Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AB2-065

Madison-Tanners Creek 138 kV

January 2018

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: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) 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 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.

General

Flat Rock Wind II, LLC proposes to connect Project #AB2-065, a 124.2 MW (16.0 Capacity) wind generating facility to the American Electric Power (AEP) Transmission system at the in-line switching station (Rushmay 138 kV) proposed to be built as an attachment facility for PJM queue positions W4-004 (see Figure 1). The new switching station is located between Madison and Tanners Creek 138 kV substations (see Figure 2). The location of the proposed wind generating facility is in Rush County, IN.

The requested Backfeed date is September 1, 2019.

The requested in service date is December 31, 2019.

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 to maintain the reliability of the AEP transmission system. Stability analysis is included as part of this study.

Attachment Facilities

Point of Interconnection (Expand the new proposed Rushmay 138 kV Switching Station)

To accommodate the interconnection at the Rushmay 138 kV switching station, the substation will have to be expanded requiring the installation of two (2) new 138 kV circuit breakers, extending the buses and starting a new string, associated protection and control equipment, SCADA, and 138 kV revenue metering

Direct Connection to the new Rushmay 138 kV Switching Station Work and Cost:

- Expand the substation, install two (2) new 138 kV circuit breakers, extend the buses and start a new string (see Figure 1). Installation of associated protection and control equipment, SCADA, and 138 kV revenue metering will also be required.
- **Estimated Station Cost: $2,000,000 (Network Upgrade n5505)**
- **Estimated 138 kV Revenue Metering Cost: $250,000 (Network Upgrade n5506)**

Protection and Relay Work and Cost:

- Install line protection and controls at the new Rushmay 138 kV switching station for Project AB2-065. **(Network Upgrade n5507)**

- **Estimated Cost: $250,000**

It is understood that Flat Rock Wind is responsible for all these connection costs associated with interconnecting the PJM project #AB2-065 to AEP transmission system. The costs above are reimbursable to AEP. The cost of Flat Rock Wind's generating plant and the costs for the line connecting the generating plant to the Rushmay 138 kV switching station are not included in this report; these are assumed to be Flat Rock Wind'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 utility to determine if a local service agreement is required.

Local and Network Impacts

The impact of the proposed wind generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet performance parameters prescribed in the AEP FERC Form 715[1] and Connection Requirements for AEP Transmission System[2]. Therefore, these criteria were used to assess the impact of the proposed facility on the AEP System. The Queue Project AB2-065 was evaluated as a 124.2 MW (Capacity 16.0 MW) injection into the W4-004/W4-008 substation (which is a tap of the Madison – Tanners Creek 138 kV line) in the AEP area. Project AB2-065 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB2-065 was studied with a commercial probability of 100%. Potential network impacts were as follows:

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1 https://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/docs/2017/AEP_East%20FERC%20715_2017_Final_Part%204.pdf

2 https://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/Requirements/AEP_Interconnection_Requirements_rev1.pdf

Summer Peak Analysis - 2020

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

Short Circuit

(Summary of impacted circuit breakers)

None

Stability Analysis

Project AB2-065 will require a +150/-75 MVAR SVC at the point of interconnection to stabilize the Madison/Pendleton DCT outage.

- **Estimated Cost: $45,000,000 (Network Upgrade n5508)**

Voltage Variations

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.

1. (AEP - DEO&K) The 05TANNER-08M.FORT 345 kV line (from bus 243233 to bus 249567 ckt 1) loads from 101.52% to 102.99% (AC power flow) of its normal rating (1409 MVA) for the single line contingency outage of 'P1-#..B2 TERMINAL-EAST BEND 4516'. This project contributes approximately 24.36 MW to the thermal violation.

CONTINGENCY 'P1-#..B2 TERMINAL-EAST BEND 4516'

OPEN BRANCH FROM BUS 249575 TO BUS 249565 CKT 1

END

2. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 164.08% to 247.99% (AC power flow) of its emergency rating (220 MVA) for the single line contingency outage of '8181_B2_TOR13901756'. This project contributes approximately 124.19 MW to the thermal violation.

CONTINGENCY '8181_B2_TOR13901756'

OPEN BRANCH FROM BUS 243382 TO BUS 247588 CKT 1 / 243382 05TANNER 138 247588 W4-004 C 138 1

END

3. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 133.12% to 177.87% (AC power flow) of its normal rating (191 MVA) for non-contingency condition. This project contributes approximately 82.39 MW to the thermal violation.

4. (AEP - AEP) The W4-004 C-05TANNER 138 kV line (from bus 247588 to bus 243382 ckt 1) loads from 161.21% to 217.66% (DC power flow) of its emergency rating

(220 MVA) for the single line contingency outage of '8182_B2_TOR14001756'. This project contributes approximately 124.19 MW to the thermal violation.

CONTINGENCY '8182_B2_TOR14001756'

OPEN BRANCH FROM BUS 243333 TO BUS 247588 CKT 1 / 243333 05MADISO 138 247588 W4-004 C 138 1

END

5. (OVEC - AEP) The 06KYGER-05SPORN 345 kV line (from bus 248005 to bus 242528 ckt 2) loads from 105.6% to 106.46% (AC power flow) of its normal rating (971 MVA) for the single line contingency outage of '349_B2_TOR21'. This project contributes approximately 9.86 MW to the thermal violation.

CONTINGENCY '349_B2_TOR21'

OPEN BRANCH FROM BUS 242528 TO BUS 248005 CKT 1 / 242528 05SPORN 345 248005 06KYGER 345 1

END

6. (AEP - AEP) The AB2-028 TAP-05DESOTO 345 kV line (from bus 923880 to bus 243218 ckt 1) loads from 106.96% to 108.27% (AC power flow) of its normal rating (1016 MVA) for the single line contingency outage of '363_B2_TOR1682'. This project contributes approximately 13.0 MW to the thermal violation.

CONTINGENCY '363_B2_TOR1682'

OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1 / 243208 05JEFRSO 765 243209 05ROCKPT 765 1

END

Additional Limitations of Concern

Numerous conditions were identified at full output that don’t require mitigation per the PJM tariff, but may subject the AB2-065 project to curtailment in actual operation.

Light Load Analysis

Network Impacts

The queue project AB2-065 was studied as a 124.2 MW (16 MW Capacity) injection into AEP system. Project AB2-065 was evaluated for compliance with reliability criteria for **Light Load conditions** in 2020. Potential network impacts were as follows:

Generator Deliverability

1. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 86.05% to 116.04% (AC power flow) of its emergency rating (220 MVA) for the fault at stuck breaker contingency outage of 'AA2-148_3'. This project contributes approximately 66.91 MW to the thermal violation.

   CONTINGENCY 'AA2-148_3'
   OPEN BRANCH FROM BUS 247588 TO BUS 243357 CKT 1
   OPEN BRANCH FROM BUS 247588 TO BUS 243382 CKT 1
   END

2. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 84.77% to 114.24% (AC power flow) of its emergency rating (220 MVA) for the fault at stuck breaker contingency outage of 'AA2-148_4'. This project contributes approximately 65.81 MW to the thermal violation.

