Generation Interconnection Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD2-107

Chavies - Bonnyman 69kV

December 2019

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.

General

Invenergy Solar Project Development LLC proposes to install PJM Project #AD2-107, a 55.0 MW (23.1 MW Capacity) solar facility in Perry County, Kentucky (see Figure 2). The primary point of interconnection is to AEP's Chavies - Bonnyman 69 kV section of Jackson – Bonnyman 69 kV circuit (see Figure 1). The secondary point of interconnection is a direct connection to AEP's Chavies 69 kV substation (see Figure 3).

The requested in service date is December 31, 2021

Point of Interconnection

Primary Point of Interconnection (Chavies - Bonnyman 69 kV)

To accommodate the interconnection on the Chavies - Bonnyman 69 kV section of the Jackson – Bonnyman 69 kV circuit, a new three (3) circuit breaker 69 kV switching station physically configured in a breaker and half bus arrangement but operated as a ring-bus will be constructed (see Figure 1). Installation of associated protection and control equipment, 69 kV line risers, SCADA, and 69 kV revenue metering will also be required. AEP reserves the right to specify the final acceptable configuration considering design practices, future expansion, and compliance requirements.

Cost Summary

This project will be responsible for the following costs:

Description	Total Cost	
Attachment Facilities	$	250,000
Direct Connection Network Upgrades	$	4,350,000
Non Direct Connection Network Upgrades	$	1,200,000
Allocation for New System Upgrades	$	0
Contribution for Previously Identified Upgrades	$	0
Total Costs	**$**	**5,800,000**

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	Estimated Cost
69 kV Revenue Metering	$250,000

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.

New Switching Station Work and Cost:

- Construct a new three (3) circuit breaker 69 kV switching station physically configured in a breaker and half bus arrangement but operated as a ring-bus (See Figure 1). Installation of associated protection and control equipment, 69 kV line risers and SCADA will also be required.
    - **Estimated Station Cost: $4,350,000**

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	Estimated Cost
Chavies - Bonnyman 69 kV T-Line Cut In	$700,000
Upgrade line protection and controls at the Bonnyman 69 kV substation.	$250,000
Upgrade line protection and controls at the Jackson 69 kV substation	$250,000
Total	**$1,200,000**

Interconnection Customer Requirements

It is understood that Invenergy Solar Project Development LLC is responsible for all costs associated with this interconnection. The costs above are reimbursable to AEP. The cost of Invenergy Solar Project Development's generating plant and the costs for the line connecting the generating plant to the Chavies - Bonnyman 69kV line are not included in this report; these are assumed to be Invenergy Solar Project Development's responsibility.

The Generation Interconnection Agreement does not in or by itself establish a requirement for American Electric Power to provide power for consumption at the developer's facilities. A separate agreement may be reached with the local utility that provides service in the area to ensure that infrastructure is in place to meet this demand and proper metering equipment is installed. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

Requirement from the PJM Open Access Transmission Tariff:

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.

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.

AEP Requirements

The Interconnection Customer will be required to comply with all AEP Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the "Requirements for Connection of New Facilities or Changes to Existing Facilities Connected to the AEP Transmission System" document located at the following link:

http://www.pjm.com/~/media/planning/plan-standards/private-aep/aep-interconnection-requirements.ashx

Network Impacts

The Queue Project AD2-107 was evaluated as a 55.0 MW (Capacity 23.1 MW) injection into a tap of the Chavies – Bonnyman 69 kV line in the AEP area. Project AD2-107 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD2-107 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis – 2021

Contingency Name	Description
AEP_P1-2_#363	CONTINGENCY 'AEP_P1-2_#363' OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1 / 243208 05JEFRSO 765 243209 05ROCKPT 765 1 END
AEP_P1-3_#8818	CONTINGENCY 'AEP_P1-3_#8818' OPEN BRANCH FROM BUS 242921 TO BUS 242924 CKT 1 / 242921 05CORNU 765 242924 05HANG R 765 1 OPEN BRANCH FROM BUS 242921 TO BUS 242934 CKT 1 / 242921 05CORNU 765 242934 05CORNU 345 1 REMOVE UNIT 1A FROM BUS 247245 / 247245 05HRKG1A 18.0 REMOVE UNIT 1B FROM BUS 247246 / 247246 05HRKG1B 18.0 REMOVE UNIT 1S FROM BUS 247247 / 247247 05HRKG1S 18.0 REMOVE UNIT 2A FROM BUS 247248 / 247248 05HRKG2A 18.0 REMOVE UNIT 2B FROM BUS 247249 / 247249 05HRKG2B 18.0 REMOVE UNIT 2S FROM BUS 247250 / 247250 05HRKG2S 18.0 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).

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)

Overload	Contingency				Bus				Loading %		Rating		MW	Flowgate
Number	Type	Name	Affected Area	Facility Description	From	To	Circuit	Power Flow	Initial	Final	Type	MVA	Contribution	Appendix
1	N-1	AEP_P1-2_#363	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	AC	195.62	195.71	ER	1370	1.29	1
2	Non	Non	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	DC	138.44	138.55	NR	1134	1.25	
3	N-1	AEP_P1-3_#8818	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	DC	115.92	116.01	ER	1370	1.25	

Steady-State Voltage Requirements

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

See Figure 4.

