Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD1-152

Clover-Sedge Hill 230kV 48 MW Capacity / 80 MW Energy

Revision 4 / May 2022

Revision 3 / November 2021

Revision 2 / November 2021

Revision 1 / October 2021

March 2019

Introduction

This System Impact Study (SIS) has been prepared in accordance with the PJM Open Access Transmission Tariff, Section 205, as well as the System Impact Study Agreement between Piney Creek Solar, LLC, the Interconnection Customer (IC) and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Virginia Electric and Power Company (VEPCO).

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 IC. As a requirement for interconnection, the IC 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 IC 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 IC 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.

Revision 1 (October 2021) Summary

This revision is being issued to incorporate results of a re-tool performed in October of 2021.

Revision 2 (November 2021) Summary

This revision is being issued to correct results of a re-tool provided in the October 2021 revision. This newest revision shows the IC is responsible for the Danville – East Danville 138 kV circuit upgrade (n6124).

Revision 3 (November 2021) Summary

This revision is being issued to correct the required work for the Danville – East Danville 138 kV circuit to include upgrades n7754.1 and n7754.2.

Revision 4 (May 2022) Summary

This revision is being issued to incorporate results of a re-tool driven by the withdrawal of AD1-023.

General

The IC has proposed a solar generating facility located in Halifax County, Virginia. The installed AD1-152 facilities will have a total capability of 80 MW with 48 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is December 31, 2020. **This study does not imply an ITO commitment to this in-service date.**

Point of Interconnection

AD1-152 will interconnect with the ITO transmission system via a new three breaker ring bus switching station that connects the Clover- Sedge Hill (formerly Halifax) 230kV line.

Cost Summary

The AD1-152 interconnection request will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$ 1,800,000
Direct Connection Network Upgrades	$ 6,300,000
Non Direct Connection Network Upgrades	$ 1,000,000
Allocation for New System Upgrades	$ 8,300,000
Contribution for Previously Identified Upgrades	$ 0
Total Costs	**$ 17,400,000**

System Reinforcements

Network Upgrade Number	Violation #	Overloaded Facility	Upgrade Description	Upgrade Cost	Allocated Cost
n6124	#1	05EDAN 1-05DANVL2 138 kV line	**AEP** **Description : Project Id : n6124** **PJM Network Upgrade n6124.** Increasing the Danville - East Danville 138 kV circuit summer rating to 337/482 MVA will still require us to rebuild the line. The network project has a projected in-service date of 09/01/2023. **Type : FAC** **Total Cost : $7,500,000** **Ratings : 337.0/482.0**	$7,500,000	$7,500,000
n7754.1			**Project ID: AEPA0021g** Replace 5 Sub cond 2000 AAC 91 Str at Danville2 138kV station. Increase summer rating to 337/482. Time Estimate: 12-18 months	$500,000	$500,000
n7754.2			**Project ID: AEPA0021h** Replace 3 Sub cond 2000 AAC 91 Str at East Danville 138kV station. Increase summer rating to 337/482. Time Estimate: 12-18 months	$300,000	$300,000
				Total New Network Upgrades	**$8,300,000**

Attachment Facilities

Generation Substation: Install metering and associated protection equipment. Estimated Cost $600,000.

Transmission: Construct approximately one span of 230 kV Attachment line between the generation substation and a new AD1-152 Switching Station. The estimated cost for this work is $1,200,000.

The estimated total cost of the Attachment Facilities is $1,800,000. It is estimated to take 18-24 months to complete this work upon execution of an Interconnection Construction Service Agreement (ICSA). These preliminary cost estimates are based on typical engineering costs. A more detailed engineering cost estimates are normally done when the IC provides an exact site plan location for the generation substation during the Facility Study phase.

Direct Network Upgrades:

Substation: Establish the new 230 kV AD1-152 Switching Substation (interconnection substation). The estimated cost of this work scope is $6,300,000. It is estimated to take 24-36 months to complete this work upon execution of an Interconnection Construction Service Agreement.

Non-Direct Network Upgrades:

Transmission: Install transmission structure in-line with transmission line to allow the proposed interconnection switching station to be interconnected with the transmission system. Estimated cost is $1,000,000 dollars and is estimated to take 24-30 months to complete.