   CONTINGENCY 'AA2-148_4'
   OPEN BRANCH FROM BUS 247588 TO BUS 243357 CKT 1
   OPEN BRANCH FROM BUS 247588 TO BUS 243382 CKT 2
   END

Contribution to Previously Identified Overloads

1. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 125.71% to 175.71% (AC power flow) of its emergency rating (220 MVA) for the tower contingency outage of 'TANNERS CREEK - W4-004'. This project contributes approximately 99.36 MW to the thermal violation.

   CONTINGENCY 'TANNERS CREEK - W4-004'
   OPEN BRANCH FROM BUS 243382 TO BUS 247588 CKT 1 / 243382 05TANNER 138 247588 05W4-004 C 138 1

OPEN BRANCH FROM BUS 243382 TO BUS 247588 CKT 2 / 243382 05TANNER 138 247588 05W4-004 C 138 1
END

2. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 117.72% to 166.34% (AC power flow) of its emergency rating (220 MVA) for the single line contingency outage of '8181_B2_TOR13901756'. This project contributes approximately 99.36 MW to the thermal violation.

CONTINGENCY '8181_B2_TOR13901756'
OPEN BRANCH FROM BUS 243382 TO BUS 247588 CKT 1 / 243382 05TANNER 138 247588 W4-004 C 138 1
END

3. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 91.64% to 125.35% (AC power flow) of its emergency rating (191 MVA) for the non-contingency scenario. This project contributes approximately 65.89 MW to the thermal violation.

4. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 87.2% to 116.66% (AC power flow) of its emergency rating (220 MVA) for the fault at stuck breaker contingency outage of '6871_C2_05DESOTO 345-C2'. This project contributes approximately 65.69 MW to the thermal violation.

CONTINGENCY '6871_C2_05DESOTO 345-C2'
OPEN BRANCH FROM BUS 243218 TO BUS 243792 CKT 2 / 243218 05DESOTO 345 243792 05LOSANTVILL 345 2
OPEN BRANCH FROM BUS 243218 TO BUS 243278 CKT 1 / 243218 05DESOTO 345 243278 05DESOTO 138 1
END

5. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 86.21% to 115.8% (AC power flow) of its emergency rating (220 MVA) for the bus fault contingency outage of '6924_C1_05COLLCO 138-2'. This project contributes approximately 66.03 MW to the thermal violation.

CONTINGENCY '6924_C1_05COLLCO 138-2'
OPEN BRANCH FROM BUS 243259 TO BUS 243262 CKT 1 / 243259 05CNTRVL 138 243262 05COLLCO 138 1
OPEN BRANCH FROM BUS 243262 TO BUS 243310 CKT 1 / 243262 05COLLCO 138 243310 05HODGIN 138 1
OPEN BRANCH FROM BUS 243262 TO BUS 246963 CKT 1 / 243262 05COLLCO 138 246963 05WESLEZ 138 1

OPEN BRANCH FROM BUS 243262 TO BUS 250106 CKT 1 / 243262 05COLLCO 138 250106 08TODHJT 138 1
END

6. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 86.05% to 115.59% (AC power flow) of its emergency rating (220 MVA) for the bus fault contingency outage of '6923_C1_05COLLCO 138-1'. This project contributes approximately 66.03 MW to the thermal violation.

CONTINGENCY '6923_C1_05COLLCO 138-1'
OPEN BRANCH FROM BUS 243262 TO BUS 243282 CKT 1 / 243262 05COLLCO 138 243282 05DREWER 138 1
OPEN BRANCH FROM BUS 243262 TO BUS 243364 CKT 1 / 243262 05COLLCO 138 243364 05RICHMO 138 1
OPEN BRANCH FROM BUS 243262 TO BUS 250001 CKT 1 / 243262 05COLLCO 138 250001 08COLINV 138 1
END

7. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 80.98% to 110.33% (AC power flow) of its emergency rating (220 MVA) for the single line contingency outage of '5615_B2_TOR2869'. This project contributes approximately 66.02 MW to the thermal violation.

CONTINGENCY '5615_B2_TOR2869'
OPEN BRANCH FROM BUS 246965 TO BUS 246964 CKT 1 / 246965 05WESLMPEQ 999 246964 05WESLMP 138 1
OPEN BRANCH FROM BUS 246965 TO BUS 246967 CKT 1 / 246965 05WESLMPEQ 999 246967 05WESLEYMP 69.0 1
OPEN BRANCH FROM BUS 246965 TO BUS 246966 CKT 1 / 246965 05WESLMPEQ 999 246966 05WESLEYMP 13.8 1
OPEN BRANCH FROM BUS 243262 TO BUS 246963 CKT 1 / 243262 05COLLCO 138 246963 05WESLSS 138 1
OPEN BRANCH FROM BUS 243382 TO BUS 246963 CKT 1 / 243382 05TANNER 138 246963 05WESLSS 138 1
OPEN BRANCH FROM BUS 246964 TO BUS 246963 CKT 1 / 246964 05WESLMP 138 246963 05WESLSS 138 1
END

8. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 80.95% to 110.3% (AC power flow) of its emergency rating (220 MVA) for the single line contingency outage of '5594_B2_TOR2529'. This project contributes approximately 66.02 MW to the thermal violation.

CONTINGENCY '5594_B2_TOR2529'

OPEN BRANCH FROM BUS 243262 TO BUS 243282 CKT 1 / 243262 05COLLCO 138 243282 05DREWER 138 1
OPEN BRANCH FROM BUS 243282 TO BUS 243382 CKT 1 / 243282 05DREWER 138 243382 05TANNER 138 1
OPEN BRANCH FROM BUS 243282 TO BUS 246074 CKT 1 / 243282 05DREWER 138 246074 05DREWERS8 12.0 1
END

9. (AEP - AEP) The W4-004 C-05MADISO 138 kV line (from bus 247588 to bus 243333 ckt 1) loads from 80.82% to 110.05% (AC power flow) of its emergency rating (220 MVA) for the single line contingency outage of '7495_B3_05STRWCS 138-12'. This project contributes approximately 65.89 MW to the thermal violation.

CONTINGENCY '7495_B3_05STRWCS 138-12'
OPEN BRANCH FROM BUS 246989 TO BUS 246990 CKT 1 / 246989 05WLD CS 138 246990 05WLDCS1 34.5 1
OPEN BRANCH FROM BUS 246989 TO BUS 247254 CKT 2 / 246989 05WLD CS 138 247254 05WLDCS2 34.5 2
END

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)

1. **To relieve the W4-004 - Madison 138kV line overload:**

Reinforcement: Existing upgrade **n5110**: To mitigate the Stability violation associated with the AA2-148 IPP, the Pendleton-Tanners Creek 138 kV line will be looped into the proposed in-line switching station identified as an attachment facility for PJM project #W4-004/-008.
Cost: $3,450,000

Due to the cost of the reinforcement, based on PJM's cost allocation criteria AB2-065 is currently not responsible for any cost. In the case that AA2-148 withdraws

or that AB2-065 comes in to service before AA2-148, then AB2-065 could become eligible for cost towards this reinforcement.

