# *PJM Generator Interconnection Request Queue #V4-010 Fremont Center-Tiffin Center (Seneca) 138kV Impact Study*

**611338**

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# V4-010 Fremont Center-Tiffin Center (Seneca) 138kV Impact Study Report

## General

Nordex has proposed installing a 200 MW wind project, consisting of 80 2.5 MW Nordex wind turbines, in Seneca County, Ohio. The project will be connected directly to the Fremont Center-Tiffin Center 138kV transmission line. The western boundary of the project is 4.5 to 5 miles east of the Tiffin Center-Freemont Center line. The center of the project is about 10 miles east of the line. The in-service date for the project is December 31, 2013.

The intent of the Impact study is to determine system reinforcements and associated costs and construction time estimates required to facilitate the addition of the new generating plant to the transmission system. The reinforcements include the direct connection of the generator to the system and any network upgrades necessary to maintain the reliability of the transmission system.

## Attachment Facilities

The V4-010 project will be connected to the transmission system via a new 3-breaker, 138kV, ring bus station. The new station will be connected into the Freemont Center-Tiffin Center 138kV transmission line.Nordex will build a 138kV transmission line from the project collector station to the new interconnection station.

It is understood that Nordex will be responsible for all the costs associated with this construction, as well as facilities associated with connecting their 200MW of generation to the in-line facilities

The AEP design and construction scope for the attachment facilities:

- Construct a new 138 kV interconnection substation to include 3 circuit breakers, relaying, 138kV revenue metering and facilities to accommodate termination of a new 138 kV line from V4-010 collector station. (Network Upgrade #n3134)

  Estimated Cost (2011 Dollars)*: **$5,000,000**

- Install transmission line structures to permit termination of the 138kV line in the interconnection substation. (Network Upgrade #n3135)

  Estimated Cost (2011 Dollars)*: **$500,000**

- Replace relay and controls at Freemont Center Station. (Network Upgrade #n3136)

Estimated Cost (2011 Dollars)*: **$250,000**

- Replace relay and controls at Freemont Center Station. (Network Upgrade #n3137)

  Estimated Cost (2011 Dollars)*: **$250,000**

- Replace relay and controls at West Freemont Station (FE).

  Estimated Cost (2011 Dollars)*: **$250,000**

Total estimated cost is **$6,250,000**

The requested in-service date is December 2013. The standard time required for construction is 18 months after signing of the Interconnection Service Agreement and Interconnection Construction Service Agreement.

An Interim Interconnection Service Agreement can be executed to facilitate meeting the requested date.

## AEP Local Network Impacts

The impact of the proposed generating facility was assessed for AEP planning criteria specifically that the transmission system meet single contingency performance based on the AEP FERC Form 715 criteria. The Everpower project was studied as both a 200 MW and a 26MW net energy injection. The results are summarized below.

Normal System (NERC Category A)– Capacity Output (2013 Summer Conditions)

- No problems identified.

Single Contingency (NERC Category B) – Capacity Output (2013 Summer Conditions)

- No problems identified.

Multiple Contingency (NERC Category C) – Full Output (2013 Summer Conditions)

- No problems identified.

Short Circuit Analysis

- No problems identified.

Stability Analysis

- For a double contingency outage of Tiffin Center – Fremont Center 138kV and the Melmore – Fostoria Central 138kV lines an unstable result is expected.

- For a double contingency outage of the Greenlawn – Melmore 138kV and the Fremont Center – Tiffin Center 138kV lines an unstable result is expected.

Both scenarios shown above can be solved by curtailment.

Local/Network Upgrades

- None.

Contributions to Previously Identified Local/Network Limitations (Full Output)

- None.

Additional Limitations of Concern – Full Output

- None.

## Network Impacts

The Queue Project #V4-010 was studied as a(n) 200.0MW(Capacity=26.0MW) injection at Freemont Center-Tiffin Center 138 kV transmission line in the AEP area. Project #V4-010 was evaluated for compliance with reliability criteria for summer peak conditions in 2014. Potential network impacts were as follows:

**Generator Deliverability**
*(Single or N-1 contingencies for the Capacity portion only of the interconnection)*

No problems identified.

**Multiple Facility Contingency**
*(Double Circuit Tower Line, Line with Failed Breaker and Bus Fault contingencies for the full energy output)*

No problems identified

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

No problems identified.

**Stability**

PJM queue projects V4-010 is a new 200 MW interconnection requests tapping the existing Tiffin Center 138 kV substation in the AEP system. This is a Nordex N90 2.5 MW based wind farm with 80 generators.

Stability analysis for the V4-010 queue project was performed at 2014 light and peak load conditions. The range of contingencies evaluated was limited to that necessary to assess compliance with AEP criteria. Simulation time was limited to 10 seconds for all faults.

Three fault types were considered in this study:

- Type A: Three-phase faults (3ph) with primary clearing time
- Type B: Stuck breaker fault cleared with backup clearing time
- Type C: Zone 2 faults cleared with secondary protection

Specific fault descriptions and breaker clearing times used for this study are provided in Appendix A.

**Results**

**Transient Stability:**

For all cases studied, transient stability is maintained with all oscillations stabilized in less than 10 seconds. Also, the voltage levels returned to normal for all cases following the fault clearance. Hence, no transient stability issues were concluded.

The maximum angle deviations for all three fault types are shown in Tables I - VI.

Table I. Maximum angle deviation for Type A faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1A | 418 | 243515 | 1 | 84.12 | -5.241 | 10.000 |
| 2A | 356 | 242940 | 4 | 82.58 | -2.034 | 0.7126 |
| 3A | 357 | 242940 | 5 | 93.54 | -2.684 | 0.5792 |
| 4A | 357 | 242940 | 5 | 93.54 | -2.666 | 0.5959 |
| 5A | 357 | 242940 | 5 | 93.54 | -2.723 | 0.5834 |
| 6A | 376 | 243190 | 1 | 102.8 | -2.450 | 2.1960 |
| 7A | 376 | 243190 | 1 | 102.8 | -2.722 | 2.1960 |
| 8A | 376 | 243190 | 1 | 102.8 | -2.719 | 2.1960 |
| 9A | 412 | 243440 | 1 | 108.9 | -2.608 | 4.2379 |