Remote Terminal Work: During the Facilities Study, ITO's System Protection Engineering Department will review transmission line protection as well as anti-islanding required to accommodate the new generation and interconnection substation. System Protection Engineering will determine the minimal acceptable protection requirements to reliably interconnect the proposed generating facility with the transmission system. The review is based on maintaining system reliability by reviewing ITO's protection requirements with the known transmission system configuration which includes generating facilities in the area. This review may determine that transmission line protection and communication upgrades are required at remote substations.

Incremental Capacity Transfer Rights

The network upgrades outlined in this report do not increase the CETL in the 2021/22 BRA case.

Interconnection Customer Requirements

ITO's Facility Connection Requirements as posted on PJM's website
http://www.pjm.com/~/media/planning/plan-standards/private-dominion/facility-connection-requirements1.ashx

Voltage Ride Through Requirements - The Customer Facility shall be designed to remain in service (not trip) for voltages and times as specified for the Eastern Interconnection in Attachment 1 of NERC Reliability Standard PRC-024-1, and successor Reliability Standards, for

both high and low voltage conditions, irrespective of generator size, subject to the permissive trip exceptions established in PRC-024-1 (and successor Reliability Standards).

Frequency Ride Through Requirements - The Customer Facility shall be designed to remain in service (not trip) for frequencies and times as specified in Attachment 2 of NERC Reliability Standard PRC-024-1, and successor Reliability Standards, for both high and low frequency condition, irrespective of generator size, subject to the permissive trip exceptions established in PRC-024-1 (and successor Reliability Standards).

Reactive Power - The Generation Interconnection Customer shall design its non-synchronous Customer Facility with the ability to maintain a power factor of at least 0.95 leading to 0.95 lagging measured at the generator's terminals.

Revenue Metering and SCADA Requirements

PJM Requirements

The IC 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.

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

Network Impacts

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
'AEP_P4_#11112_05J.FERR 765_A1	CONTINGENCY 'AEP_P4_#11112_05J.FERR 765_A1' OPEN BRANCH FROM BUS 242511 TO BUS 242514 CKT 1 / 242511 05BROADF 765 242514 05J.FERR 765 1 OPEN BRANCH FROM BUS 242514 TO BUS 242520 CKT 1 / 242514 05J.FERR 765 242520 05J.FERR 500 1 OPEN BRANCH FROM BUS 242520 TO BUS 306719 CKT 1 / 242520 05J.FERR 500 306719 8ANTIOCH 500 1 OPEN BRANCH FROM BUS 242566 TO BUS 242567 CKT ZB / 242566 05BROADF 138 242567 05BROADX 138 ZB END
DVP_P1-2: LN 556	CONTINGENCY 'DVP_P1-2: LN 556' OPEN BRANCH FROM BUS 314686 TO BUS 314906 CKT 1 /* 6CLOVER 230.00 - 8CLOVER 500.00 OPEN BRANCH FROM BUS 314686 TO BUS 314906 CKT 2 /* 6CLOVER 230.00 - 8CLOVER 500.00 OPEN BRANCH FROM BUS 314686 TO BUS 314906 CKT 3 /* 6CLOVER 230.00 - 8CLOVER 500.00 OPEN BRANCH FROM BUS 314906 TO BUS 314936 CKT 1 /* 8CLOVER 500.00 - 8RAWLINGS 500.00 OPEN BUS 314906 /* ISLAND END

Summer Peak Analysis – 2021

The Queue Project AD1-152 was evaluated as an 80.0 MW (Capacity 48.0 MW) injection tapping into Clover-SledgeHill 230kV line in the VAP area. Project AD1-152 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD1-152 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).

	Contingency		Affected		Bus			Power	Loading %		Rating		MW	
#	Type	Name	Area	Facility Description	From	To	Cir.	Flow	Initial	Final	Type	MVA	Contribution	Ref
1	LFFB	'AEP_P4_#11112_05J.FERR 765_A1	AEP - AEP	05EDAN 1-05DANVL2 138 kV line	242631	242620	1	AC	99.11	100.21	ER	415	5.4	1

Short Circuit

(Summary of impacted circuit breakers)

New circuit breakers found to be over-duty:

None.