New violations were identified as a result of the Stability upgrade **n5110**. Additional reinforcement required to mitigate these violations is listed below.

Additional Reinforcement: Perform a sag study on the W4-004 – Madison 138 kV line to increase the SE rating. The sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 23 mile section of line would need to be rebuilt. PJM Network Upgrade **n5488**.
Cost: $92,000

Due to the cost of this reinforcement, based on PJM's cost allocation criteria, AB2-065 is currently not responsible for any cost. In the case that AA2-148 withdraws or that AB2-065 comes in to service before AA2-148, then AB2-065 could become eligible for cost towards this reinforcement.

The W4-004 Tap – Madison 138 kV section of the Madison – Tanners Creek 138 kV circuit overloads for various single, breaker, bus, and tower contingencies, the worst being the Tanners Creek – W4004 Tap tower contingency. The final loading on this section of line is 175.7% as is shown in the table above.

System Reinforcements from Light Load Analysis

The following work is required to mitigate the overload on the W4-004 Tap – Madison 138 kV section of the Madison – Tanners Creek 138 kV circuit:

Network Upgrade	Upgrade	Cost
n5488	Perform a sag study on the W4-004 – Madison 138 kV line to increase the SE rating. The sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 23 mile section of line would need to be rebuilt. PJM Network Upgrade	$92,000
	If the Sag Study will not be sufficient to mitigate the tower outage, therefore the W4-004 Tap – Madison 138 kV section of the Madison – Tanners Creek 138 kV circuit will have to be rebuilt/reconductored depending on the existing structures. This section of line is approximately 23.0 miles.	$34,500,000
	Total Cost to mitigate overload on the W4-004 Tap – Madison 138 kV line	**$34,592,000**

Table 2

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.

Conclusion

Based upon the results of this System Impact Study, the construction of the 124.2 MW (16.0 MW Capacity) wind generating facility of Flat Rock Wind II (PJM Project #AB2-065) will require the following additional interconnection charges. This plan of service will interconnect the proposed wind generating facility in a manner that will provide operational reliability and flexibility to both the AEP system and the Flat Rock Wind II generating facility.

Category	Network Upgrade Number	Cost Breakdown for Point of Interconnection (Rushmay 138 kV Switching Station)	
Attachment Cost	**n5505**	Expand Rushmay 138 kV Switching Station	$2,000,000
Non-Direct Connection Cost Estimate	**n5506**	138 kV Revenue Metering	$250,000
	n5507	Install line protection and controls at the new Rushmay 138 kV switching station for Project AB2-065	$250,000
	n5488	Perform a sag study on the W4-004 – Madison 138 kV line to increase the SE rating. The sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 23 mile section of line would need to be rebuilt. PJM Network Upgrade	$92,000
		If the Sag Study will not be sufficient to mitigate the tower outage, the W4-004 Tap – Madison 138 kV section of the Madison – Tanners Creek 138 kV circuit will have to be rebuilt/reconductored depending on the existing structures. This section of line is approximately 23.0 miles.	$34,500,000
	n5508	Install +150/-75 MVAR SVC at the point of interconnection to mitigate dynamic compensation	$45,000,000
		Total Estimated Cost for Project AB2-065	**$47,592,000**

Table 3

These estimates are preliminary in nature, as they were determined without the benefit of detailed engineering studies. Final estimates will require an on-site review and coordination to determine final construction requirements.

Figure 1: Point of Interconnection (New Rushmay 138 kV Switching Station)