"PJM is not requiring a stability study because the POI requested is subtransmission but AEP did perform and complete their own stability study for this project and concluded the following: The AD2-107 Plant fails to ride-through all credible planning event contingencies consistent with NERC TPL-001-4. This may be because of the long duration fault clearing times.

A potential islanding configuration involving AD2-107 would occur for the P6 combined contingency of Jackson – Lee City 69kV circuit and AD2-107 – Bonnyman 69kV circuit outages. This scenario is noted, but was not included in the study."

Stability and Reactive Power Requirement for Low Voltage Ride Through

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

See Figure 4.

"PJM is not requiring a stability study because the POI requested is subtransmission but AEP did perform and complete their own stability study for this project and concluded the following: The AD2-107 Plant fails to ride-through all credible planning event contingencies consistent with NERC TPL-001-4. This may be because of the long duration fault clearing times.

A potential islanding configuration involving AD2-107 would occur for the P6 combined contingency of Jackson – Lee City 69kV circuit and AD2-107 – Bonnyman 69kV circuit outages. This scenario is noted, but was not included in the study."

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)

1. To resolve the Trimble – Clifty 345 kV line overloads:

Impacts identified on the Trimble – Clifty 345 kV LG&E – PJM tie line. A potential constraint was identified by PJM on the Trimble – Clifty 345 kV line (LG&E/OVEC tie line). The upgrade (LG&E) on the Trimble – Clifty 345 kV line, if determined to be a constraint by LG&E, is to reconductor the line with a high temperature conductor and upgrade necessary terminal equipment to achieve ratings of 2610/2610 MVA SN/SE. Cost estimate is $17.4M with a time estimate of 18 months. An LG&E affected system study is required to determine if the AD2-107 queue project causes any impacts on the LG&E system, including the Trimble-Clifty LG&E-OVEC tie line. Final LG&E Impacts and necessary LG&E system upgrade(s) will be determined once the LG&E affected system study is completed by LG&E.
AD2-107 will be required to sign onto a LG&E Affected System Study.

No OVEC end upgrades required on this line.

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

Overload	Contingency				Bus				Loading %		Rating		MW	Flowgate
Number	Type	Name	Affected Area	Facility Description	From	To	Circuit	Power Flow	Initial	Final	Type	MVA	Contribution	Appendix
4	N-1	AEP_P1-2_#363	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	DC	182.96	183.15	ER	1370	3.08	
5	Non	Non	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	AC	140.53	140.76	NR	1134	2.98	

Incremental Capacity Transfer Rights (ICTRs)

Will be determined at a later study phase

Affected System Analysis & Mitigation

LGEE Impacts:

Potential LG&E Impacts found. An LG&E affected system study will be required to determine LG&E impacts.

Impacts also identified on the Trimble – Clifty 345 kV LG&E – PJM tie line. A potential constraint was identified by PJM on the Trimble – Clifty 345 kV line (LG&E/OVEC tie line). The upgrade (LG&E) on the Trimble – Clifty 345 kV line, if determined to be a constraint by LG&E, is to reconductor the line with a high temperature conductor and upgrade necessary terminal equipment to achieve ratings of 2610/2610 MVA SN/SE. Cost estimate is $17.4M with a time estimate of 18 months. An LG&E affected system study is required to determine if the AD2-107 queue project causes any impacts on the LG&E system, including the Trimble-Clifty LG&E-OVEC tie line. Final LG&E Impacts and necessary LG&E system upgrade(s) will be determined once the LG&E affected system study is completed by LG&E.
AD2-107 will be required to sign onto an LG&E Affected System Study.

MISO Impacts:

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

Duke, Progress & TVA Impacts:

Potential TVA Impacts found. A TVA affected system study will be required to determine TVA impacts.

OVEC Impacts:

