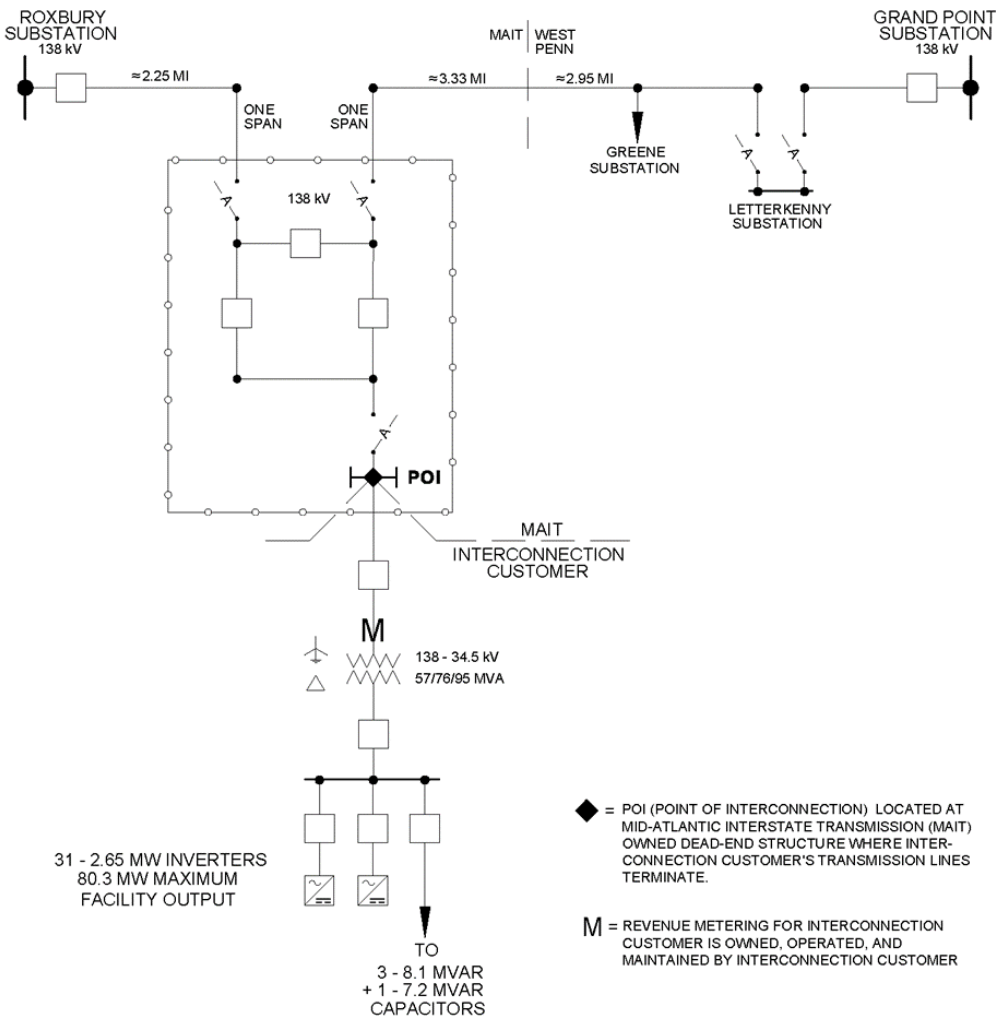
None

Contribution to Previously Identified System Reinforcements

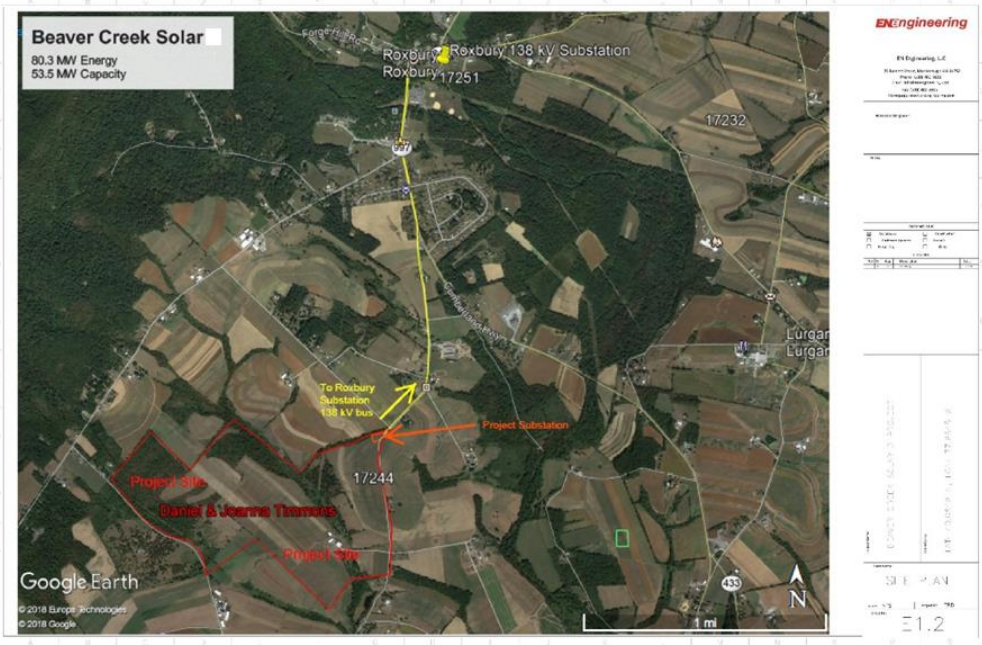
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)
(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

None

Attachment 1: One Line Diagram



Attachment 2: Project Location



Attachment 3: 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.