Single-Line Diagram

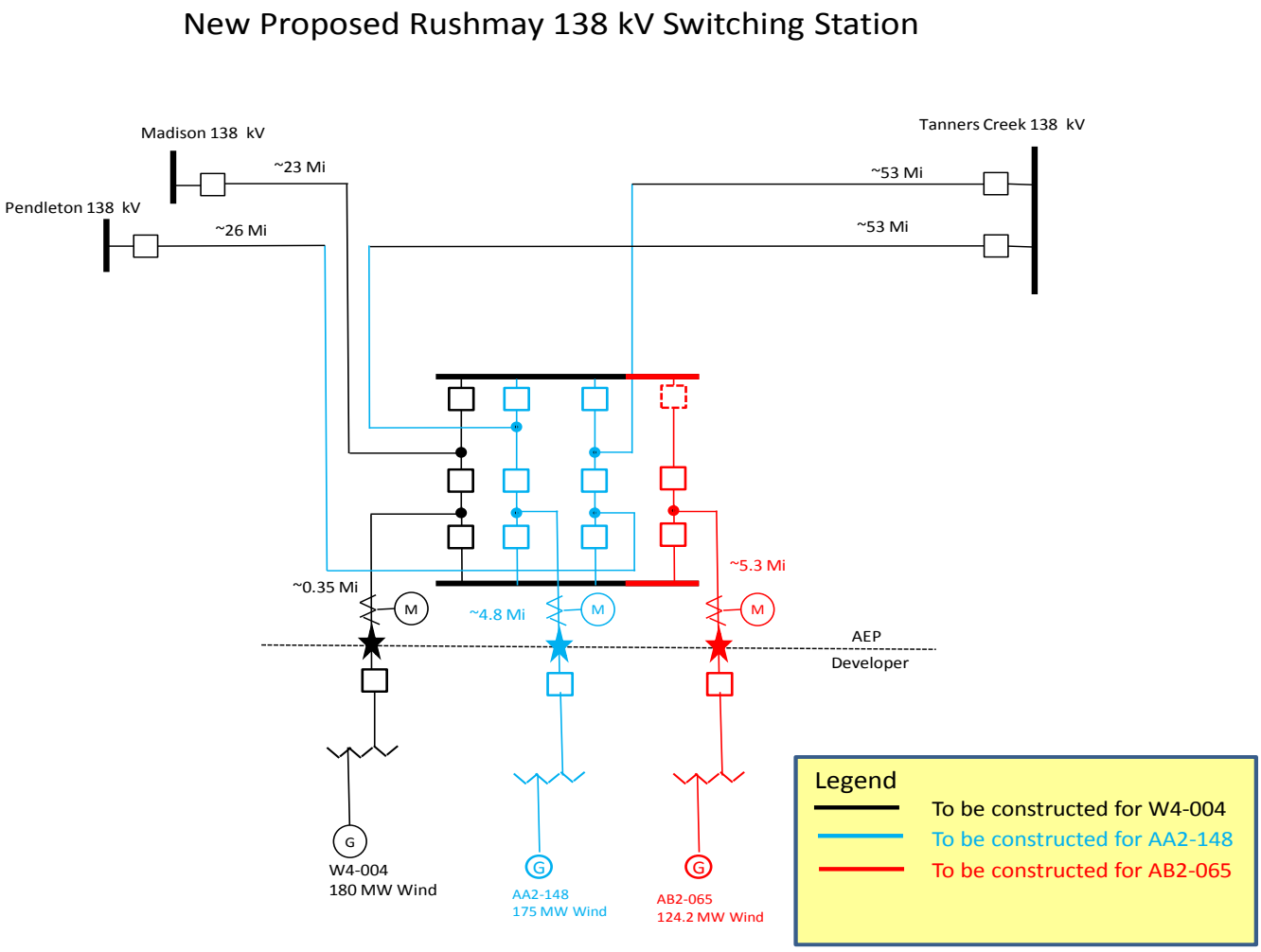
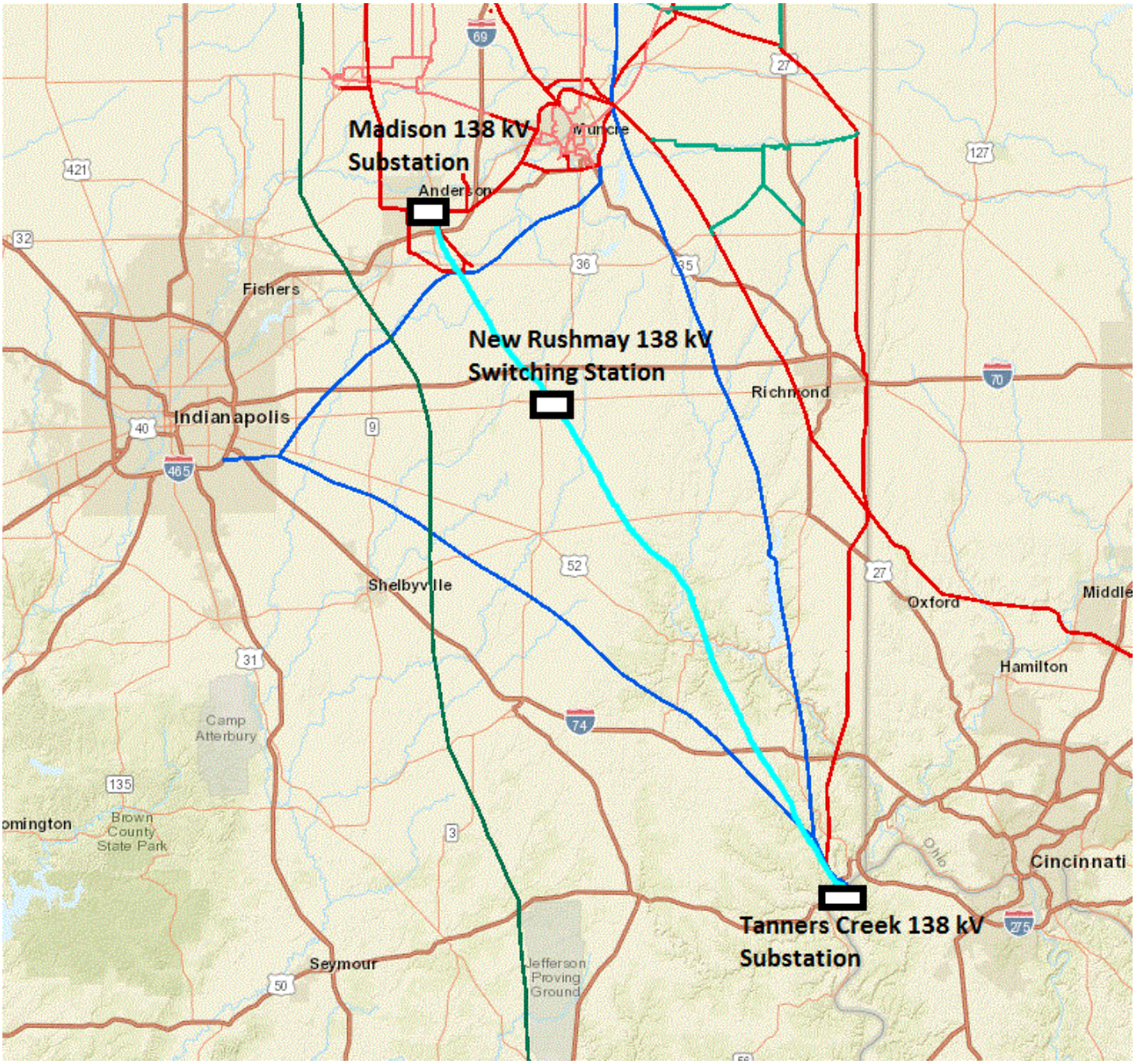


Figure 2: Point of Interconnection (New Rushmay 138 kV Switching Station)



Attachment 1

AB2-065

System Impact Study

Dynamic Simulation Analysis

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Executive Summary

Generator Interconnection Request AB2-065 is for a 124.2 MW Maximum Facility Output (MFO) wind powered facility consisting of 36 x Vestas 3.45 MW wind turbines. AB2-065 has a Point of Interconnection (POI) at the W4-004/AA2-148 tap of the Madison – Tanners Creek 138 kV circuit in the American Electric Power (AEP) transmission system, Fayette County, Indiana.

The dynamic model for the AB2-065 plant is based on the Vestas Gridstreamer v8.1.1 PSS/E user defined model supplied by PJM, as indicated by the developer in the System Impact Study Data Form.

Figure 1 shows the simplified one-line diagram of the AB2-065 loadflow model. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AB2-065 loadflow model.

This report describes a dynamic simulation analysis of AB2-065 as part of the overall system impact study.

AB2-065 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 74 contingencies were studied, each with at least a 10 second simulation time period. Studied scenarios included:

a) Steady state operation (20 second simulation);

b) Three-phase faults with normal clearing time;

c) Single-phase faults with stuck breaker;

d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from fault due to primary communications/relay failure.

No relevant Bus, or High Speed Reclosing (HSR) 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 contingency 1T.05 (fault at W4-004/AB2-065 138 kV on Madison circuit 1 resulting in tower failure, fault cleared with loss of Pendleton circuit) results in W4-004_W4-008 being tripped off on Low Voltage Ride-Through (LVRT) protection. Also, low voltage issues were observed for P6.02 cotingency.

With AB2-065 out of service, W4-004_W4-008 does not trip on LVRT for these contingencies.

As the low voltages leading to the W4-004_W4-008 to trip occur after a contingency has occurred, mitigation of dynamic compensation of upto **+150/-75 MVAR** at AB2-065 POI was attempted. The addition of compensation resolved the tripping and low voltage issues. Therefore the dynamic compensation is a required upgrade for AB2-065 project.

1. Introduction

Generator Interconnection Request AB2-065 is for a 124.2 MW Maximum Facility Output (MFO) wind powered facility consisting of 36 x Vestas 3.45 MW wind turbines. AB2-065 has a Point of Interconnection (POI) at the W4-004/AA2-148 tap of the Madison – Tanners Creek 138 kV circuit in the American Electric Power (AEP) transmission system, Fayette County, Indiana.

Dynamic simulation analysis is required as part of PJM's Generation and Transmission Interconnection Process. This Scope of Work describes how the dynamic simulation analysis of AB2-065 will be carried out as part of the overall system impact study.