Table II. Maximum angle deviation for Type A faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1A | 359 | 242940 | D | 52.16 | -1.958 | 9.9882 |
| 2A | 356 | 242940 | 4 | 51.15 | -1.281 | 0.8167 |
| 3A | 356 | 242940 | 4 | 51.15 | -1.696 | 0.8084 |
| 4A | 356 | 242940 | 4 | 51.15 | -1.659 | 0.8167 |
| 5A | 356 | 242940 | 4 | 51.15 | -1.745 | 0.8167 |
| 6A | 381 | 243195 | 2 | 51.32 | -1.58 | 2.5919 |
| 7A | 381 | 243195 | 2 | 51.32 | -1.78 | 2.5919 |
| 8A | 381 | 243195 | 2 | 51.32 | -1.783 | 2.5919 |
| 9A | 381 | 243195 | 2 | 51.32 | -1.652 | 2.5919 |

Table III. Maximum angle deviation for Type B faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1B | 412 | 243440 | 1 | 108.9 | -4.798 | 9.9799 |
| 2B | 412 | 243440 | 1 | 108.9 | -4.716 | 9.9799 |
| 3B1 | 356 | 242940 | 4 | 82.58 | -3.446 | 0.8417 |
| 3B2 | 356 | 242940 | 4 | 82.58 | -3.522 | 0.8417 |
| 4B1 | 376 | 243190 | 1 | 102.8 | -7.641 | 9.9799 |
| 4B2 | 356 | 242940 | 4 | 82.58 | -3.221 | 0.8417 |
| 5B1 | 356 | 242940 | 4 | 82.58 | -2.502 | 0.8042 |
| 5B2 | 412 | 243440 | 1 | 108.9 | -7.497 | 9.9799 |
| 6B | 412 | 243440 | 1 | 108.9 | -6.236 | 9.9799 |
| 7B | 376 | 243190 | 1 | 102.8 | 2.905 | 1.7918 |
| 8B | 412 | 243440 | 1 | 108.9 | -8.026 | 9.9799 |
| 9B | 376 | 243190 | 1 | 102.8 | -13.82 | 9.9799 |

Table IV. Maximum angle deviation for Type B faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1B | 359 | 242940 | D | 52.16 | -1.517 | 9.9799 |
| 2B | 359 | 242940 | D | 52.16 | -1.521 | 9.9799 |
| 3B1 | 356 | 242940 | 4 | 51.15 | -1.814 | 0.9126 |
| 3B2 | 356 | 242940 | 4 | 51.15 | -1.951 | 0.9209 |
| 4B1 | 359 | 242940 | D | 52.16 | -3.949 | 9.9799 |
| 4B2 | 356 | 242940 | 4 | 51.15 | -1.678 | 0.9167 |
| 5B1 | 356 | 242940 | 4 | 51.15 | -1.277 | 0.8959 |

Table IV. Maximum angle deviation for Type B faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 5B2 | 359 | 242940 | D | 52.16 | -3.871 | 9.9799 |
| 6B | 377 | 243191 | 2 | 63.19 | -2.753 | 9.9799 |
| 7B | 381 | 243195 | 2 | 51.32 | -2.087 | 2.7086 |
| 8B | 346 | 242933 | 1 | 42.31 | -4.174 | 9.9799 |
| 9B | 422 | 243654 | 3 | 64.88 | -7.331 | 9.9799 |

Table V. Maximum angle deviation for Type C faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1C | 418 | 243515 | 1 | 84.12 | -4.226 | 9.9799 |
| 2C | 356 | 242940 | 4 | 82.58 | -1.059 | 0.7792 |
| 3C | 356 | 242940 | 4 | 82.58 | -2.985 | 1.0501 |
| 4C | 356 | 242940 | 4 | 82.58 | -2.104 | 0.9751 |
| 5C | 356 | 242940 | 4 | 82.58 | -1.903 | 0.7792 |
| 6C | 356 | 242940 | 4 | 82.58 | -1.222 | 1.1459 |
| 7C | 356 | 242940 | 4 | 82.58 | -1.741 | 1.2001 |
| 8C | 356 | 242940 | 4 | 82.58 | -1.141 | 1.1751 |
| 9C | 356 | 242940 | 4 | 82.58 | -1.500 | 1.1626 |

Table VI. Maximum angle deviation for Type C faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1C | 359 | 242940 | D | 52.16 | -1.541 | 9.9799 |
| 2C | 422 | 243654 | 3 | 64.88 | -0.6469 | 1.7168 |
| 3C | 422 | 243654 | 3 | 64.88 | -2.182 | 1.5251 |
| 4C | 422 | 243654 | 3 | 64.88 | -1.324 | 1.5585 |
| 5C | 422 | 243654 | 3 | 64.88 | -1.245 | 1.6335 |
| 6C | 422 | 243654 | 3 | 64.88 | 0.9741 | 9.9799 |
| 7C | 422 | 243654 | 3 | 64.88 | -0.8438 | 1.9877 |
| 8C | 381 | 243195 | 2 | 51.32 | 0.6573 | 1.0543 |
| 9C | 381 | 243195 | 2 | 51.32 | 0.681 | 1.0543 |

The wind farm was modeled with two equivalent generators (WTGs) connected to Tiffin 138 kV bus through a single circuit transmission line and equivalent GSUs and main 34.5/138 kV step-up transformers. The reactive power range of each of the equivalent generator was set at +32.84 Mvar/ -44 Mvar (0.95 lagging and 0.9 leading power factor). The terminal voltage of each generator was set at 1.000 pu.

Low Voltage Ride-Through (LVRT): The LVRT test for V4-010 was performed by applying a three-phase 9-cycle fault at Tiffin 138 kV bus (POI) using the light and peak load base cases. It is noted that V4-010 stayed connected during these fault conditions.

The voltages at the collector buses and generator terminals are not adequate for simulating low voltage ride through test if the WTGs are dispatched at 0.95 leading power factor using the 2014 Summer Peak base-case. If the nearby reactive resources and taps of the main transformers and GSUs (which should not be) are exploited then voltages become acceptable. Under these conditions, a three-phase 9-cycle fault at the 138 kV tap point resulted in tripping of the WTGs on low voltage, which is primarily due to protection settings of Nordex WTGs. The WTGs stay on-line for a 7-cycle three phase-fault. However, for all the cases simulated, the V4-010 queue project rides through the faults specified in Section A.4.

Based on the above, it is concluded that V4-010 meets the LVRT test specified in FERC order 661 and 661A.

**Note**: While the stability analysis has been performed at extreme system conditions, there is a potential that evaluation at a different level of generator MW and/or MVAR output at different system load levels and operating conditions may disclose unforeseen stability problems. The regional reliability analysis routinely performed to test all system changes will include one such evaluation. Any problems uncovered in that or other operating or planning studies will need to be resolved.