None

Figure 1: (Chavies - Bonnyman 69 kV) Single-Line Diagram

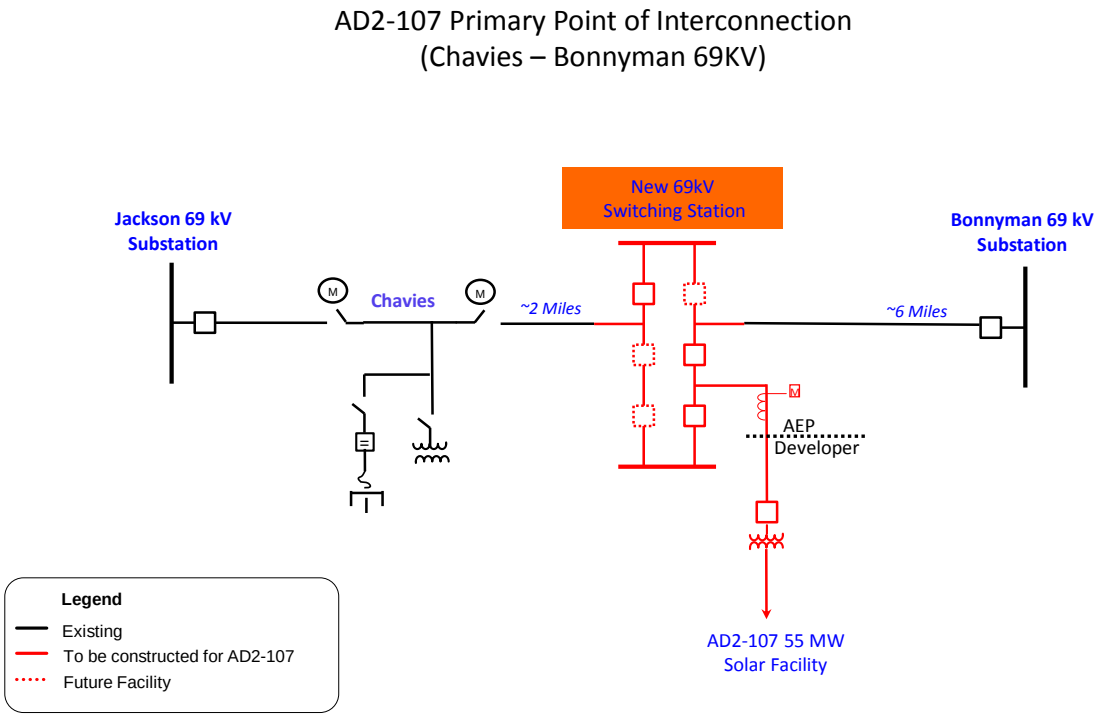

Figure 2: Primary Point of Interconnection (Chavies – Bonnyman 69 kV)

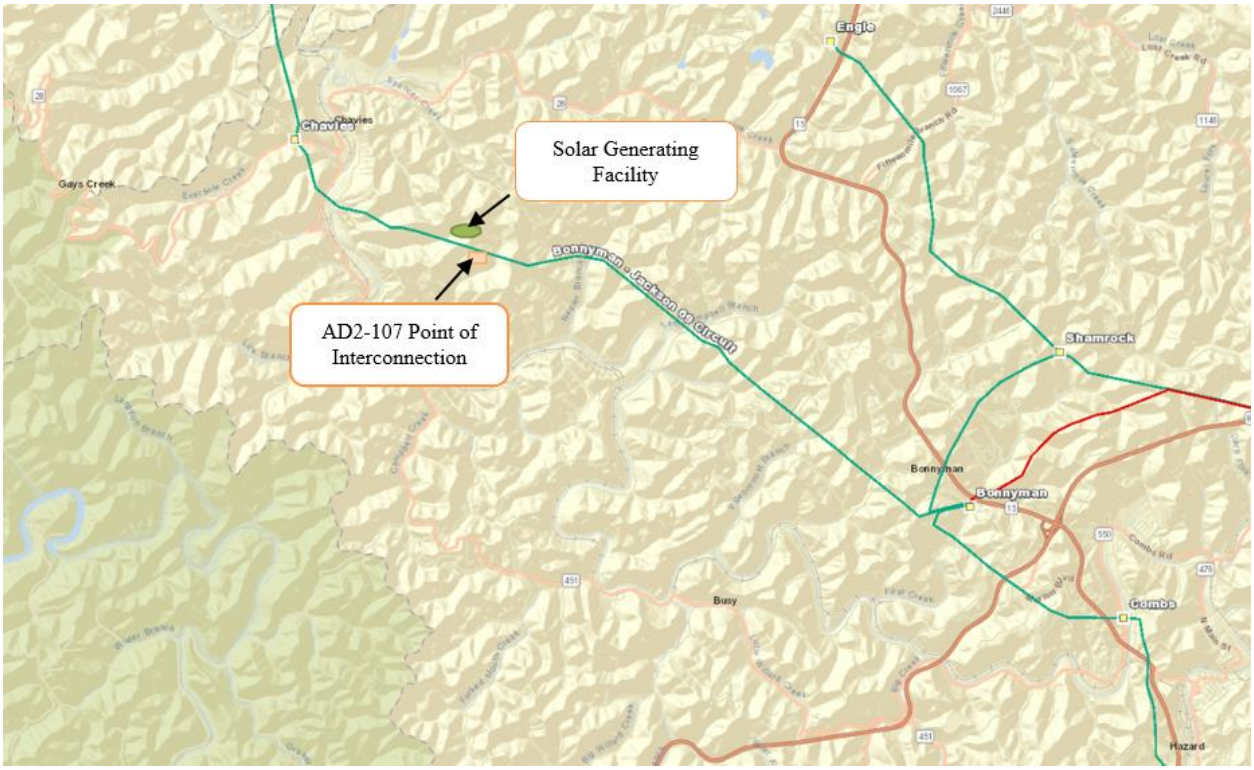

Figure 3: Appendices

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

(LGEE - OVEC) The 7TRIMBLE-06CLIFTY 345 kV line (from bus 324114 to bus 248000 ckt 1) loads from 195.62% to 195.71% (AC power flow) of its emergency rating (1370 MVA) for the single line contingency outage of 'AEP_P1-2_#363'. This project contributes approximately 1.29 MW to the thermal violation.