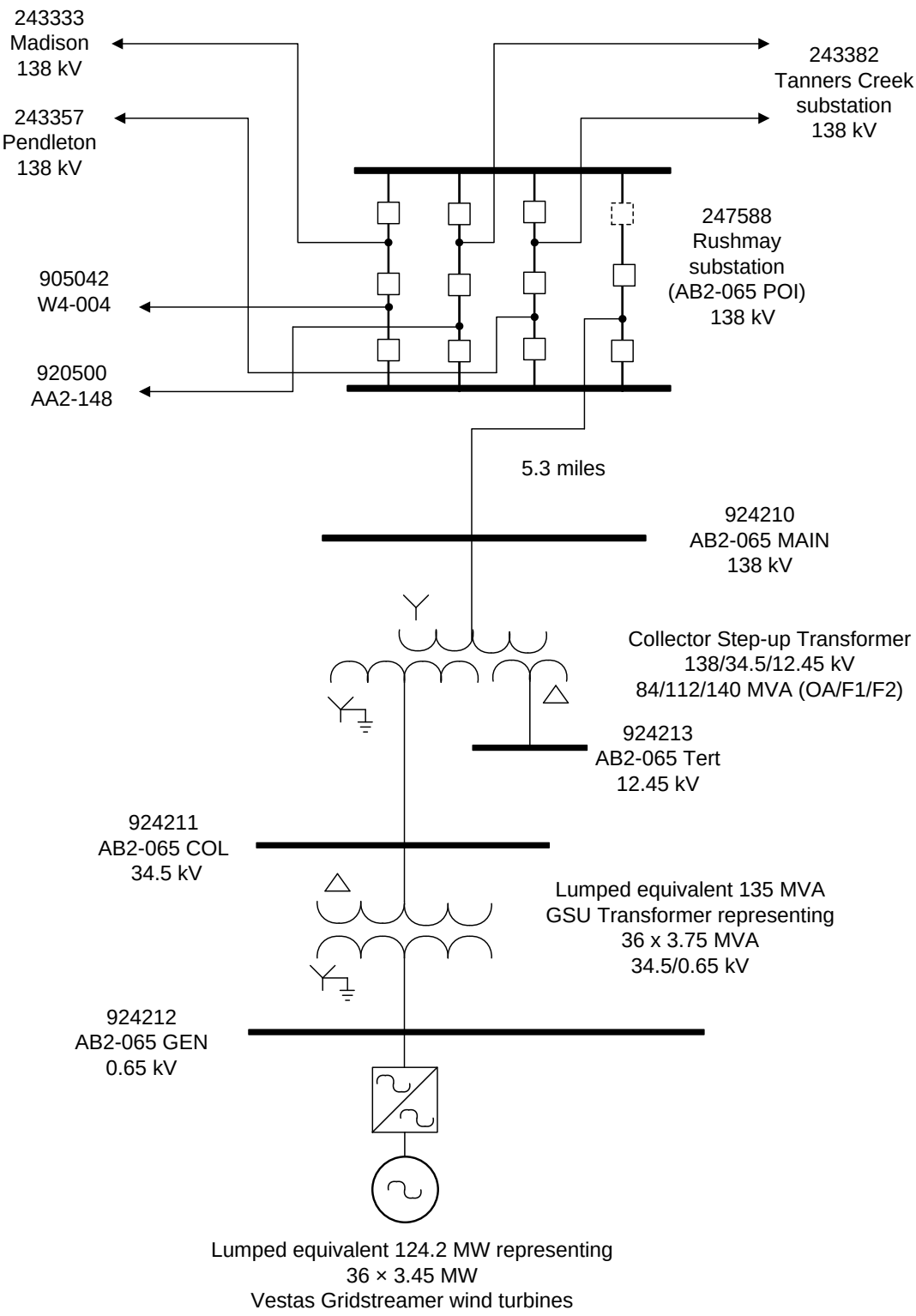

Figure 1: AB2-065 Plant Model

Table 1: AB2-065 Plant Model

	Impact Study Data	Model
Inverter Type	36 x Vestas Gridstreamer 3.45 MW wind turbine generators MVA base = 3.8 MVA Vt = 650 kV Unsaturated sub-transient reactance = j0 pu @ MVA base	Lumped equivalent representing 36 x Vestas Gridstreamer 3.45 MW wind turbine generators Pgen 124.2 MW Pmax 124.2 MW Pmin 0 MW Qgen 8.15 MVAr Qmax 40.986 MVAr Qmin -40.986 MVAr Mbase 136.8 MVA Zsorce Mbase 0.0052 + j0.859 pu @
GSU transformer(s)	36 x 34.5/0.065 kV Delta-Wye Gnd Transformers Rating = 3.75 MVA (OA) Transformer base = 3.75 MVA Impedance = 0.00695 + j0.0897 pu @ MVA base Number of taps = 5 Tap step size = 2.5	Lumped equivalent representing 36 x 34.5/0.65 kV 3.75 MVA transformers Transformer base = 135 MVA Rating = 135 MVA Impedance = 0.00695 + j0.0897 pu @ MVA base Number of taps = 5 Tap step size = 2.5%

Main collector step-up transformer	138/34.5/12.45 kV Wye//Wye Grd/ Delta Transformer Rating = 84/112/140 MVA (OA/F1/F2) Transformer base = 84 MVA Impedance HV to LV: 0.004 + j0.1049 HV to Tertiary: 0.005 + j0.1248 LV to Tertiary: 0.001 + 0.0299 @ MVA base Number of taps = 33 Tap step size = 0.375%	138/34.5/12.45 kV Transformer Transformer base = 84 MVA Rating = 84/112/140 MVA Impedance HV to LV: 0.004 + j0.1049 HV to Tertiary: 0.005 + j0.1248 LV to Tertiary: 0.001 + 0.0299 @ MVA base Number of taps = 33 Tap step size = 0.375%
Station load	0.1 MW + 0.01 MVAr LV side of GSU	Not modelled
Auxiliary load	2 MW + 0.2 MVAr LV side of GSU	Not modelled

2. PSS/E Load Flow and Dynamics Case Setup

The dynamics simulation analysis will be carried out using PSS/E Version 33.7.

The load flow scenario and fault cases for this study will be based on PJM's Regional Transmission Planning Process[3].

The selected load flow scenarios are the RTEP 2020 summer peak load case, with the following modifications:

a) Addition of all applicable queue projects prior to AB2-065.

b) Addition of AB2-065 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AB2-065.

d) Dispatch of units in the PJM system to maintain slack generators within limits.

e) Merchant transmission projects X3-028 and S57/S58 set online and at maximum power import into PJM.

In the load flow the AB2-065 generators will be set to maximum power output and unity power factor at the generator bus.

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AB2-065 will be dispatched online at maximum output (PMAX).

