Revised Generation Interconnection Impact Study Report

For

PJM Generation Interconnection Request Queue Position AD2-071

Pipe Creek – Strawton 138 kV

February 2022

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, a generator interconnection may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection, may also contribute to the need for the same network reinforcement. Cost allocation rules for network upgrades can be found in PJM Manual 14A, Attachment B. 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 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.

An Interconnection Customer 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.

General

Madison County Solar Project, LLC proposes to install PJM Project #AD2-071, a 100.0 MW (67.0 MW Capacity) solar generating facility in Madison County, Indiana (see Figure 2). The point of interconnection is to AEP's Pipe Creek – Strawton 138 kV section of the Deer Creek – Fisher Body – Strawton 138 kV circuit (see Figure 1).

The requested in service date is December 1, 2021. This study does not imply AEP's commitment to this in-service date.

The objective of this System Impact Study is to determine budgetary cost estimates and approximate construction timelines for identified transmission facilities required to connect the proposed generating facilities to the AEP transmission system. These reinforcements include the Attachment Facilities, Local Upgrades, and Network Upgrades required for maintaining the reliability of the AEP transmission system.

Cost Summary

Cost Breakdown for Point of Interconnection (Pipe Creek – Strawton 138 kV)		
Attachment Cost	138 kV Revenue Metering	$250,000
Direct Connection	New 138 kV Switching Station and associated protection and controls.	$6,000,000
Non-Direct Connection Cost Estimate	Pipe Creek – Strawton 138 kV T-Line Cut In	$1,000,000
	Upgrade line protection and controls at the Pipe Creek 138 kV substation	$250,000
	Upgrade line protection and controls at the Strawton 138 kV substation.	$250,000
	New System Reinforcements *Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)*	$0
	Contribution to Previously Identified System Reinforcements *(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, identified for earlier generation or transmission interconnection projects in the PJM Queue)*	$0
	Total Estimated Cost for Project AD2-071	**$7,750,000**

The estimates are preliminary in nature, as they were determined without the benefit of detailed engineering studies. The cost of remediation for sag limited conductors is not included in this estimate. Final estimates will require an on-site review and coordination to determine final construction requirements.

Primary Point of Interconnection (Pipe Creek – Strawton 138 kV)

To accommodate the interconnection on the Pipe Creek – Strawton 138 kV section of the Deer Creek – Fisher Body – Strawton circuit, a new three (3) circuit breaker 138 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, 138 kV line risers, SCADA, and 138 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.

Attachment Facilities

The total preliminary cost estimate for the Attachment Facilities work is given in the following table below.

Description	Total Cost
138 kV Revenue Metering	**$250,000**
Total	**$250,000**

Direct Connection Cost Estimate

The total preliminary cost estimate for Direct Connection work is given in the following table below.

Description	Total Cost
Construct a new three (3) circuit breaker 138 kV switching station physically configured in a breaker and half bus arrangement but operated as a ring-bus. Installation of associated protection and control equipment, 138 kV line risers and SCADA will also be required (see Figure 1).	**$6,000,000**
Total	**$6,000,000**

Non-Direct Connection Cost Estimate

The total preliminary cost estimate for Non-Direct Connection work is given in the following table below:

Description	Estimated Cost
Upgrade line protection and controls at the Pipe Creek 138 kV station.	$250,000
Upgrade line protection and controls at the Strawton 138 kV substation.	$250,000
Pipe Creek – Strawton 138kV T-Line Cut In	$1,000,000
Total	**$1,500,000**

Schedule

It is anticipated that the time between receipt of executed agreements and Commercial Operation may range from 12 to 18 months if no line work is required. If line work is required, construction time would be between 24 to 36 months after signing an interconnection agreement.