Contributions to previously identified circuit breakers found to be over-duty:

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)

The reactive power capability of AD1-152 meets the 0.95 leading Power Factor requirement whereas the 0.95 lagging Power Factor requirement is not met at the high side of the main transformer as shown in the table below. An additional 5.6 MVAr is required to meet the lagging power factor requirement based on the data provided.

AD1-152 Reactive Power Capability Assessment

Generator	MFO (MW)	Required Power Factor Range		Maximum Lagging (MVAr)	Minimum Leading (MVAr)
		Lagging	Leading		
AD1-152	80	0.95	0.95		
Total Reactive Power Required				26.3	-26.3
Reactive Power from Generators				**Qmax**	**Qmin**
				32.6	-32.6
Customer Planned Compensation				0	0
Reactive Power Losses				-11.9	-11.9
Total Available Reactive Power at high side of Main Transformer				20.7	-44.5
Deficiency in Reactive Power				5.6	Meet

New System Reinforcements

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

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 is calculated and reported for in 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 IC 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 interconnection request by addressing 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.

	Contingency		Affected		Bus			Power	Loading %		Rating		MW
#	Type	Name	Area	Facility Description	From	To	Circuit	Flow	Initial	Final	Type	MVA	Contribution
1	N-1	DVP_P1-2: LN 556	DVP - CPLE	AC1-221 TAP-6PERSON230 T 230 kV line	927250	304070	1	AC	99.72	105.61	ER	718	44.52

Light Load Analysis in 2021

Not required.