[3] Manual 14B: PJM Region Transmission Planning Process, Rev 19, September 15 2011, Attachment G : PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

3. Dynamic Fault Analysis

AB2-065 will be tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 53 contingencies will be studied, each with a 10 second simulation time period. Contingencies to be studied include:

e) Steady state operation (20 second simulation);

f) Three phase faults with normal clearing time;

g) Single-phase faults with phase delayed clearing due to a stuck breaker;

h) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from fault due to primary communications/relay failure.

i) Single phase faults with loss of multiple-circuit tower line;

No Bus contingencies were identified.

Buses at which the faults listed above will be applied are

- W4-004 TAP 138 kV (AB2-065 POI)
- Madison 138 kV
- Tanners Creek 138 kV
- U2-090 345 kV

Additional delayed (Zone 2) clearing at remote and faults will be applied on lines from College Corner 138 kV, Dearborn 345 kV, Desoto 345 kV, V4-033 345 kV, Miami For 345 kV, East Bend 345 kV, Hanna 345 kV, Lawrenceburg 345 kV towards the queue project.

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

A complete list of the contingencies that will be studied is outlined in Table 2 to Table 10. Clearing times listed are as per revision 17 of *2015 Revised Clearing times for each PJM company* spreadsheet.

Attachment 3 contains the one-line diagrams of the AEP network in the vicinity of AB2-065, showing where faults will be applied.

4. Evaluation Criteria

The results should indicate that, for the fault contingencies to be tested on the AB2-065 evaluation:

a) The system with AB2-065 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

b) The AB2-065 is able to ride through faults (except for faults where protective action trips AB2-065).

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

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

5. Summary of Results

Plots from the dynamic simulations with results summarized in Table 2 to Table 10.

For contingency 1T.05 (fault at W4-004/AB2-065 138 kV on Madison circuit 1 resulting in tower failure, fault cleared with loss of Pendleton circuit) results in W4-004_W4-008 being tripped off on Low Voltage Ride-Through (LVRT) protection. Also, low voltage issues were observed for P6.02 cotingency.

With AB2-065 out of service, W4-004_W4-008 does not trip on LVRT for these contingencies.

As the low voltages leading to the W4-004_W4-008 to trip occur after a contingency has occurred, mitigation of dynamic compensation of upto +150/-75 MVAR at AB2-065 POI was attempted. The addition of compensation resolved the tripping and low voltage issues.

All fault contingencies tested on the 2020 Summer Peak case met the recovery criteria:

a) AB2-065 was able to ride through the faults (except for faults where protective action tripped a generator(s)),

b) 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.

6. Recommendations and Mitigations

AB2-065 project will require +150/-75 MVAR SVC at the POI to stabilize the Madison/Pendleton DCT outage.

Table 2: Steady State Operation

Fault ID	Duration
SS.01	Steady state 20 sec

Table 3: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
3N.01	Fault at W4-004/AA2-148/AB2-065 138 kV POI on AB2-065 circuit (trips AB2-065).	5.5	Stable
3N.02	Fault at W4-004/AA2-148/AB2-065 138 kV POI on W4-004/W4-008 circuit (trips W4-004/W4-008).	5.5	Stable
3N.03	Fault at W4-004/AA2-148/AB2-065 138 kV POI on Madison circuit.	5.5	Stable
3N.04	Fault at W4-004/AA2-148 Tap 138 kV POI on Tanners Creek circuit 1.	5.5	Stable
3N.05	Fault at W4-004/AA2-148 Tap 138 kV POI on Tanners Creek circuit 2.	5.5	Stable
3N.06	Fault at W4-004/AA2-148 Tap 138 kV POI on Pendleton circuit.	5.5	Stable
3N.07	Fault at Madison 138 kV on W4-004/AA2-148/AB2-065 (Tanners Creek) circuit.	5.5	Stable
3N.08	Fault at Madison 138 kV on Delco Remy 5 circuit.	5.5	Stable
3N.09	Fault at Madison 138 kV on Fall Creek circuit.	5.5	Stable
3N.10	Fault at Madison 138 kV on Daleville – Medford – Desoto circuit.	5.5	Stable
3N.11	Fault at Madison 138 kV on Meadowbrook – Pendleton circuit.	5.5	Stable
3N.12	Fault at Madison 138 kV on Cross Street Tap – Arnold Hogan circuit.	5.5	Stable
3N.13	Fault at Tanners Creek 138 kV on W4-004/AA2-148/AB2-065 circuit 1.	5.5	Stable
3N.14	Fault at Tanners Creek 138 kV on W4-004/AA2-148/AB2-065 circuit 2.	5.5	Stable
3N.15	~~Fault at Tanners Creek 138 kV on Tanners Creek Generating Unit 1.~~	5.5	Stable
3N.16	~~Fault at Tanners Creek 138 kV on Tanners Creek Generating Unit 2.~~	5.5	Stable
3N.17	Fault at Tanners Creek 138 kV on Drewersburg – College Corner circuit 1.	5.5	Stable
3N.18	Fault at Tanners Creek 138 kV on Wesley switch – College Corner circuit 2.	5.5	Stable
3N.19	Fault at Tanners Creek 138 kV on 138 kV / 345 kV Transformer T-5.	5.5	Stable
3N.20	Fault at Pendleton 138 kV on W4-004/AA2-148/AB2-065 circuit.	5.5	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
3N.21	Fault at Pendleton 138 kV on Falls Creek circuit.	5.5	Stable
3N.22	Fault at Pendleton 138 kV on Rose Hill – Linwood – South Elwood Tap Sw. – Strawton circuit.	5.5	Stable
3N.23	Fault at Pendleton 138 kV on Pendleton 138 kV / 34 kV Transformer 2.	5.5	Stable
3N.24	Fault at Pendleton 138 kV on Meadowbrook – Madison circuit.	5.5	Stable