Interconnection Customer Requirements

It is understood that Madison County Solar Project is responsible for all costs associated with this interconnection. The cost of Madison County Solar Project's generating plant and the costs for the line connecting the generating plant to the point of interconnection are not included in this report; these are assumed to be Madison County Solar Project'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 AD2-071 was evaluated as a 100.0 MW (Capacity 67.0 MW) injection into a tap of the Strawton – Pipe Creek 138 kV line in the AEP area. Project AD2-071 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AD2-071 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Base Case Used

Summer Peak Analysis – 2021 Case

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
AEP_P1-2_#6964-A	CONTINGENCY 'AEP_P1-2_#6964-A' OPEN BRANCH FROM BUS 246763 TO BUS 936560 CKT 1 / 246763 05PIPECK 138 936560 AD2-071 TAP 138 1 END
AEP_P1-2_#8773	CONTINGENCY 'AEP_P1-2_#8773' OPEN BRANCH FROM BUS 247116 TO BUS 246988 CKT 1 / 247116 05ALEXAN 138 246988 05STRWTN 138 1 END
AEP_P4_#8775_05STRWTN 138	CONTINGENCY 'AEP_P4_#8775_05STRWTN 138' OPEN BRANCH FROM BUS 247116 TO BUS 246988 CKT 1 / 247116 05ALEXAN 138 246988 05STRWTN 138 1 OPEN BRANCH FROM BUS 246771 TO BUS 246988 CKT 1 / 246771 05SELWDZ 138 246988 05STRWTN 138 1 END

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)

AD2-071 Multiple Facility Contingency															
		Contingency	Affected	Facility	Bus				Loading		Rating		MW	FG
#	Type	Name	Area	Description	From	To	Cir.	PF	Initial	Final	Type	MVA	Con.	App.
1	LFFB	AEP_P4_#8775_05STRWTN 138	AEP	05PIPECK-05GRNTTA 138 kV line	246763	243303	1	AC	79.47	122.42	ER	205	91.43	1
2	LFFB	AEP_P4_#8775_05STRWTN 138	AEP	AD2-071 TAP-05PIPECK 138 kV line	936560	246763	1	AC	81.21	124.25	ER	205	91.43	2

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

None. See Attachment 4

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

None. See Attachment 4

Short Circuit

(Summary of impacted circuit breakers)

None

Light Load Analysis

Light Load Studies (applicable to wind, coal, nuclear, and pumped storage projects).

Not required for Solar projects

Affected System Analysis & Mitigation

LGEE Impacts:
None

MISO Impacts:
None

Duke, Progress & TVA Impacts:
None

OVEC 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.

AD2-071 Delivery of Energy Portion of Interconnection Request															
		Contingency	Affected	Facility	Bus				Loading		Rating		MW	FG
#	Type	Name	Area	Description	From	To	Cir.	PF	Initial	Final	Type	MVA	Con.	App.
3	N-1	AEP_P1-2_#8773	AEP	05PIPECK-05GRNTTA 138 kV line	246763	243303	1	AC	77.06	104.19	ER	205	59.09	
4	N-1	AEP_P1-2_#6964-A	AEP	05STRWTN-05ALEXAN 138 kV line	246988	247116	1	AC	113.1	145.48	ER	150	49.4	
5	N-1	AEP_P1-2_#6964-A	AEP	05ALEXAN-05JONES 138 kV line	247116	246913	1	AC	101.2	133.42	ER	150	49.4	
6	N-1	AEP_P1-2_#8773	AEP	AD2-071 TAP-05PIPECK 138 kV line	936560	246763	1	AC	78.73	106	ER	205	59.09	

New System Reinforcements

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

#	Overloaded Facility	Upgrade Description	Cost	Cost Allocation	Upgrade Number
#1	05PIPECK-05GRNTTA 138 kV line (from bus 246763 to bus 243303 ckt 1)	**AEP** AEP SE rating is 205 MVA. AEP Reinforcement: **Project ID:** s2092.1 Rebuild 16.5 miles of the Deer Creek - Makahoy 138 kV line using 795 ACSR Drake conductor. Rebuild 3.9 miles of the Deer Creek - Makahoy 138 kV line as double circuit using 795 ACSR Drake conductor west from Deer Creek. Operate as double circuit to allow for bringing the Grant line into Deer Creek eliminating the 3 terminal line. Projected in-service date: 12/15/2022	$45,800,000 + $1,300,000	$0	S2092.1 S2092.2