Bus Number	Bus Name	Full Contribution
247287	05AND G3	0.83
243442	05RKG1	40.44
243443	05RKG2	39.82
342900	1COOPER1 G	3.24
342903	1COOPER2 G	6.29
342918	1JKCT 1G	2.55
342921	1JKCT 2G	2.55
342924	1JKCT 3G	2.55
342927	1JKCT 4G	1.69
342930	1JKCT 5G	1.68
342933	1JKCT 6G	1.69
342936	1JKCT 7G	1.69
342939	1JKCT 9G	1.73
342942	1JKCT 10G	1.73

Bus Number	Bus Name	Full Contribution
LTF	CBM-W2	141.44
LTF	CIN	25.75
LTF	CLIFTY	94.98
LTF	CPLE	1.19
LTF	DEARBORN	0.5
LTF	IPL	15.71
981181	J708	40.83
981521	J759	9.26
981531	J762	29.44
981571	J783	9.26
938311	J795	3.67
938731	J800	15.73
938861	J829	12.54
938921	J842 C	3.98

342945	1LAUREL 1G	1.83
932551	AC2-075 C	1.09
933441	AC2-157 C	8.17
935011	AD1-134	8.11
935141	AD1-148	2.48
936281	AD2-036 C	3.24
936381	AD2-048 C	3.96
936571	AD2-072 C O1	11.6
936771	AD2-100 C O1	6.98
936821	AD2-105 C O1	3.3
936831	AD2-106 C O1	1.97
936841	AD2-107 C O1	1.29
LTF	CARR	0.32
LTF	CBM-S1	40.52
LTF	CBM-S2	6.91
LTF	CBM-W1	21.72
938931	J843 C	4.32
939021	J856	9.33
274650	KINCAID ;1U	6.43
274651	KINCAID ;2U	6.41
LTF	LGEE	19.02
LTF	MEC	21.89
LTF	RENSSELAER	0.25
LTF	ROWAN /* 35% REVERSE 4479078	< 0.01
LTF	WEC	1.75
900404	X3-028 C	161.22
LTF	Z1-043	8.4
930461	AB1-087	59.11
930471	AB1-088	59.11
LTF	AB2-013	5.11
925981	AC1-074 C	4.54

Figure 4: Dynamic Simulation Analysis

1. INTRODUCTION

This study was undertaken to evaluate the stability performance of PJM generation interconnection request AD2-107. The study was conducted in accordance with the NERC TPL-001-4 standard.

2. OVERVIEW OF GENERATION/TRANSMISSION FACILITIES

The maximum facility output (MFO) at the AD2-107 solar farm is 55 MW and is made up of 19 x 3.36MVA TMEIC PVH-L3360GR solar inverters. The point of interconnection (POI) is a three breaker switching station cutting into the 69kV circuit between AEP's Bonnyman and Chavies substations. All generator modeling data originated from the developer and was provided to AEP by PJM.

The current planned in-service date for AD2-107 is 12/31/2021. This study is utilizing the 2017 series MMWG light load dynamic case for the 2022 year as this is the most appropriate case available at the time of the study.

3. TESTING CRITERIA

NERC TPL-001-4 Table 1 specifies the system conditions and disturbance events for which stable operation is required. In addition, satisfactory damping of generator post-disturbance power oscillations is required.

The Table 1 testing criteria are applied in time domain simulations to evaluate the stability performance of a generation facility. For each disturbance, the resulting transmission system response is simulated and then analyzed to assess the impact of the disturbance scenario on the proposed generators and the surrounding system.

For purposes of the transient voltage criteria required by TPL-001-4 R5 and in accordance with the PJM-wide criterion, this study assumes that transient voltage dips or delayed fault recovery at the transmission station below 70 percent voltage for no more than 2.5 seconds are acceptable. Similarly, for purposes of TPL-001-4 R4.1.3, damping of post-disturbance power swings within a damping ratio of 3 percent is considered acceptable.

4. STUDY SCOPE and DATA

With reference to the above stability testing criteria, the cases to be simulated were determined and are listed in Table 1 below. These cases involve either three-phase or phase-to-ground primary cleared faults. Phase-to-ground faults were only conducted for the remote end breakers at the remote end substations to the POI.

The base case applied in this study is the 2017 series ERAG / MMWG 2022 Spring Light Load case in accordance with TPL-001-4 R2.4. All ERAG / MMWG dynamic base cases include modeling of automatic dynamic control devices relevant to the study area in accordance with TPL-001-4 R4.3.2. Updates were made to the dynamic case to include the AD2-107 models provided.

The AD2-107 Plant was dispatched at its MFO of 55 MW. No other dispatch at other generating plants were modified from the base case.

AEP stability study criteria and practice for sub-transmission (less than 100kV) generation interconnection requests assumes AEP Protection and Control recommended default study clearing times as described below. Because of the protection and control technology and infrastructure currently in place in most of AEP's sub-transmission system (where some form of pilot scheme is not present), the variability and uncertainty of the fault clearing times are too great and a conservative assessment is necessary.