Table 4: Single-phase Faults With Stuck Breaker

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
1B.01	Fault at W4-004/AA2-148/AB2-065 138 kV POI on AA2-148 circuit (trips AA2-148). Center breaker stuck. Fault cleared with loss of Tanners Creek circuit.	5.5 / 16	Stable
1B.02	Fault at W4-004/AA2-148/AB2-065 138 kV POI on W4-004 circuit (trips W4-004/W4-008). Center breaker stuck. Fault cleared with loss of Madison circuit.	5.5 / 16	Stable
1B.03	Fault at W4-004/AA2-148/AB2-065 138 kV POI on Madison circuit. Center breaker stuck. Fault cleared with loss of W4-004/008 (Trips W4-004/008).	5.5 / 16	Stable
1B.04	Fault at W4-004/AA2-148/AB2-065 138 kV POI on Tanners Creek circuit 1. Center breaker stuck. Fault cleared with loss of Pendleton circuit.	5.5 / 16	Stable
1B.05	Fault at W4-004/AA2-148/AB2-065 138 kV POI on Tanners Creek circuit 2. Center breaker stuck. Fault cleared with loss of AA2-148 circuit (Trips AA2-148).	5.5 / 16	Stable
1B.06	Fault at W4-004/AA2-148 Tap 138 kV on Pendleton circuit. Center breaker stuck. Fault cleared with loss of Tanners Creek circuit 1.	5.5 / 16	Stable
1B.07	Fault at Madison 138 kV on W4-004/AA2-148/AB2-065 (Tanners Creek) circuit. Breaker U stuck. Fault cleared with loss of Daleville – Desoto circuit and Delco Remy 5 circuit.	5.5 / 16	Stable
1B.08	Fault at Madison 138 kV on Delco Remy 5 circuit. Breaker Y stuck. Fault cleared with loss of W4-004/AA2-148/AB2-065 circuit and Daleville – Desoto circuit.	5.5 / 16	Stable
1B.09	Fault at Madison 138 kV on Fall Creek circuit. Breaker T stuck. Fault cleared with loss of Cross Street Tap – Arnold Hogan circuit, Meadowbrook – Pendleton circuit and Madison 138 kV / 34 kV Transformer 1.	5.5 / 16	Stable
1B.10	Fault at Madison 138 kV on Daleville – Desoto circuit. Breaker N stuck. Fault cleared with loss of W4-004/AA2-148/AB2-065 (Tanners Creek) circuit and Delco Remy 5 circuit.	5.5 / 16	Stable
1B.11	Fault at Madison 138 kV on Meadowbrook – Pendleton circuit. Breaker X stuck. Fault cleared with loss of Cross Street Tap – Arnold Hogan circuit, Fall Creek circuit and Madison 138 kV / 34 kV Transformer 1.	5.5 / 16	Stable
1B.12	Fault at Tanners Creek 138 kV on W4-004/AA2-148/AB2-065 circuit 1. Breaker B stuck. Fault cleared with loss of Wesley Switch – College Corner circuit 2.	5.5 / 16	Stable
1B.13	Fault at Tanners Creek 138 kV on W4-004/AA2-148/AB2-065 circuit 2. Breaker A stuck. Fault cleared with loss of Drewersburg – College Corner circuit 1.	5.5 / 16	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
1B.14	~~Fault at Tanners Creek 138 kV on Tanners Creek Generating Unit 1. Breaker G stuck. Fault cleared with loss of Wesley Switch – College Corner circuit 2 and W4-004/AA2-148/AA2-148 (Madison) circuit.~~	5.5 / 16	Stable
1B.15	~~Fault at Tanners Creek 138 kV on Tanners Creek Generating Unit 1. Breaker H stuck. Fault cleared with loss of Wesley Switch – College Corner circuit 1 and Pendleton circuit.~~	5.5 / 16	Stable
1B.16	~~Fault at Tanners Creek 138 kV on Tanners Creek Generating Unit 2. Breaker F stuck. Fault cleared with loss of Drewersburg – College Corner circuit 1 and Pendleton circuit.~~	5.5 / 16	Stable
1B.17	~~Fault at Tanners Creek 138 kV on Tanners Creek Generating Unit 2. Breaker E stuck. Fault cleared with loss of Wesley Switch – College Corner circuit 2 and W4-004/AA2-148/AA2-148 (Tanners Creek) circuit.~~	5.5 / 16	Stable
1B.18	Fault at Tanners Creek 138 kV on Drewersburg – College Corner circuit 1. Breaker C stuck. Fault cleared with loss of Pendleton circuit.	5.5 / 16	Stable
1B.19	Fault at Tanners Creek 138 kV on Wesley switch – College Corner circuit 2. Breaker D stuck. Fault cleared with loss of W4-004/AA2-148/AB2-065 (Madison) circuit.	5.5 / 16	Stable
1B.20	Fault at Tanners Creek 138 kV on 345 kV / 138 kV transformer T-5. Breaker J stuck. Fault cleared with loss of Wesley Switch – College Corner circuit 2 and W4-004/AA2-148/AB2-065 (Madison) circuit.	5.5 / 16	Stable
1B.21	Fault at Tanners Creek 138 kV on 345 kV / 138 kV transformer T-5. Breaker K stuck. Fault cleared with loss of Drewersburg – College Corner circuit 1 and Pendleton circuit.	5.5 / 16	Stable
1B.22	Fault at Pendleton 138 kV on W4-004/AA2-148/AB2-065 circuit. Breaker B stuck. Fault cleared with loss of Meadowbrook – Madison circuit.	5.5 / 16	Stable
1B.23	Fault at Pendleton 138 kV on Falls Creek circuit. Breaker M stuck. Fault cleared with loss of Rose Hill – Linwood – South Elwood Tap Sw. circuit and Pendleton 138 kV / 34 kV Transformer 2.	5.5 / 16	Stable
1B.24	Fault at Pendleton 138 kV on Rose Hill – Linwood – South Elwood Tap Sw. – Strawton circuit. Breaker A stuck. Fault cleared with loss of Fall creek circuit and Pendleton 138 kV / 34 kV Transformer 2.	5.5 / 16	Stable
1B.25	Fault at Pendleton 138 kV on Meadowbrook – Madison circuit. Breaker N stuck. Fault cleared with loss of W4-004/AA2-148/AB2-065 circuit.	5.5 / 16	Stable
1B.26	Fault at W4-004/AA2-148/AB2-065 138 kV POI on AB2-065 circuit (trips AB2-065). Breaker stuck. Fault cleared with no additional loss.	5.5 / 16	Stable

Table 5: Single-phase Faults With Delayed (Zone 2) Clearing at line end closest to AB2-065 POI

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
1D.01	Fault at 80% of 138 kV line from W4-004/AA2-148/AB2-065 138 kV POI to Madison. Delayed clearing at W4-004/AA2-148/AB2-065.	5.5 / 60	Stable
1D.02	Fault at 80% of 138 kV line from W4-004/AA2-148/AB2-065 138 kV POI to Tanners Creek circuit 1. Delayed clearing at W4-004/AA2-148/AB2-065.	5.5 / 60	Stable
1D.03	Fault at 80% of 138 kV line from W4-004/AA2-148/AB2-065 138 kV POI to Tanners Creek circuit 2. Delayed clearing at W4-004/AA2-148/AB2-065.	4.5 / 60	Stable
1D.04	Fault at 80% of 138 kV line from W4-004/AA2-148/AB2-065 138 kV POI to Pendleton circuit. Delayed clearing at W4-004/AA2-148/AB2-065.	4.5 / 60	Stable
1D.05	Fault at 80% of 138 kV line from Madison 138 kV to (Cross Street Tap) Arnold Hogan. Delayed clearing at Madison.	5.5 / 60	Stable
1D.06	Fault at 80% of 138 kV line from Madison 138 kV to (Daleville) Desoto. Delayed clearing at Madison.	5.5 / 60	Stable
1D.07	Fault at 80% of 138 kV line from Madison 138 kV to Fall Creek. Delayed clearing at Madison.	5.5 / 60	Stable
1D.08	Fault at 80% of 138 kV line from Madison 138 kV to Delco Remy 5. Delayed clearing at Madison.	5.5 / 60	Stable
1D.09	Fault at 80% of 138 kV line from Madison 138 kV to (Meadowbrook) Pendleton. Delayed clearing at Madison.	5.5 / 60	Stable
1D.10	Fault at 80% of 138 kV line from Tanners Creek 138 kV to (Drewersburg) College Corner on circuit 1. Delayed clearing at Tanners Creek.	5.5 / 60	Stable
1D.11	Fault at 80% of 138 kV line from Tanners Creek 138 kV to (Wesley Switch) College Corner on circuit 2. Delayed clearing at Tanners Creek.	5.5 / 60	Stable
1D.12	Fault at 80% of line from Tanners Creek 345 kV to Dearborn. Delayed clearing at Tanners Creek.	4.5 / 60	Stable
1D.13	Fault at 80% of line from Tanners Creek 345 kV to Desoto on circuit no. 1. Delayed clearing at Tanners Creek.	4.5 / 60	Stable
1D.14	Fault at 80% of line from Tanners Creek 345 kV to V4-033 (Desoto) on circuit no. 2. Delayed clearing at Tanners Creek.	4.5 / 60	Stable
1D.15	Fault at 80% of line from Tanners Creek 345 kV to Miami Fort. Delayed clearing at Tanners Creek.	4.5 / 60	Stable
1D.16	Fault at 80% of line from Tanners Creek 345 kV to East Bend. Delayed	4.5 / 60	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
	clearing at Tanners Creek.		
1D.17	Fault at 80% of line from Pendleton 138 kV to Fall Creek. Delayed clearing at Pendleton.	4.5 / 60	Stable
1D.18	Fault at 80% of line from Pendleton 138 kV to Rose Hill – Linwood – South Elwood Tap Sw. – Strawton circuit. Delayed clearing at Pendleton.	4.5 / 60	Stable
1D.19	Fault at 80% of line from Pendleton 138 kV to Meadowbrook – Madison circuit. Delayed clearing at Pendleton.	4.5 / 60	Stable