Moreover, when the proposed generating station is designed and plant specific dynamics data for the plant and its controls are available, and if it is different than the data provided for this study, a transient stability analysis at a variety of expected operating conditions using the more accurate data shall be performed to verify impact on the dynamic performance of the system. As more accurate or unit specific dynamics data for the proposed facility, as well as plant layout become available, it must be forwarded to PJM.

## 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

## New System Reinforcements

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

None

## Contribution to Previously Identified System Reinforcements

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

None

### 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. The Melmore-Fostoria Central 138 kV line (from bus 243039 to bus 243006 ckt 1) loads from 65.44% to 110.13% (AC power flow) of its emergency rating (245 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('5149_B2_TOR709_WOMOAB'). This project contributes approximately 110.85 MW to the thermal violation.

2. The Melmore-Fostoria Central 138 kV line (from bus 243039 to bus 243006 ckt 1) loads from 82.04% to 116.22% (AC power flow) of its normal rating (167 MVA) for non-contingency condition. This project contributes approximately 58.42 MW to the thermal violation.

3. The Melmore-Howard 138 kV line (from bus 243039 to bus 243024 ckt 1) loads from 83.06% to 110.17% (AC power flow) of its normal rating (138 MVA) for non-contingency condition. This project contributes approximately 39.19 MW to the thermal violation.

4. The Howard-Brookside 138 kV line (from bus 243024 to bus 238586 ckt 1) loads from 145.11% to 150.01% (AC power flow) of its emergency rating (173 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('911_B2'). This project contributes approximately 18.83 MW to the thermal violation.

5. The Howard-Brookside 138 kV line (from bus 243024 to bus 238586 ckt 1) loads from 168.42% to 174.47% (AC power flow) of its normal rating (133 MVA) for

non-contingency condition. This project contributes approximately 17.87 MW to the thermal violation.

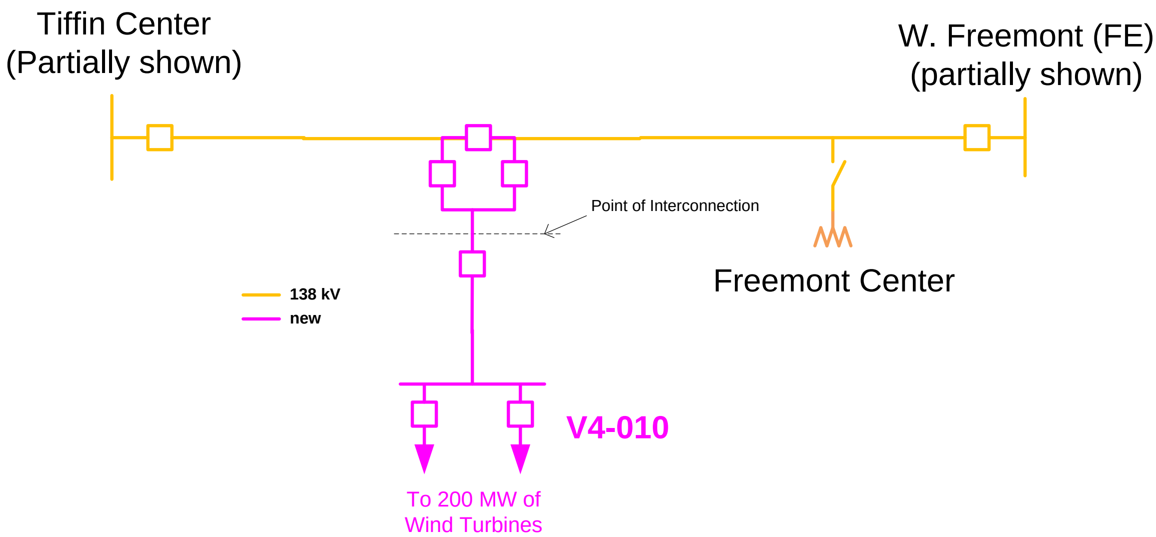
## ATSI Integration

V4-010 does not have any AEP violations, however, due to the recent integration of ATSI area into PJM, PJM is reviewing contingencies in the ATSI territory for all the queue projects in T, U, V, W1, W2, W3 queues that could affect ATSI facilities. Several violations due to contingencies in the ATSI area have been found. PJM is currently working with ATSI in resolving these issues. V4-010 could have some cost responsibility for the fixes to these violations. This analysis is ongoing and will be completed during the Facilities Study.

## Cost

The V4-010 project is responsible for 100% of the direct connection cost of **$6,000,000.** There are no network upgrades for the project. The total cost responsibility for the V4-010 project is **$6,000,000.**

**Figure #1**
**V4-010 Freemont Center-**
**Tiffin Center (Seneca)**
**138kV**



**APPENDIX A**
**V4-010**
**(Tiffin Center 138 kV)**

## A.1) POWER FLOW CONDITIONS

2014 Light and Peak Load Base Cases

## A.2) BREAKER CLEARING TIMES (CYCLES)

Table A.1. AEP Clearing Times (Cycles)

| Station | Primary (3ph/slg) | Stuck Breaker (Total) | Zone 2 (Total) | Re-closing |
|---|---|---|---|---|
| 500 kV | 4 | 14 | 4 | N/A |
| 345 kV | 4 | 15 | 4 | N/A |
| 230 kV | 5 | 15 | 5 | N/A |
| 115kV & 138 kV | 5 | 18 | 63 | N/A |

## A.3) NETWORK CONDITIONS

All facilities in service (base case)

## A.4) FAULTS CONSIDERED

*Note: For simplicity of fault type identification,* PJM *has adopted the following notation:*

A faults: *three-phase faults with normal clearing time*
B faults: *slg faults due to stuck breaker with delayed clearing time*
C faults: *slg faults with delayed clearing time due to protection system failure*

*This notation is for internal purposes only, and does not necessarily correspond with the NERC category definition stated in TPL-001.*

Tiffin Center 138 kV

1a 3ph fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Tiffin Center - Fremont Center 138 kV ckt 1
Fremont Center - Freemont 138 kV ckt 1
Tiffin Center 138 kV
Fremont Center 138 kV
V4-010