Therefore, all sub-transmission fault clearing times assumed for P1, P6, and P7 type contingencies are 60 cycles. P2 contingencies studied that involved a sub-transmission non-bus tie internal circuit breaker fault assume a fault clearing time of 70 cycles. P4 contingencies studied that involved a sub-transmission non-bus tie internal circuit breaker assume a fault clearing time of 90 cycles. P5 contingencies involving relay failure to operate assume a fault clearing time of 90 cycles.

5. STUDY RESULTS

The study results for each stability simulation case are indicated in Table 1 below.

As noted in the Table 1 results, the AD2-107 generator fails to ride-through in a number of cases/ System stability was, nevertheless, maintained in all cases. There ae no other criteria violations observed.

Plots of the dynamic simulation cases involving three-phase and phase-to-ground faults are attached below.

6. CONCLUSION

The AD2-107 Plant fails to ride-through all credible planning event contingencies consistent with NERC TPL-001-4. This may be because of the long duration fault clearing times.

A potential islanding configuration involving AD2-107 would occur for the P6 combined contingency of Jackson – Lee City 69kV circuit and AD2-107 – Bonnyman 69kV circuit outages. This scenario is noted, but was not included in the study.

Table 1 – AD2-107 Stability Study Cases with Default Clearing Times

	Prior Outage *	Outaged Facility	NERC Category	Fault Type and Location	Fault Clearing Time (cycles)	Result
Case 1	None	AD2-107 - Jackson 69 kV	P1	3 Phase @ Jackson	Faulted end = 10 Remote end = 60	System Stable
Case 2	None	AD2-107 - Jackson 69 kV	P1	3 Phase @ AD2-107	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 3	None	AD2-107 - Bonnyman 69 kV	P1	3 Phase @ Bonnyman	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 4	None	AD2-107 - Bonnyman 69 kV	P1	3 Phase @ AD2-107	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 5	None	Lee City – Jackson 69 kV	P1	3 Phase @ Lee City	Faulted end = 10 Remote end = 60	System Stable

Case 6	None	Lee City – Jackson 69 kV	P1	3 Phase @ Jackson	Faulted end = 10 Remote end = 60	System Stable
Case 7	None	Lee City – Morgan 69 kV	P1	3 Phase @ Lee City	Faulted end = 10 Remote end = 60	System Stable
Case 8	None	Lee City – Morgan 69 kV	P1	3 Phase @ Morgan	Faulted end = 10 Remote end = 60	System Stable

	Prior Outage *	**Outaged Facility**	**NERC Category**	**Fault Type and Location**	**Fault Clearing Time (cycles)**	**Result**
Case 9	None	Helechawa - Sublett 69 kV	P1	3 Phase @ Sublett	Faulted end = 10 Remote end = 60	System Stable
Case 10	None	Helechawa - Sublett 69 kV	P1	3 Phase @ Helechawa	Faulted end = 10 Remote end = 60	System Stable
Case 11	None	Helechawa - Campton 69 kV	P1	3 Phase	Faulted end = 10	System Stable

				@ Campton	Remote end = 60	
Case 12	None	Helechawa - Campton 69 kV	P1	3 Phase @ Helechawa	Faulted end = 10 Remote end = 60	System Stable
Case 13	None	Lee City – Helechawa 69 kV	P1	3 Phase @ Lee City	Faulted end = 10 Remote end = 60	System Stable
Case 14	None	Lee City – Helechawa 69 kV	P1	3 Phase @ Helechawa	Faulted end = 10 Remote end = 60	System Stable
Case 15	None	Bonnyman – Hazard 69 kV #1	P1	3 Phase @ Bonnyman	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 16	None	Bonnyman – Hazard 69 kV #1	P1	3 Phase @ Hazard	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline

	Prior Outage *	Outaged Facility	NERC Category	Fault Type and Location	Fault Clearing Time (cycles)	Result
Case 17	None	Bonnyman – Hazard 69 kV #2	P1	3 Phase @ Bonnyman	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 18	None	Bonnyman – Hazard 69 kV #2	P1	3 Phase @ Hazard	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 19	None	Beaver Creek – Soft Shell 138 kV	P1	3 Phase @ Beaver Creek	5.5	System Stable
Case 20	None	Bonnyman 138/69 kV TRF	P1	3 Phase	5.5	System Stable
Case 21	None	Bonnyman 69 kV CB A	P2	Single Phase @ CB A	70	System Stable AD2-107 Tripped Offline
Case 22	None	Jackson 69 kV CB B	P2	Single Phase @ CB B	70	System Stable
Case 23	None	Bonnyman 69 kV CB A	P4	Single Phase @ Bus Side	90	System Stable AD2-107 Tripped

						Offline
Case 24	None	Jackson 69 kV CB B	P4	Single Phase @ Bus Side	90	System Stable