Table 6: Single-phase Faults With Loss of Multiple-Circuit Tower Line

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
1T.01	Fault at Tanners Creek 345 kV on V4-033 (Desoto) circuit 2 resulting in tower failure. Fault cleared with loss of U2-090 (Desoto) circuit 2. CONTINGENCY 6873'	4.5	Stable
1T.02	Fault at V4-033 345 kV on U2-090 (Desoto) circuit 2 resulting in tower failure. Fault cleared with loss of Tanners Creek circuit 2 (Trips V4-033). CONTINGENCY '8713'	4.5	Stable
1T.03	Fault at Tanners Creek 138 kV on W4-004/008/AB2-065 circuit 1 resulting in tower failure. Fault cleared with loss of W4-004/AB2-065 circuit 2.	4.5	Stable
1T.04	Fault at Madison 138 kV on W4-004/AB2-065 circuit 1 resulting in tower failure. Fault cleared with loss of Falls creek circuit.	4.5	Stable
1T.05	Fault at W4-004/AB2-065 138 kV on Madison circuit 1 resulting in tower failure. Fault cleared with loss of Pendleton circuit.	4.5	Stable (with mitigation)
1T.06	Fault at Pendleton 138 kV on Fall Creek circuit 1 resulting in tower failure. Fault cleared with loss of W4-004/AB2-065 circuit.	4.5	Stable
1T.07	Fault at AB2-065 POI – Tanners Creek 138 kV circuit#1 resulting in tower failure. Fault cleared with loss of AB2-065 POI – Tanners Creek 138 kV circuit#2	4.5	Stable

Table 7: Three-phase faults with Unsuccessful High Speed Reclosing

Fault ID	Fault description	Clearing near / HSR Times (Cycles)	Results

Fault ID	Fault description	Clearing near / HSR Times (Cycles)	Results
3R.01	Fault at Tanners Creek 138 kV on AB2-065 POI circuit#1 • Fault cleared after 5.5 cycles with loss of AB2-065 POI circuit#1 • High speed reclosers 'A' close after 15.5 cycles (21 cycles total) reconnecting AB2-065 POI circuit#1 • Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening AB2-065 POI circuit#1	5.5/15.5	Stable
3R.02	Fault at Tanners Creek 138 kV on AB2-065 POI circuit#2 • Fault cleared after 4.5 cycles with loss of AB2-065 POI circuit#2 • High speed reclosers 'B' close after 15.5 cycles (21 cycles total) reconnecting AB2-065 POI circuit#2 • Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening AB2-065 POI circuit#2	5.5/15.5	Stable
3R.03	Fault at Tanners Creek 138 kV on College Corner circuit#1 • Fault cleared after 4.5 cycles with loss of College Corner circuit#1 • High speed reclosers 'C' close after 15.5 cycles (21 cycles total) reconnecting College Corner circuit#1 • Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening College Corner circuit#1	5.5/15.5	Stable
3R.04	Fault at Tanners Creek 138 kV on College Corner circuit#2 • Fault cleared after 4.5 cycles with loss of College Corner circuit#2 • High speed reclosers 'C' close after 15.5 cycles (21 cycles total) reconnecting College Corner circuit#2 Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening College Corner circuit#2	5.5/15.5	Stable
3R.05	Fault at Tanners Creek 345 kV on Losantville circuit#1 • Fault cleared after 4.5 cycles with loss of Losantville circuit#1 • High speed reclosers 'P2' and 'P' close after 15.5 cycles (21 cycles total) reconnecting Losantville circuit#1 • Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening Losantville circuit#1	5.5/15.5	Stable
3R.06	Fault at Tanners Creek 345 kV on Losantville circuit#2 • Fault cleared after 4.5 cycles with loss of Losantville circuit#2 • High speed reclosers 'Q2' and 'Q' close after 15.5 cycles (21 cycles total) reconnecting Losantville circuit#2 • Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening Losantville circuit#2	5.5/15.5	Stable

Fault ID	Fault description	Clearing near / HSR Times (Cycles)	Results
3R.07	Fault at Tanners Creek 345 kV on Hanna circuit • Fault cleared after 4.5 cycles with loss of Hanna circuit • High speed reclosers 'R2' and 'R' close after 15.5 cycles (21 cycles total) reconnecting Hanna circuit • Reclose unsuccessful, fault cleared after 5.5 cycles (26.5 cycles total) by opening Hanna circuit	5.5/15.5	Stable

1. Prior outage of W4-004/AB2-065 POI – Madison 138 kV line

Table 8: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P6.01	Fault at W4-004/AB2-065 POI – Tanners Creek 138 kV line	4.5	Stable

2. Prior outage of W4-004/AB2-065 POI – Madison 138 kV line

Table 9: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P6.02	Fault at W4-004/AB2-065 POI – Pendleton 138 kV line	4.5	Stable

3. Prior outage of W4-004/AB2-065 POI – Pendleton 138 kV line

Table 10: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P6.03	Fault at W4-004/AB2-065 POI – Tanners Creek 138 kV line	4.5	Stable

4. Prior outage of W4-004/AB2-065 POI – Tanners Creek 138 kV circuit#1

Table 11: Three-phase Faults With Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Results
P6.04	W4-004/AB2-065 POI – Tanners Creek 138 kV circuit#2	4.5	Stable