#	Overloaded Facility	Upgrade Description	Cost	Cost Allocation	Upgrade Number
		AEP Reinforcement: **Project ID:** s2092.2 At Deer Creek Station: Install a 138 kV circuit breaker for the new line exit. Projected in-service date: 10/01/2022 **Notes:** 1. AD2-071 currently does not receive cost allocation towards this upgrade. 2. As changes to the PJM queue process occur (such as prior queued projects withdrawing from the queue, reducing in size, etc.) AD2-071 could receive cost allocation. 3. Although Queue Project AD2-071 may not presently have cost responsibility for this upgrade, Queue Project AD2-071 may need this upgrade in-service to be deliverable to the PJM system. 4. If Queue Project AD2-071 comes into service prior to completion of the upgrade, Queue Project AD2-071 will need an interim study.			
#2	AD2-071 TAP-05PIPECK 138 kV line (from bus 936560 to bus 246763 ckt 1)	**AEP** AEP SE rating is 205 MVA. AEP Reinforcement: **Project ID**: s2092.1 Rebuild 16.5 miles of the Deer Creek - Makahoy 138 kV line using 795 ACSR Drake conductor. Rebuild 3.9 miles of the Deer Creek - Makahoy 138 kV line as double circuit using 795 ACSR Drake conductor west from Deer Creek. Operate as double circuit to allow for bringing the Grant line into Deer Creek eliminating the 3 terminal line. Projected in-service date: 12/15/2022 AEP Reinforcement: **Project ID**: s2092.2 At Deer Creek Station: Install a 138 kV circuit breaker for the new line exit. Projected in-service date: 10/01/2022. **Notes:** 1. AD2-071 currently does not receive cost allocation towards this upgrade. 2. As changes to the PJM queue process occur (such as prior queued projects withdrawing from the queue, reducing in size, etc.) AD2-071 could receive cost allocation.	$45,800,000 + 1,300,000	$0	S2092.1 S2092.2