	Prior Outage *	**Outaged Facility**	**NERC Category**	**Fault Type and Location**	**Fault Clearing Time (cycles)**	**Result**
Case 25	None	Bonnyman 69 kV Bus Diff Relay Failure	P5	Single Phase @ Bus Side	90	System Stable AD2-107 Tripped Offline
Case 26	None	Jackson 69 kV Bus Diff Relay Failure	P5	Single Phase @ Bus Side	90	System Stable
Case 27	Bonnyman 138/69 kV TRF	Bonnyman – Hazard 69 kV #1	P6	3 Phase @ Bonnyman	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 28	Bonnyman 138/69 kV TRF	Bonnyman – Hazard 69 kV #1	P6	3 Phase @ Hazard	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 29	Bonnyman 138/69 kV TRF	Bonnyman – Hazard 69 kV #2	P6	3 Phase @	Faulted end = 10 Remote end =	System Stable AD2-107 Tripped

				Bonnyman	60	Offline
Case 30	Bonnyman 138/69 kV TRF	Bonnyman – Hazard 69 kV #2	P6	3 Phase @ Hazard	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 31	Bonnyman – Hazard 69 kV #1	Bonnyman – Hazard 69 kV #2	P6	3 Phase @ Bonnyman	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 32	Bonnyman – Hazard 69 kV #1	Bonnyman – Hazard 69 kV #2	P6	3 Phase @ Hazard	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline

	Prior Outage *	**Outaged Facility**	**NERC Category**	**Fault Type and Location**	**Fault Clearing Time (cycles)**	**Result**
Case 33	Helechawa - Sublett 69 kV	Lee City – Morgan 69 kV	P6	3 Phase @ Lee City	Faulted end = 10 Remote end = 60	System Stable
Case 34	Helechawa - Sublett 69 kV	Helechawa - Campton 69 kV	P6	Single Phase @ Campton	Faulted end = 10 Remote end = 60	System Stable

Case 35	Lee City – Morgan 69 kV	Helechawa - Campton 69 kV	P6	Single Phase @ Campton	Faulted end = 10 Remote end = 60	System Stable
Case 36	Lee City – Morgan 69 kV	AD2-107 - Bonnyman 69 kV	P6	3 Phase @ Bonnyman	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 37	Lee City – Morgan 69 kV	AD2-107 - Bonnyman 69 kV	P6	3 Phase @ AD2-107	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 38	Lee City – Helechawa 69 kV	AD2-107 - Bonnyman 69 kV	P6	3 Phase @ Lee City	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 39	Lee City – Helechawa 69 kV	AD2-107 - Bonnyman 69 kV	P6	3 Phase @ Helechawa	Faulted end = 10 Remote end = 60	System Stable AD2-107 Tripped Offline
Case 40	None	Bonnyman – Soft Shell 138 kV Bonnyman – Hazard 69 kV #1	P7	3 Phase @ Bonnyman	138kV Line = 5.5 69kV Line = 60	System Stable AD2-107 Tripped Offline

* All of the prior outage cases listed above are not followed by any system adjustments and so also qualify as Type 1 stability extreme disturbances in TPL-001-4 Table 1.

Appendix A – IDV and DYR File Data

AD2-107_Rev0_2019_01_29.idv

@! AD2-107 Model

@! tap into 69 kV Chavies - Bonnyman circuit

@! TMEIC PVH-L3360GR

PSSE 33

BAT_PURGBRN,243710,243714,'1'

RDCH

1

936841,'AD2-107_GEN ', 0.6300,2, 205,1259, 1,1.02500, -
31.6587,1.10000,0.90000,1.10000,0.90000

936842,'AD2-107_COLA', 34.5000,1, 205,1259, 1,1.03012, -
4.2866,1.10000,0.90000,1.10000,0.90000

936843,'AD2-107_TER ', 13.8000,1, 205,1259, 1,1.03269, -
33.7795,1.10000,0.90000,1.10000,0.90000

936844,'AD2-107_COLB', 34.5000,1, 205,1259, 1,1.03012, -
4.2866,1.10000,0.90000,1.10000,0.90000

936845,'AD2-107_MAIN', 69.0000,1, 205,1259, 1,1.02826, -
11.3087,1.10000,0.90000,1.10000,0.90000

936846,'AD2-107_POI ', 69.0000,1, 205,1259, 1,1.02797, -
11.3499,1.10000,0.90000,1.10000,0.90000

0 / END OF BUS DATA, BEGIN LOAD DATA

936844,'AX',1, 205,1259, 2.380, 1.153, 0.000, 0.000, 0.000, 0.000, 1,1,0

0 / END OF LOAD DATA, BEGIN FIXED SHUNT DATA

0 / END OF FIXED SHUNT DATA, BEGIN GENERATOR DATA

936841,'1 ', 55.000, 17.283, 27.984, -27.984,1.02500, 0, 63.840, 0.00000E+0, 9.99900E+3, 0.00000E+0, 0.00000E+0,1.00000,1, 100.0, 57.380, 0.000, 1,1.0000, 0, 1.0, 0, 1.0, 0, 1.0,1, 1.0000

0 / END OF GENERATOR DATA, BEGIN BRANCH DATA

243710,936846,'1 ', 3.71502E-2, 9.47521E-3, 0.00000, 75.00, 75.00, 0.00, 0.00000, 0.00000, 0.00000, 0.00000,1,2, 6.35, 1,1.0000