1b slg fault @ Tiffin Center 138 kV

Fault cleared within 138 kV breaker primary clearing time
Loss of: Fremont Center - Freemont 138 kV ckt 1
V4-010
Breaker Failure
slg fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Tiffin Center - Fremont Center 138 kV ckt 1
Tiffin Center 138 kV
Fremont Center 138 kV
Greenlawn 138 kV

1c slg fault @ 80% of Tiffin Center - Fremont Center 138 kV ckt 1
Fremont Center breaker tripped within 138 kV primary time
Tiffin Center breaker tripped within 138 kV secondary time
Loss of: Tiffin Center - Fremont Center 138 kV ckt 1
Fremont Center - Freemont 138 kV ckt 1
Tiffin Center 138 kV
Fremont Center 138 kV
V4-010

2a 3ph fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Tiffin Center - Greenlawn 138 kV ckt 1
Greenlawn - Melmore Tap 138 kV ckt 1
Greenlawn 138 kV

2b slg fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Greenlawn - Melmore Tap 138 kV ckt 1
V4-010
Breaker Failure
slg fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Freemont Center 138 kV
Tiffin Center 138 kV
Greenlawn 138 kV

2c slg fault @ 80% of Tiffin Center - Greenlawn 138 kV ckt 1
Greenlawn breaker tripped within 138 kV primary time
Tiffin Center breaker tripped within 138 kV secondary time
Loss of: Tiffin Center - Greenlawn 138 kV ckt 1
Greenlawn - Melmore Tap 138 kV ckt 1
Greenlawn 138 kV

Melmore 138 kV

3a 3ph fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Greenlawn 138 kV ckt 1

3b1 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Greenlawn 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melomore - Fostoria Central 138 kV ckt 1

3b2 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Greenlawn 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melomore - V1-010 138 kV ckt 1

3c slg fault @ 80% of Melmore - Greenlawn 138 kV ckt 1
Greenlawn breaker tripped within 138 kV primary time
Melmore breakers tripped within 138 kV secondary time.
Loss of: Melmore - Greenlawn 138 kV ckt 1

4a 3ph fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Fostoria Central 138 kV ckt-1

4b1 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Fostoria Central 138 kV ckt-1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: U4-028 & U4-029

4b2 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Fostoria Central 138 kV ckt-1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melmore - Greenlawn 138 kV ckt-1

4c slg fault @ 80% of Melmore - Fostoria Central 138 kV ckt-1

Fostoria breakers tripped within 138 kV primary time
Melmore breakers tripped within 138 kV secondary time.
Loss of: Melmore - Fostoria Central 138 kV ckt-1

5a 3ph fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1

5b1 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melmore - Greenlawn 138 kV ckt-1

5b2 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: U4-028 & U4-029

5c slg fault @ 80% of Melmore - V1-010 138 kV Tap 138 kV ckt 1
V1-010 breakers tripped within 138 kV primary time
Melmore breakers tripped within 138 kV secondary time.
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1

West Freemont 138 kV
(assumed 138 kV line-end breaker at Ottawa)

6a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Freemont Center 138 kV ckt 1
Freemont 138 kV

6b slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Freemont - Freemont Center 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: West Freemont - Freemont 138 kV ckt 1
Freemont 138 kV
West Freemont CT A18

6c slg fault @ 80% of West Freemont - Freemont Center 138 kV ckt 1
Freemont Center breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Freemont Center 138 kV ckt 1
Freemont 138 kV

7a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Woodville 138 kV ckt 1

7b slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Woodville 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: None (T3)

7c slg fault @ 80% of West Freemont - Woodville 138 kV ckt 1
Woodville breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Woodville 138 kV ckt 1

8a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Lemoyne 138 kV ckt 1

8b slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Lemoyne 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: West Freemont CT A17

8c slg fault @ 80% of West Freemont - Lemoyne 138 kV ckt 1
Lemoyne breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Lemoyne 138 kV ckt 1

9a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Ottawa 138 kV ckt 1

9b slg fault @ West Freemont 138 kV

Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Ottawa 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: West Freemont ST A16

9c slg fault @ 80% of West Freemont - Ottawa 138 kV ckt 1
Ottawa breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Ottawa 138 kV ckt 1

### A.4.1) Maintenance outage faults

No faults with outages due to maintenance were studied.

## A.5) Reinforcements

The following reinforcements were considered in the study:

None

## Appendix B

## PROJECT DATA

### B.1) Wind farm and wind turbine data for U1-060

Queue Letter/Position/Unit ID: ______________________________ V4-010

**Wind farm data**

Primary Fuel Type: ______________________________ Wind

Maximum Net MW Output: ______________________________ 200

Maximum Gross MW Output: ______________________________ 200

Station Service Load in MW/MVAR: ______________________________ 5/1

**Wind turbine data**

Wind Turbine Type: ______________________________ Nordex N90

MW Size: ______________________________ 2.5

MVA Base: ______________________________ 2.5

Nominal Power Factor: ______________________________ 0.95-0.95 at gen. Term.

Terminal Voltage (kV): ______________________________ 0.66

Control Mode: ______________________________ Power Factor

Number of Turbines (total): ______________________________ 80

Positive Sequence Impedance R1 (on MVA base): ______________________________ .0074

Saturated Sub-Transient Reactance X’’d(v): ______________________________ 0.316

**Wind farm capacitors**

Queue Letter/Position/Unit ID: ______________________________ V4-010

Additional Capacitor: ______________________________ N/A

Location of Additional Capacitor: ______________________________ N/A

Type of Additional Capacitor: ______________________________ N/A

Steps of Switching Shunt: ______________________________ N/A

**Unit GSU data**

Queue Letter/Position/Unit ID:______________________________________________ V4-010

Generator Step-up Transformer MVA Base: _______________________________________ 2.75

Generator Step-up Transformer Impedance (R+jX, on MVA Base):___________ 0.575+jX5.75

Generator Step-up Transformer Reactance-to-Resistance Ratio (X/R):____________________10

Generator Step-up Transformer Rating (MVA): ___________________________________ 2.75

Generator Step-up Transformer Low-side Voltage (kV):_____________________________ 0.66

Generator Step-up Transformer High-side Voltage (kV): ____________________________ 34.5

Generator Step-up Transformer Off-nominal Turns Ratio: __________________________ 52.27

Generator Step-up Transformer Number of Taps and Step Size:_____________________5/2.5%

**Main transformer data**

Queue Letter/Position/Unit ID:______________________________________________ V4-010

Generator Step-up Transformer MVA Base: _______________________________________2-60