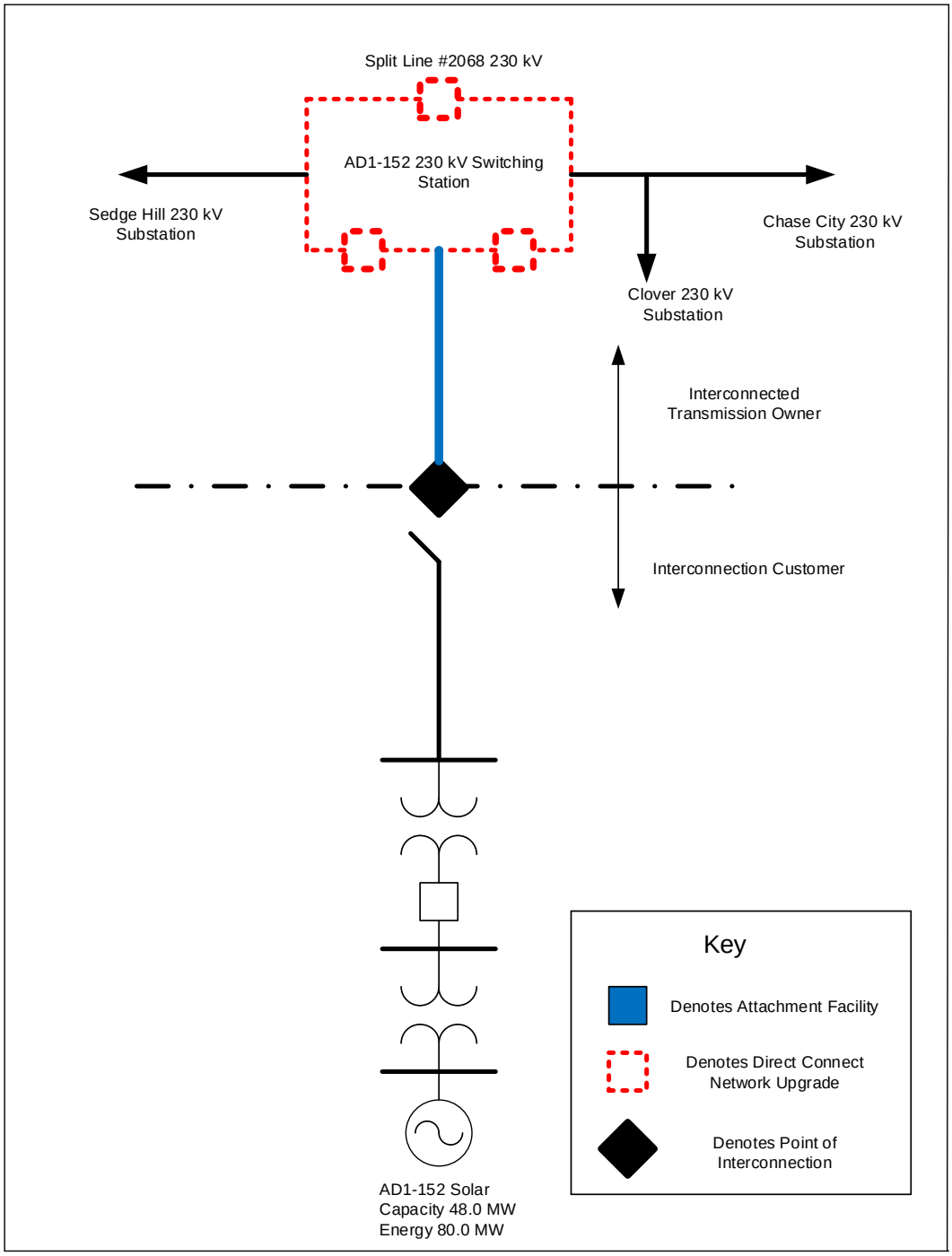
Affected System Analysis & Mitigation

Duke Energy:

None.

Attachment 1.

System Configuration



Appendices

Appendix 1

(AEP - AEP) The 05EDAN 1-05DANVL2 138 kV line (from bus 242631 to bus 242620 ckt 1) loads from 99.11% to 100.21% (AC power flow) of its emergency rating (415 MVA) for the line fault with failed breaker contingency outage of 'AEP_P4_#11112_05J.FERR 765_A1'. This project contributes approximately 5.4 MW to the thermal violation.

CONTINGENCY 'AEP_P4_#11112_05J.FERR 765_A1'
OPEN BRANCH FROM BUS 242511 TO BUS 242514 CKT 1 / 242511 05BROADF 765 242514 05J.FERR 765 1
OPEN BRANCH FROM BUS 242514 TO BUS 242520 CKT 1 / 242514 05J.FERR 765 242520 05J.FERR 500 1
OPEN BRANCH FROM BUS 242520 TO BUS 306719 CKT 1 / 242520 05J.FERR 500 306719 8ANTIOCH 500 1
OPEN BRANCH FROM BUS 242566 TO BUS 242567 CKT ZB / 242566 05BROADF 138 242567 05BROADX 138 ZB
END

Bus Number	*Bus Name*	*Full Contribution*
244012	*05PINNACLE*	*-2.13*
315131	*1EDGECMA*	*3.58*
315132	*1EDGECMB*	*3.58*
314557	*3BETHELC*	*0.34*
314554	*3BTLEBRO*	*0.36*
314572	*3EMPORIA*	*0.13*
314578	*3HORNRTN*	*1.17*
314603	*3SCOT NK*	*1.2*
314620	*6CASHIE*	*0.26*
314574	*6EVERETS*	*0.95*
932631	*AC2-084 C*	*2.49*
932632	*AC2-084 E*	*1.23*
932761	*AC2-100 C*	*3.59*

932762	*AC2-100 E*	*1.75*
932991	*AC2-123 C*	*-2.41*
933941	*AD1-017 C*	*0.79*
933942	*AD1-017 E*	*1.28*
933991	*AD1-022 C*	*2.63*
933992	*AD1-022 E*	*1.43*
934311	*AD1-055 C*	*1.01*
934312	*AD1-055 E*	*0.26*
934331	*AD1-057 C O1*	*3.99*
934332	*AD1-057 E O1*	*2.13*
934341	*AD1-058 C*	*3.91*
934342	*AD1-058 E*	*0.99*
934521	*AD1-076 C O1*	*16.05*
934522	*AD1-076 E O1*	*8.17*
934611	*AD1-087 C O1*	*2.95*
934612	*AD1-087 E O1*	*1.38*
934621	*AD1-088 C*	*3.6*
934622	*AD1-088 E*	*1.69*
934991	*AD1-131 C*	*1.28*
934992	*AD1-131 E*	*0.85*
935171	*AD1-152 C O1*	*3.24*
935172	*AD1-152 E O1*	*2.16*
LTF	*AMIL*	*0.07*
LTF	*BLUEG*	*1.48*
LTF	*CANNELTON*	*0.16*
LTF	*CARR*	*0.08*