243714,936846,'1 ', 1.13450E-2, 2.89479E-3, 0.00000, 75.00, 75.00, 0.00, 0.00000, 0.00000, 0.00000, 0.00000,1,2, 1.94, 1,1.0000

936842,936844,'1 ', 0.00000E+0, 1.00000E-4, 0.00000, 63.84, 63.84, 63.84, 0.00000, 0.00000, 0.00000, 0.00000,1,2, 0.00, 1,1.0000

936845,936846,'1 ', 3.80000E-4, 1.51000E-3, 0.00002, 63.84, 63.84, 63.84, 0.00000, 0.00000, 0.00000, 0.00000,1,1, 0.08, 1,1.0000

0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA

936842,936841, 0,'1 ',1,2,1, 0.00000E+00, 0.00000E+00,2,'EQUIVALE ',1, 1,1.0000, 0,1.0000, 0,1.0000, 0,1.0000,'YNd1 '

7.13000E-3, 5.70600E-2, 63.84

1.02500, 0.000, 30.000, 63.84, 63.84, 63.84, 0, 0, 1.05000, 0.95000, 1.05000, 0.95000, 5, 0, 0.00000, 0.00000, 0.000

1.00000, 0.000

936845,936844,936843,'1 ',1,2,1, 0.00000E+00, 0.00000E+00,2,'GSU TRAN ',1, 1,1.0000, 0,1.0000, 0,1.0000, 0,1.0000,'YN0yn0d1 '

2.22500E-3, 9.00000E-2, 37.00, 9.90000E-4, 3.66000E-2, 37.00, 3.50000E-3, 1.40000E-1, 37.00,1.03269, -3.7795

1.02500, 69.000, 0.000, 37.00, 50.00, 62.00, 0, 0, 1.05000, 0.95000, 1.05000, 0.95000, 5, 0, 0.00000, 0.00000, 0.000

1.00000, 34.500, 0.000, 37.00, 50.00, 62.00, 0, 0, 1.05000, 0.95000, 1.05000, 0.95000, 5, 0, 0.00000, 0.00000, 0.000

1.00000, 13.800, -30.000, 37.00, 50.00, 62.00, 0, 0, 1.05000, 0.95000, 1.05000, 0.95000, 5, 0, 0.00000, 0.00000, 0.000

0 / END OF TRANSFORMER DATA, BEGIN AREA DATA

205, 0, 1002.000, 10.000,'AEP '

0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA

0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA

0 / END OF VSC DC LINE DATA, BEGIN IMPEDANCE CORRECTION DATA

0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA

0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION LINE DATA

0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA

1259,'AEP-KP-SUBT '

0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA

0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA

1,'CENT HUD '

0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA

0 / END OF FACTS DEVICE DATA, BEGIN SWITCHED SHUNT DATA

936844,1,1,0,1.02500,0.97500, 0, 100.0,' ', 3.50, 2, 1.75

0 / END OF SWITCHED SHUNT DATA, BEGIN GNE DATA

0 / END OF GNE DATA, BEGIN INDUCTION MACHINE DATA

0 / END OF INDUCTION MACHINE DATA

Q

AD2-107_Rev0_2019_01_29.dyr

/***

/*** AD2-107 - 55 MW MFO

/*** POI at 69 kV kV Chavies - Bonnyman circuit

/***

/***
***

/ PSSE Version 33

/***
***

936841 'USRMDL' 1 'REGCAU1' 101,1,1,14,3,4,1, 0.2, 1, 0.75, 0, 0.23, 2, 0.1, 0, -0.4357, 0.02, 0, 10, -10, 0.1 /

936841 'USRMDL' 1 'REECAU1' 102, 0, 6, 45, 6, 9, 0,0,0,0,0,0, 0.8, 1.5, 0.02, -0.1, 0.1, 0, 0.4357, -0.4357, 1, 0, 0, 0, 0.05, 0.4357, -0.4357, 1.1, 0.9, 0, 0, 0, 0, 0, 0.02, 2, -2, 1, 0, 1, 0.02, 0, 1, 2, 1, 0, 0, 0, 0, 0, 1, 2, 1, 0, 0, 0, 0 /

936841 'USRMDL' 1 'REPCAU1' 107,0,7,27,7,9,

936845 936845 936846 1 0 1 1

0.02, 0.1, 0.1, 0, 0.1, 0.8, 0, 0, 0.1314, 1, -1, -0.001, 0.001, 0.4357, -0.4357, 1.0, 1.0, 0.02, -0.0006, 0.0006, 999, -999, 1.0, 0, 0.02, 20, 20 /