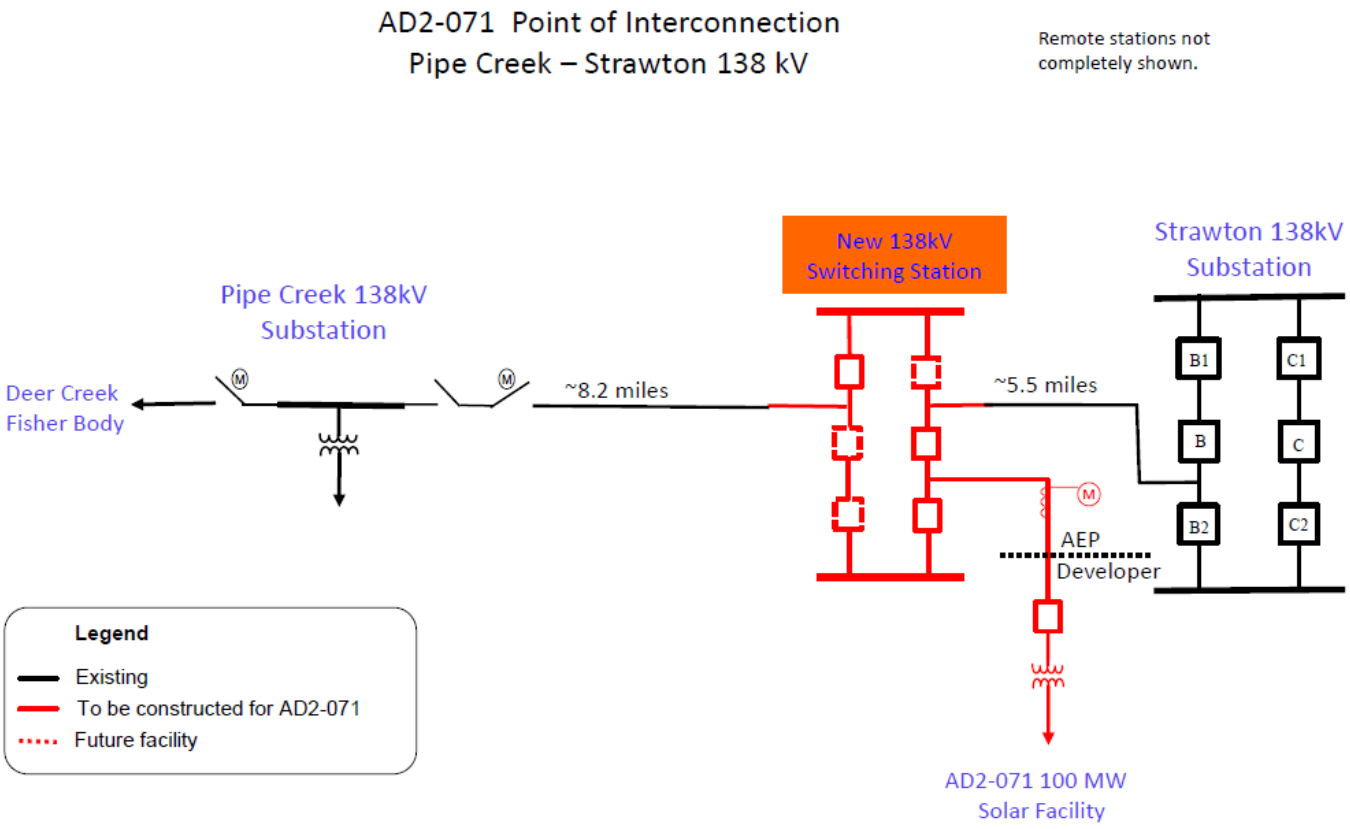
#	Overloaded Facility	Upgrade Description	Cost	Cost Allocation	Upgrade Number
		3. Although Queue Project AD2-071 may not presently have cost responsibility for this upgrade, Queue Project AD2-071 may need this upgrade in-service to be deliverable to the PJM system. 4. If Queue Project AD2-071 comes into service prior to completion of the upgrade, Queue Project AD2-071 will need an interim study.			
		Total Cost	**$47,100,000**	**$0**	