LTF	*CBM-S1*	*2.63*
LTF	*CBM-S2*	*17.19*
LTF	*CBM-W2*	*9.74*
LTF	*CLIFTY*	*8.91*
LTF	*CPLE*	*5.54*
LTF	*EDWARDS*	*0.29*
LTF	*ELMERSMITH*	*0.38*
LTF	*G-007A*	*0.49*
LTF	*GIBSON*	*0.39*
LTF	*NEWTON*	*0.51*
LTF	*O-066A*	*0.22*
LTF	*RENSSELAER*	*0.07*
LTF	*TATANKA*	*0.13*
LTF	*TILTON*	*0.41*
LTF	*TRIMBLE*	*0.29*
900672	*V4-068 E*	*0.09*
LTF	*VFT*	*1.3*
917332	*Z2-043 E*	*0.34*
917342	*Z2-044 E*	*0.25*
917512	*Z2-088 E OP1*	*1.62*
918492	*AA1-063AE OP*	*1.32*
918512	*AA1-065 E OP*	*1.41*
918532	*AA1-067 E*	*0.28*
918562	*AA1-072 E*	*0.06*
919692	*AA2-053 E*	*1.28*
919701	*AA2-057 C*	*2.94*

919702	*AA2-057 E*	*1.47*
LTF	*AA2-074*	*3.77*
920042	*AA2-088 E*	*3.14*
920592	*AA2-165 E*	*0.19*
920672	*AA2-174 E*	*0.15*
930402	*AB1-081 E*	*1.71*
930861	*AB1-132 C*	*4.76*
930862	*AB1-132 E*	*2.04*
931231	*AB1-173 C*	*0.74*
931232	*AB1-173 E*	*0.35*
931241	*AB1-173AC*	*0.74*
931242	*AB1-173AE*	*0.35*
923911	*AB2-031 C O1*	*0.74*
923912	*AB2-031 E O1*	*0.36*
923991	*AB2-040 C O1*	*2.42*
923992	*AB2-040 E O1*	*1.98*
924021	*AB2-043 C O1*	*1.16*
924022	*AB2-043 E O1*	*1.91*
924151	*AB2-059 C O1*	*4.71*
924152	*AB2-059 E O1*	*2.43*
924161	*AB2-060 C O1*	*3.33*
924162	*AB2-060 E O1*	*1.57*
924301	*AB2-077 C O1*	*0.75*
924302	*AB2-077 E O1*	*0.5*
924311	*AB2-078 C O1*	*0.75*
924312	*AB2-078 E O1*	*0.5*

924321	*AB2-079 C O1*	*0.75*
924322	*AB2-079 E O1*	*0.5*
924501	*AB2-099 C*	*0.19*
924502	*AB2-099 E*	*0.08*
924511	*AB2-100 C*	*3.36*
924512	*AB2-100 E*	*1.65*
925121	*AB2-169 C*	*2.19*
925122	*AB2-169 E*	*1.96*
925171	*AB2-174 C O1*	*2.29*
925172	*AB2-174 E O1*	*2.07*
925591	*AC1-034 C*	*3.05*
925592	*AC1-034 E*	*2.3*
925612	*AC1-036 E*	*0.52*
925781	*AC1-054 C*	*2.93*
925782	*AC1-054 E*	*1.35*
926051	*AC1-083 C*	*3.93*
926052	*AC1-083 E*	*6.41*
926071	*AC1-086 C*	*7.02*
926072	*AC1-086 E*	*3.19*
926201	*AC1-098 C*	*2.33*
926202	*AC1-098 E*	*1.39*
926211	*AC1-099 C*	*0.78*
926212	*AC1-099 E*	*0.46*
926271	*AC1-105 C*	*2.29*
926272	*AC1-105 E*	*1.14*
927021	*AC1-189 C*	*3.54*

927022	*AC1-189 E*	*1.76*
927141	*AC1-208 C*	*3.44*
927142	*AC1-208 E*	*1.53*
927251	*AC1-221 C*	*1.56*
927252	*AC1-221 E*	*1.56*
927261	*AC1-222 C*	*1.46*
927262	*AC1-222 E*	*1.39*