93684101 'VTGTPAT' 936845 936841 1 -1 1.200 0.16 0.0 /

93684102 'VTGTPAT' 936845 936841 1 -1 1.175 0.2 0.0 /

93684103 'VTGTPAT' 936845 936841 1 -1 1.15 0.5 0.0 /

93684104 'VTGTPAT' 936845 936841 1 -1 1.10 1 0.0 /

93684105 'VTGTPAT' 936845 936841 1 0.45 5 0.16 0.0 /

93684106 'VTGTPAT' 936845 936841 1 0.65 5 0.30 0.0 /

93684107 'VTGTPAT' 936845 936841 1 0.75 5 2 0.0 /

93684108 'VTGTPAT' 936845 936841 1 0.90 5 3 0.0 /

93684109 'FRQTPAT' 936845 936841 1 -100 61.8 0 0.0 /

93684110 'FRQTPAT' 936845 936841 1 -100 60.5 600.66 0.0 /

93684111 'FRQTPAT' 936845 936841 1 57.8 100 0 0.0 /

93684112 'FRQTPAT' 936845 936841 1 59.5 100 1792.049 0.0 /

Appendix B – Dispatch of Generation within the Study Area

Bus Number	Bus Name	Id	Area Num	Area Name	Zone Num	Zone Name	In Service	PGen (MW)	PMax (MW)	PMin (MW)
242737	05OPOSSUMCK1138.00	Z	205	AEP	1250	AEP-AP-BES	1	0.00	0.00	0.00
242891	05AMG1 26.000	1	205	AEP	1250	AEP-AP-BES	1	615.59	800.00	300.00
242892	05AMG2 26.000	2	205	AEP	1250	AEP-AP-BES	1	800.00	800.00	300.00
242893	05AMG3 26.000	3H	205	AEP	1250	AEP-AP-BES	1	656.00	656.00	250.00
242893	05AMG3 26.000	3R	205	AEP	1250	AEP-AP-BES	1	644.00	644.00	250.00
242894	05MTG1 26.000	1H	205	AEP	1250	AEP-AP-BES	1	667.00	667.00	250.00
242894	05MTG1 26.000	1R	205	AEP	1250	AEP-AP-BES	1	653.00	653.00	250.00
242906	05CLAY-1 11.000	1	205	AEP	1250	AEP-AP-BES	1	11.19	19.00	0.00
242906	05CLAY-1 11.000	2	205	AEP	1250	AEP-AP-BES	1	11.19	19.00	0.00
242907	05CLAY-2 11.000	3	205	AEP	1250	AEP-AP-BES	1	11.19	19.00	0.00
242907	05CLAY-2 11.000	4	205	AEP	1250	AEP-AP-BES	1	11.19	19.00	0.00
246843	05SMG1 13.800	1	205	AEP	1250	AEP-AP-BES	1	-79.00	66.00	-79.00
246845	05SMG3 13.800	3	205	AEP	1250	AEP-AP-BES	1	-135.00	106.00	-135.00
246847	05SMG5 13.800	5	205	AEP	1250	AEP-AP-BES	1	-79.00	66.00	-79.00

246895	05VACITY 23.000	1	205	AEP	1250	AEP-AP-BES	1	614.00	614.00	300.00
247284	05LEESVG 13.800	1	205	AEP	1250	AEP-AP-BES	1	11.78	20.00	0.00
247284	05LEESVG 13.800	2	205	AEP	1250	AEP-AP-BES	1	11.78	20.00	0.00
247723	05PHILPOTT 138.00	1	205	AEP	1250	AEP-AP-BES	1	8.83	15.00	0.00
909181	X2-052 CT1 18.000	1	205	AEP	1250	AEP-AP-BES	1	225.00	230.00	110.00
909182	X2-052 CT2 18.000	1	205	AEP	1250	AEP-AP-BES	1	225.00	230.00	0.00
909183	X2-052 ST1 18.000	1	205	AEP	1250	AEP-AP-BES	1	225.00	235.00	76.00
936841	AD2-107_GEN 0.6300	1	205	AEP	1259	AEP-KP-SUBT	1	55.00	57.38	0.00
342900	1COOPER1 G 13.800	1	320	EKPC	1315	EKPC	1	124.00	124.00	45.00
342903	1COOPER2 G 20.000	1	320	EKPC	1315	EKPC	1	240.00	240.00	112.00
342948	1LOVE HYDRO 4.1600	1	320	EKPC	1315	EKPC	1	8.66	23.30	0.00
342948	1LOVE HYDRO 4.1600	2	320	EKPC	1315	EKPC	1	8.66	23.30	0.00
342948	1LOVE HYDRO 4.1600	3	320	EKPC	1315	EKPC	1	8.66	23.30	0.00
342957	1SPURLK1G 22.000	1	320	EKPC	1315	EKPC	1	344.00	344.00	145.00
342960	1SPURLK2G 22.000	1	320	EKPC	1315	EKPC	1	496.97	555.00	260.00
342963	1SPURLK3G 18.000	1	320	EKPC	1315	EKPC	1	306.00	306.00	140.00

342966	1SPURLK4G 18.000	1	320	EKPC	1315	EKPC	1	306.00	306.00	266.22
364915	1WINDROCK WG0.6900	1	347	TVA	1368	KNOXVILLE	1	27.00	27.10	27.00
324217	4BROWN PLANT138.00	S1	363	LGEE	380	KU - CENTRAL	1	10.00	10.00	0.00