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): H-L ______0.283+j8.5

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): H-L ______0.283+j8.5

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): L-L ______0.283+j8.5

Generator Step-up Transformer Reactance-to-Resistance Ration (X/R):___________________30

Generator Step-up Transformer Rating (MVA): ______________________________ 60/80/100

Generator Step-up Transformer Low-side Voltage (kV):_____________________________ 34.5

Generator Step-up Transformer High-side Voltage (kV): _____________________________138

Generator Step-up Transformer Tertiary Voltage (kV):_______________________________ 13.8

Generator Step-up Transformer Off-nominal Turns Ratio: ______________________________4

Generator Step-up Transformer Number of Taps: _____________________________________5

Generator Step-up Transformer Step Size:________________________________________ 0.025

**Transmission line data:**

Queue Letter/ ID: ________________________________________________________ V4-010

Transmission Line MVA Base: ____________________________________________100MVA

Transmission Line kV Base:_________________________________________________ 138kV

Transmission Line length (mi):_________________________________________________ 7.6

Conductor Type: ____________________________________________________ ACSR

Transmission Line Positive Seq. Impedance (R+jX, p.u. on MVA Base): _____ 0.00059+j0.0036

Transmission Line Zero Seq. Impedance (R+jX, p.u. on MVA Base): _______ 0.00288+j0.01163

Transmission Line Positive Seq. Charging Admittance (B, p.u. on MVA Base): _________ .1619

**Wind project cable:**

Queue Letter/ ID: ___________________________________________________ V4-010

Cable Type:__________________________________________________ 1000 kcmil AL

Cable Impedance: _____________________________________________ 0.1274+j.20302

# *PJM Generator Interconnection Request Queue #V4-010 Tiffin Center (Seneca) 138kV Impact Study*

**611338**

**September 2010**

# V4-010 Tiffin Center (Seneca) 138kV Impact Study Report

## General

EverPower Ohio, LLC has proposed installing a 250 MW wind project, consisting of 100 2.5 MW Nordex wind turbines, in Seneca County, Ohio. The project will be connected directly to the Tiffin Center station. Interconnection to the Tiffin Center station will need to account for the transformer presently installed at the station. The western boundary of the project is 4.5 to 5 miles east of the Tiffin Center-Freemont Center line. The center of the project is about 10 miles east of the line. The in-service date for the project is December 31, 2013.

The intent of the Impact study is to determine system reinforcements and associated costs and construction time estimates required to facilitate the addition of the new generating plant to the transmission system. The reinforcements include the direct connection of the generator to the system and any network upgrades necessary to maintain the reliability of the transmission system.

## Attachment Facilities

The attachment facilities will consist of a direct connection to the Tiffin Center 138kV station. The new connection will consist of one (1) 138kV circuit breaker with 138kV metering and associated equipment at Tiffin Center station (See Figure 1). The cost for these attachment facilities is approximately **$1,500,000**

This estimate is preliminary in nature, as it was determined without the benefit of detailed engineering studies. Final estimates will require an on-site review and coordination to determine final construction requirements
.
It may take approximately one year after obtaining the authorization to construct the facilities as outlined above

It is understood that Everpower Ohio will be responsible for all the costs associated with this construction, as well as facilities associated with connecting their 250MW of generation to the in-line facilities

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

## Network Impacts

The Queue Project #V4-010 was studied as a(n) 200.0MW(Capacity=26.0MW) injection at **Tiffin Center 138 kV** substation in the AEP area. Project #V4-010 was evaluated for compliance with reliability criteria for summer peak conditions in 2014. Potential network impacts were as follows:

**Generator Deliverability**
*(Single or N-1 contingencies for the Capacity portion only of the interconnection)*

No problems identified.

**Multiple Facility Contingency**
*(Double Circuit Tower Line, Line with Failed Breaker and Bus Fault contingencies for the full energy output)*

No problems identified

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

No problems identified.

**Stability**
The stability and Low Voltage Ride Through (LVRT) will be done in the Facilities Study

## 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

## New System Reinforcements

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

None

## Contribution to Previously Identified System Reinforcements

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

None

**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. The Melmore-Fostoria Central 138 kV line (from bus 243039 to bus 243006 ckt 1) loads from 65.44% to 110.13% (AC power flow) of its emergency rating (245 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('5149_B2_TOR709_WOMOAB'). This project contributes approximately 110.85 MW to the thermal violation.

2. The Melmore-Fostoria Central 138 kV line (from bus 243039 to bus 243006 ckt 1) loads from 82.04% to 116.22% (AC power flow) of its normal rating (167 MVA) for non-contingency condition. This project contributes approximately 58.42 MW to the thermal violation.

3. The Melmore-Howard 138 kV line (from bus 243039 to bus 243024 ckt 1) loads from 83.06% to 110.17% (AC power flow) of its normal rating (138 MVA) for non-contingency condition. This project contributes approximately 39.19 MW to the thermal violation.

4. The Howard-Brookside 138 kV line (from bus 243024 to bus 238586 ckt 1) loads from 145.11% to 150.01% (AC power flow) of its emergency rating (173 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('911_B2'). This project contributes approximately 18.83 MW to the thermal violation.

5. The Howard-Brookside 138 kV line (from bus 243024 to bus 238586 ckt 1) loads from 168.42% to 174.47% (AC power flow) of its normal rating (133 MVA) for non-contingency condition. This project contributes approximately 17.87 MW to the thermal violation.