Contribution to Previously Identified System Reinforcements

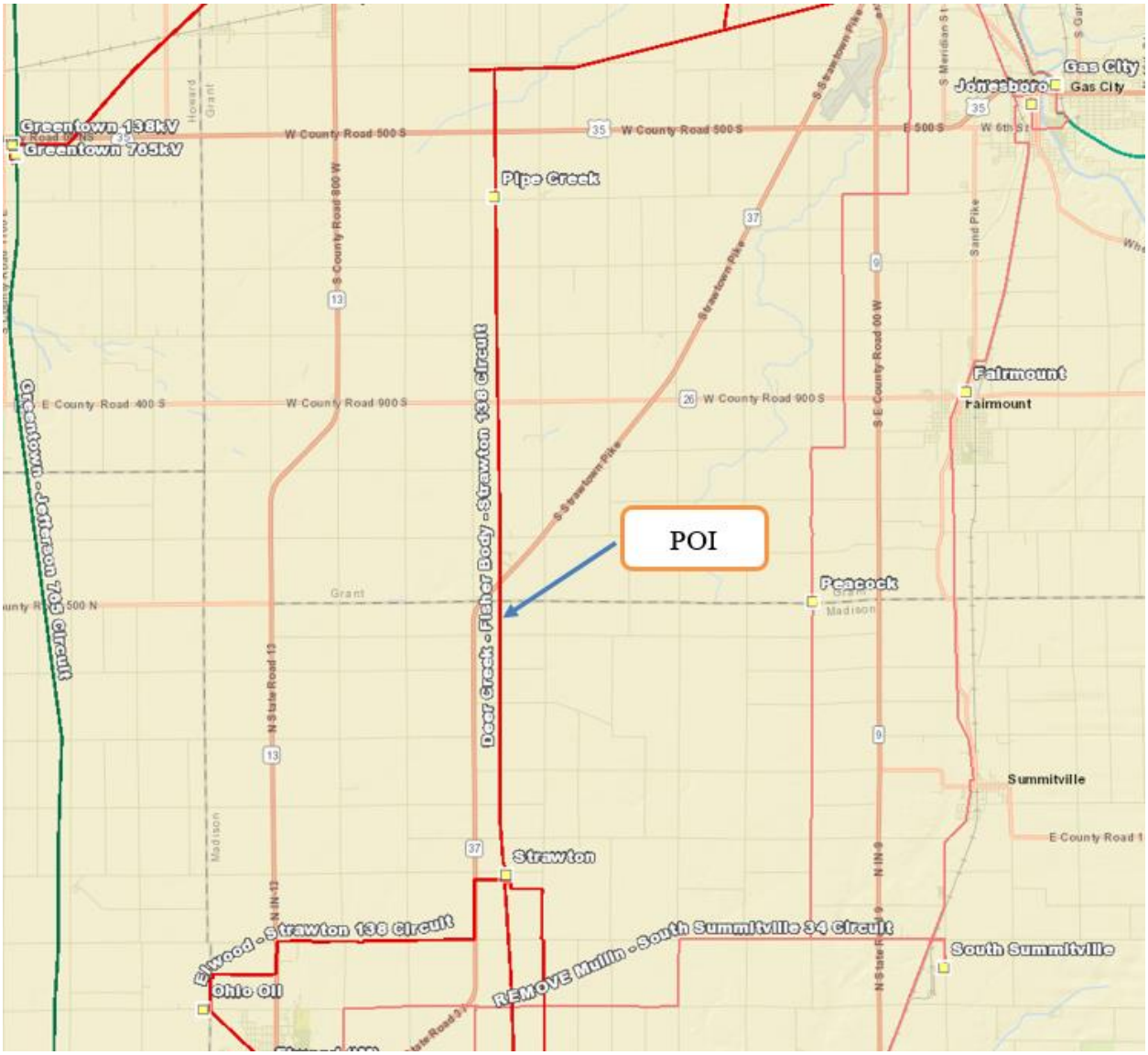
(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)
(Summary form of Cost allocation for transmission lines and transformers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

None

Attachment 1: Single Line Diagram



Attachment 2: Point of Interconnection



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.

Appendix 1

(AEP - AEP) The 05PIPECK-05GRNTTA 138 kV line (from bus 246763 to bus 243303 ckt 1) loads from 79.47% to 122.42% (AC power flow) of its emergency rating (205 MVA) for the line fault with failed breaker contingency outage of 'AEP_P4_#8775_05STRWTN 138'. This project contributes approximately 91.43 MW to the thermal violation.

Bus Number	Bus Name	Full Contribution
246991	05WLD G1 C	2.09
247914	05WLD G1 E	75.88
247255	05WLD G2 C	2.19
247958	05WLD G2 E	79.62
936561	AD2-071 C	61.26
936562	AD2-071 E	30.17
LTF	AMIL	< 0.01
LTF	CARR	< 0.01
LTF	CATAWBA	< 0.01
LTF	CBM-S1	0.03
LTF	CBM-W2	0.13
LTF	CIN	0.15
LTF	COTTONWOOD	0.01