Attachment 4: Stability Analysis

Executive Summary

Generator Interconnection Request AD2-062 is for an 80.3 MW Maximum Facility Output (MFO) solar generating facility consisting of 31 x 2.65 MW TMEIC PVH-L2700 Solar Inverters with a Point of Interconnection (POI) tapping the Roxbury to Greene 138 kV line with a new interconnection switching station in Franklin County, Pennsylvania, in the First Energy (FE-PENELEC) transmission system.

The power flow scenario for the analysis was based on the RTEP 2021 summer peak load case, modified to include applicable queue projects. AD2-062 has been dispatched online at maximum facility output, with approximately unity power factor at the high-side of the station transformer.

AD2-062 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. For this study, 53 contingencies were simulated, each with a 10 second simulation time period. Studied faults included:

- Steady-state operation (20 second simulation)
- Three-phase faults with normal clearing time
- Single-phase faults with a stuck breaker
- Single-phase faults with loss of multiple-circuit tower

The 53 fault contingencies tested on the 2021 summer peak load case met the recovery criteria:

- The AD2-062 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.

Attachment 5: Reactive Power Assessment

A power factor assessment was performed for the AD2-062 project evaluating if the plant meets PJM's power factor requirement for a non-synchronous generator. PJM requires a non-synchronous generator to provide 0.95 lagging power factor and 0.95 leading power factor measured at the high side of the station transformer. The reactive capability curve shown in Figure 2, provided by TMEIC for a PVH-L2700GR Solar Inverter, was used to determine the reactive power for the plant. Note the capacitor bank was off-line when determining the reactive power losses for the project but the 31.5 Mvar compensation was considered when determining the total reactive power available at the high side of the station transformer. Table 2 summarizes the results for the power factor assessment for the AD2-062 queue project.

The AD2-062 plant met both the 0.95 leading and 0.95 lagging power factor requirement.

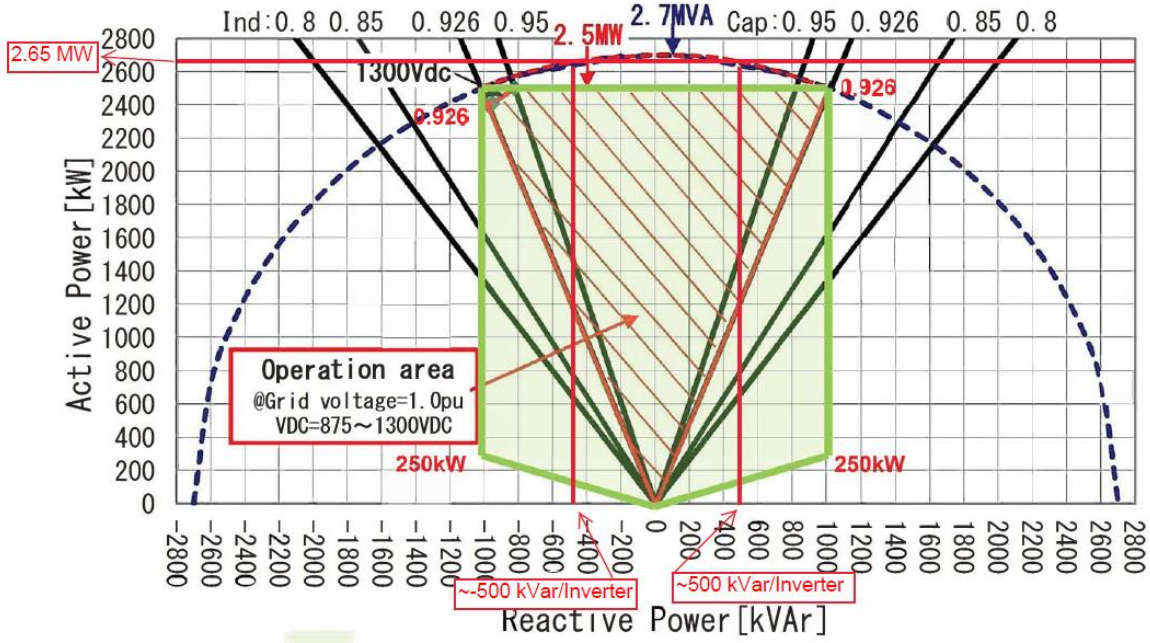


Figure 2: Reactive capability curve for the AD2-062 queue project

with a TMEIC PVH-L2700GR Solar Inverter.

Table 2: Power Factor Assessment for the AD2-062 Queue Project

Generator	MFO (MW)	Required Power Factor Range		Maximum Lagging (Mvar)	Minimum Leading (Mvar)
		Lagging	Leading		
AD2-062	82.15	0.95	0.95		
Total Reactive Power Required				27.00	-27.00
Reactive Power from Generator				**Qmax**	**Qmin**
				15.50	-15.50
Customer Planned Compensation				31.5	-31.5
Reactive Power Losses				-15.85	-15.85
Total Available Reactive Power at High Side of Main Transformer				31.15	-62.85
Deficiency in Reactive Power				Meet	Meet

The Beaver Creek Solar, LLC facility was found to meet their reactive power requirements.