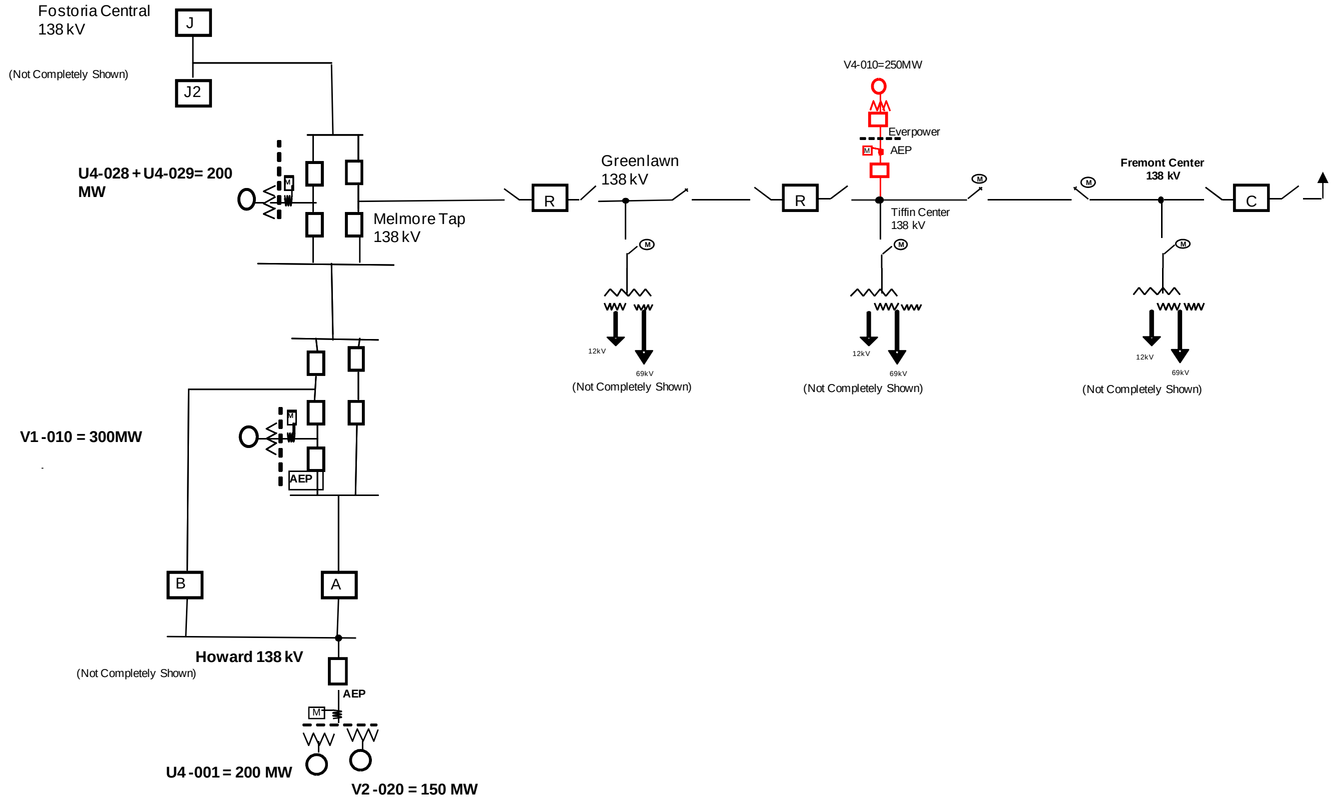
## Cost

The V4-010 project is responsible for 100% of the direct connection cost of **$1,500,000.** There are no network upgrades for the project. The total cost responsibility for the V4-010 project is **$1,500,000,** pending the results of the Stability and LVRT analysis**.**

## Figure #1

# Project One-Line Diagram

**Option 2: Connect to the Tiffin Center 138 kV bus (Fig 1)**




*Disclaimer:*

*The above one-line diagram shows the requirements for interconnection to the AEP system. The developer is responsible for configuration at the collector station.*

## PROJECT DATA

### B.1) Wind farm and wind turbine data for U1-060

Queue Letter/Position/Unit ID: ________ V4-010

**Wind farm data**

Primary Fuel Type: ________ Wind

Maximum Net MW Output: ________ 200

Maximum Gross MW Output: ________ 200

Station Service Load in MW/MVAR: ________ 5/1

**Wind turbine data**

Wind Turbine Type: ________ Nordex N90

MW Size: ________ 2.5

MVA Base: ________ 2.5

Nominal Power Factor: ________ 0.95-0.95 at gen. Term.

Terminal Voltage (kV): ________ 0.66

Control Mode: ________ Power Factor

Number of Turbines (total): ________ 80

Positive Sequence Impedance R1 (on MVA base): ________ .0074

Saturated Sub-Transient Reactance X''d(v): ________ 0.316

**Wind farm capacitors**

Queue Letter/Position/Unit ID: ________ V4-010

Additional Capacitor: ________ N/A

Location of Additional Capacitor: ________ N/A

Type of Additional Capacitor: ________ N/A

Steps of Switching Shunt: ________ N/A

**Unit GSU data**

Queue Letter/Position/Unit ID: ________ V4-010

Generator Step-up Transformer MVA Base: ______________________________________ 2.75

Generator Step-up Transformer Impedance (R+jX, on MVA Base):____________ 0.575+jX5.75

Generator Step-up Transformer Reactance-to-Resistance Ratio (X/R):____________________10

Generator Step-up Transformer Rating (MVA): ___________________________________ 2.75

Generator Step-up Transformer Low-side Voltage (kV):______________________________ 0.66

Generator Step-up Transformer High-side Voltage (kV): ____________________________ 34.5

Generator Step-up Transformer Off-nominal Turns Ratio: __________________________ 52.27

Generator Step-up Transformer Number of Taps and Step Size:_____________________5/2.5%

**Main transformer data**

Queue Letter/Position/Unit ID:_____________________________________________ V4-010

Generator Step-up Transformer MVA Base: ______________________________________2-60

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): H-L ______0.283+j8.5

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): H-L ______0.283+j8.5

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): L-L ______0.283+j8.5

Generator Step-up Transformer Reactance-to-Resistance Ration (X/R):___________________30

Generator Step-up Transformer Rating (MVA): ______________________________ 60/80/100

Generator Step-up Transformer Low-side Voltage (kV):______________________________ 34.5

Generator Step-up Transformer High-side Voltage (kV): _____________________________138

Generator Step-up Transformer Tertiary Voltage (kV):_______________________________ 13.8

Generator Step-up Transformer Off-nominal Turns Ratio: ______________________________4

Generator Step-up Transformer Number of Taps: ____________________________________5

Generator Step-up Transformer Step Size:_______________________________________ 0.025

**Transmission line data:**

Queue Letter/ ID: _________________________________________________________ V4-010

Transmission Line MVA Base: _____________________________________________100MVA

Transmission Line kV Base:_______________________________________________ 138kV

Transmission Line length (mi):______________________________________________ 7.6

Conductor Type: __________________________________________________________ ACSR

Transmission Line Positive Seq. Impedance (R+jX, p.u. on MVA Base): _____0.00059+j0.0036

Transmission Line Zero Seq. Impedance (R+jX, p.u. on MVA Base): ________ 0.00288+j0.01163

Transmission Line Positive Seq. Charging Admittance (B, p.u. on MVA Base): __________ .1619

**Wind project cable:**

Queue Letter/ ID: ________________________________________________________________ V4-010

Cable Type:______________________________________________________________ 1000 kcmil AL

Cable Impedance: _________________________________________________________0.1274+j.20302

# *PJM Generator Interconnection Request*
# *Queue #V4-010*
# *Tiffin Center (Seneca) 138kV*
# *Impact Study*

**611338**

**September 2010**
**October 2010 Version 2**

# V4-010 Tiffin Center (Seneca) 138kV Impact Study Report

## General

Nordex has proposed installing a 200 MW wind project, consisting of 80 2.5 MW Nordex wind turbines, in Seneca County, Ohio. The project will be connected directly to the Tiffin Center station. Interconnection to the Tiffin Center station will need to account for the transformer presently installed at the station. The western boundary of the project is 4.5 to 5 miles east of the Tiffin Center-Freemont Center line. The center of the project is about 10 miles east of the line. The in-service date for the project is December 31, 2013.