Bus Number	Bus Name	Full Contribution
LTF	EDWARDS	0.03
LTF	FARMERCITY	0.01
LTF	G-007	< 0.01
LTF	HAMLET	< 0.01
LTF	IPL	0.18
LTF	LGEE	0.02
LTF	O-066	0.05
LTF	PRAIRIE	0.02
LTF	RENSSELAER	< 0.01
LTF	TATANKA	0.02
LTF	TILTON	< 0.01
LTF	UNIONPOWER	< 0.01

Appendix 2

(AEP - AEP) The AD2-071 TAP-05PIPECK 138 kV line (from bus 936560 to bus 246763 ckt 1) loads from 81.21% to 124.25% (AC power flow) of its emergency rating (205 MVA) for the line fault with failed breaker contingency outage of 'AEP_P4_#8775_05STRWTN 138'. This project contributes approximately 91.43 MW to the thermal violation.

Bus Number	Bus Name	Full Contribution
246991	05WLD G1 C	2.09
247914	05WLD G1 E	75.88
247255	05WLD G2 C	2.19
247958	05WLD G2 E	79.62
936561	AD2-071 C	61.26
936562	AD2-071 E	30.17
LTF	AMIL	< 0.01
LTF	CARR	< 0.01
LTF	CATAWBA	< 0.01
LTF	CBM-S1	0.03
LTF	CBM-W2	0.13
LTF	CIN	0.15
LTF	COTTONWOOD	0.01

Bus Number	Bus Name	Full Contribution
LTF	EDWARDS	0.03
LTF	FARMERCITY	0.01
LTF	G-007	< 0.01
LTF	HAMLET	< 0.01
LTF	IPL	0.18
LTF	LGEE	0.02
LTF	O-066	0.05
LTF	PRAIRIE	0.02
LTF	RENSSELAER	< 0.01
LTF	TATANKA	0.02
LTF	TILTON	< 0.01
LTF	UNIONPOWER	< 0.01

Attachment 4: Dynamic Simulation Analysis

Executive Summary

Generator Interconnection Request AD2-071 is for a 100 MW Maximum Facility Output (MFO) solar generation plant. AD2-071 consists of 40 × 2.5 MW, TMEIC PVH-L2700 solar PV inverters. The Point of Interconnection (POI) is a tap on Pipe Creek – Strawton 138 kV circuit in the American Electric Power (AEP) transmission system, Madison County, Indiana.

This report describes a dynamic simulation analysis of AD2-071 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2021 peak load case, modified to include applicable queue projects. AD2-071 has been dispatched online at maximum power output, with 1.0 p.u. voltage at the generator bus.

AD2-071 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. Steady-state condition and 51 contingencies were studied, each with a 20 second simulation time period. Studied faults included:

a) Steady state operation (20 second);

b) Three-phase faults with normal clearing time;

c) Single-phase faults with single phase stuck breaker;

d) Single-phase faults with delayed (Zone 2) clearing at line end closest to AD2-071 POI.

No relevant bus or high speed reclosing contingencies were identified.

For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.

For all of the fault contingencies tested on the 2021 peak load case:

a) AD2-071 was able to ride through the faults except for faults where protective action trips the generator.

b) AD2-071 Post-contingency oscillations were positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recovered to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element tripped, other than those either directly connected or designed to trip as a consequence of that fault.

The reactive power capability of AD2-071 meets the 0.95 leading and lagging PF requirement at the high side of the main transformer.

AD2-071 was originally tripped for contingency P5.01 due to prolonged undervoltage conditions. Contingency P5.01 caused AD2-071 to be tripped off line due to a VTGTPAT undervoltage condition (138kV Tap Bus voltage was below 0.65 Vpu for 60 cycles). The time setting was lengthened slightly from 1 second to 1.1 seconds so that local protection would coordinate properly with the existing circuit breaker clearing times. No tripping was observed after this change. The developer has approved of this change.

Response of AD2-071 power output, fault on AD2-071 – Deer Creek, in P5.02 is of interest during the time of the fault. After the fault is cleared, normal behavior is re-established.

No mitigations were found to be required.