The intent of the Impact study is to determine system reinforcements and associated costs and construction time estimates required to facilitate the addition of the new generating plant to the transmission system. The reinforcements include the direct connection of the generator to the system and any network upgrades necessary to maintain the reliability of the transmission system.

## Attachment Facilities

A new 138kV bus will need to be established at Tiffin Center Station. The station design will be completed by the addition of two 138 kV circuit breakers (see Figure 1) and associated equipment at Tiffin Center, including 138kV metering and necessary relaying. Nordex may be required to obtain any additional land at Tiffin Center station needed for the expansion of the station, if necessary, in order to accommodate the new 138kV bus, the circuit breakers and their associated equipment. Nordex shall obtain all necessary permits, including those from the Ohio Power Siting Board (OPSB).

It is understood that Nordex will be responsible for all the costs associated with this construction, as well as facilities associated with connecting their 200MW of generation to the in-line facilities

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

- Installation of the proposed 138kV bus with (2) 138kV breakers, 138kV metering and other associated equipment:

| | |
|---|---|
| Estimated attachment facilities cost | **$2,300,000** |

The requested in-service date is December 2013. The standard time required for construction is 18 months after signing of the Interconnection Service Agreement and Interconnection Construction Service Agreement.

An Interim Interconnection Service Agreement can be executed to facilitate meeting the requested date.

## AEP Local Network Impacts

The impact of the proposed generating facility was assessed for AEP planning criteria specifically that the transmission system meet single contingency performance based on the AEP FERC Form 715 criteria. The Everpower project was studied as both a 200 MW and a 26MW net energy injection. The results are summarized below.

Normal System – Capacity Output (2013 Summer Conditions)

- No problems identified.

Single Contingency – Capacity Output (2013 Summer Conditions)

- No problems identified.

Multiple Contingency – Full Output (2013 Summer Conditions)

- No problems identified.

Short Circuit Analysis

- No problems identified.

Stability Analysis

- For a double contingency outage of Tiffin Center – Fremont Center 138kV and the Melmore – Fostoria Central 138kV lines an unstable result is expected.

- For a double contingency outage of the Greenlawn – Melmore 138kV and the Fremont Center – Tiffin Center 138kV lines an unstable result is expected.

Local/Network Upgrades

- None.

Contributions to Previously Identified Local/Network Limitations (Full Output)

- V4-010 contributes to the overload of the Howard – Brookside 138kV circuit increasing the loading from 217 % to 231.4 % (300.2 MVA) of its summer normal rating of 133 MVA for base case conditions.

- V4-010 contributes to the overload of the V1-010 - Chatfield 138kV circuit increasing the loading from 132 % to 158.8 % (284 MVA) of its summer emergency rating of 179 MVA for a double contingency outage of the Tiffin Center – Fremont Center 138kV circuit and the Fostoria Central – Melmore Tap 138kV circuit.

- V4-010 contributes to the overload of the Chatfield – South Tiffin 138kV circuit increasing the loading from 116 % to 149 % (248 MVA) of its summer emergency rating of 167 MVA for a double contingency outage of the Tiffin Center – Fremont Center 138kV circuit and the Fostoria Central – Melmore Tap 138kV circuit

<u>Additional Limitations of Concern – Full Output</u>

- V4-010 overloads the Tiffin Center 138/69kV transformer to 180.8 % (130.2 MVA) of its summer emergency rating of 72 MVA for a double contingency outage of the Tiffin Center – Fremont Center 138kV circuit and the Fostoria Central – Melmore Tap 138kV circuit.

- V4-010 overloads the South Tiffin – Airco N.C. COOP – West End Fostoria 138kV circuit transformer to 133 % (222 MVA) of its summer emergency rating of 167 MVA for a double contingency outage of the Tiffin Center – Fremont Center 138kV circuit and the Fostoria Central – Melmore Tap 138kV circuit.

- V4-010 overloads the Fremont Center – Tiffin Center 138kV circuit to 121.3% (248 MVA) of its summer normal rating of 205 MVA for base case conditions.

- V4-010 overloads the Tiffin Center 138/69kV transformer to 127.9 % (92.1 MVA) of its summer emergency rating of 72 MVA for a single contingency outage of the Tiffin Center – Fremont Center 138kV circuit.

- V4-010 overloads the Tiffin Center – Greenlawn 138kV circuit 112 % (160 MVA) of its summer emergency rating of 143 MVA for a single contingency outage of the Tiffin Center – Fremont Center 138kV circuit.

- V4-010 overloads the Melmore Tap – Fostoria Central 138kV circuit 152 % (254MVA) of its summer emergency rating of 167 MVA for a single contingency outage of the Tiffin Center – Fremont Center 138kV circuit.

- V4-010 overloads the Tiffin Center – Riverview 69 kV line 186 % (129 MVA) of its summer emergency rating of 73 MVA for a single contingency outage of the Tiffin Center – Fremont Center 138kV circuit.

## Network Impacts

The Queue Project #V4-010 was studied as a(n) 200.0MW(Capacity=26.0MW) injection at **Tiffin Center 138 kV** substation in the AEP area. Project #V4-010 was evaluated for compliance with reliability criteria for summer peak conditions in 2014. Potential network impacts were as follows:

### Generator Deliverability

*(Single or N-1 contingencies for the Capacity portion only of the interconnection)*

No problems identified.

### Multiple Facility Contingency

*(Double Circuit Tower Line, Line with Failed Breaker and Bus Fault contingencies for the full energy output)*

No problems identified

### Short Circuit

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

No problems identified.

### Stability

PJM queue projects V4-010 is a new 200 MW interconnection requests tapping the existing Tiffin Center 138 kV substation in the AEP system. This is a Nordex N90 2.5 MW based wind farm with 80 generators.

Stability analysis for the V4-010 queue project was performed at 2014 light and peak load conditions. The range of contingencies evaluated was limited to that necessary to assess compliance with AEP criteria. Simulation time was limited to 10 seconds for all faults.

Three fault types were considered in this study:

- Type A: Three-phase faults (3ph) with primary clearing time
- Type B: Stuck breaker fault cleared with backup clearing time
- Type C: Zone 2 faults cleared with secondary protection

Specific fault descriptions and breaker clearing times used for this study are provided in Appendix A.

**Results**

**Transient Stability:**

For all cases studied, transient stability is maintained with all oscillations stabilized in less than 10 seconds. Also, the voltage levels returned to normal for all cases following the fault clearance. Hence, no transient stability issues were concluded.

The maximum angle deviations for all three fault types are shown in Tables I - VI.

Table I. Maximum angle deviation for Type A faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1A | 418 | 243515 | 1 | 84.12 | -5.241 | 10.000 |
| 2A | 356 | 242940 | 4 | 82.58 | -2.034 | 0.7126 |
| 3A | 357 | 242940 | 5 | 93.54 | -2.684 | 0.5792 |
| 4A | 357 | 242940 | 5 | 93.54 | -2.666 | 0.5959 |
| 5A | 357 | 242940 | 5 | 93.54 | -2.723 | 0.5834 |
| 6A | 376 | 243190 | 1 | 102.8 | -2.450 | 2.1960 |
| 7A | 376 | 243190 | 1 | 102.8 | -2.722 | 2.1960 |
| 8A | 376 | 243190 | 1 | 102.8 | -2.719 | 2.1960 |
| 9A | 412 | 243440 | 1 | 108.9 | -2.608 | 4.2379 |

Table II. Maximum angle deviation for Type A faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1A | 359 | 242940 | D | 52.16 | -1.958 | 9.9882 |
| 2A | 356 | 242940 | 4 | 51.15 | -1.281 | 0.8167 |
| 3A | 356 | 242940 | 4 | 51.15 | -1.696 | 0.8084 |
| 4A | 356 | 242940 | 4 | 51.15 | -1.659 | 0.8167 |
| 5A | 356 | 242940 | 4 | 51.15 | -1.745 | 0.8167 |
| 6A | 381 | 243195 | 2 | 51.32 | -1.58 | 2.5919 |
| 7A | 381 | 243195 | 2 | 51.32 | -1.78 | 2.5919 |
| 8A | 381 | 243195 | 2 | 51.32 | -1.783 | 2.5919 |
| 9A | 381 | 243195 | 2 | 51.32 | -1.652 | 2.5919 |

Table III. Maximum angle deviation for Type B faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|

Table III. Maximum angle deviation for Type B faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1B | 412 | 243440 | 1 | 108.9 | -4.798 | 9.9799 |
| 2B | 412 | 243440 | 1 | 108.9 | -4.716 | 9.9799 |
| 3B1 | 356 | 242940 | 4 | 82.58 | -3.446 | 0.8417 |
| 3B2 | 356 | 242940 | 4 | 82.58 | -3.522 | 0.8417 |
| 4B1 | 376 | 243190 | 1 | 102.8 | -7.641 | 9.9799 |
| 4B2 | 356 | 242940 | 4 | 82.58 | -3.221 | 0.8417 |
| 5B1 | 356 | 242940 | 4 | 82.58 | -2.502 | 0.8042 |
| 5B2 | 412 | 243440 | 1 | 108.9 | -7.497 | 9.9799 |
| 6B | 412 | 243440 | 1 | 108.9 | -6.236 | 9.9799 |
| 7B | 376 | 243190 | 1 | 102.8 | 2.905 | 1.7918 |
| 8B | 412 | 243440 | 1 | 108.9 | -8.026 | 9.9799 |
| 9B | 376 | 243190 | 1 | 102.8 | -13.82 | 9.9799 |

Table IV. Maximum angle deviation for Type B faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1B | 359 | 242940 | D | 52.16 | -1.517 | 9.9799 |
| 2B | 359 | 242940 | D | 52.16 | -1.521 | 9.9799 |
| 3B1 | 356 | 242940 | 4 | 51.15 | -1.814 | 0.9126 |
| 3B2 | 356 | 242940 | 4 | 51.15 | -1.951 | 0.9209 |
| 4B1 | 359 | 242940 | D | 52.16 | -3.949 | 9.9799 |
| 4B2 | 356 | 242940 | 4 | 51.15 | -1.678 | 0.9167 |
| 5B1 | 356 | 242940 | 4 | 51.15 | -1.277 | 0.8959 |
| 5B2 | 359 | 242940 | D | 52.16 | -3.871 | 9.9799 |
| 6B | 377 | 243191 | 2 | 63.19 | -2.753 | 9.9799 |
| 7B | 381 | 243195 | 2 | 51.32 | -2.087 | 2.7086 |
| 8B | 346 | 242933 | 1 | 42.31 | -4.174 | 9.9799 |
| 9B | 422 | 243654 | 3 | 64.88 | -7.331 | 9.9799 |

Table V. Maximum angle deviation for Type C faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1C | 418 | 243515 | 1 | 84.12 | -4.226 | 9.9799 |
| 2C | 356 | 242940 | 4 | 82.58 | -1.059 | 0.7792 |
| 3C | 356 | 242940 | 4 | 82.58 | -2.985 | 1.0501 |
| 4C | 356 | 242940 | 4 | 82.58 | -2.104 | 0.9751 |

Table V. Maximum angle deviation for Type C faults
2014 Light Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 5C | 356 | 242940 | 4 | 82.58 | -1.903 | 0.7792 |
| 6C | 356 | 242940 | 4 | 82.58 | -1.222 | 1.1459 |
| 7C | 356 | 242940 | 4 | 82.58 | -1.741 | 1.2001 |
| 8C | 356 | 242940 | 4 | 82.58 | -1.141 | 1.1751 |
| 9C | 356 | 242940 | 4 | 82.58 | -1.500 | 1.1626 |

Table VI. Maximum angle deviation for Type C faults
2014 Summer Peak Load Conditions

| Fault | Chan | Bus | ID | Initial Angle | Max Deviation | Time |
|---|---|---|---|---|---|---|
| 1C | 359 | 242940 | D | 52.16 | -1.541 | 9.9799 |
| 2C | 422 | 243654 | 3 | 64.88 | -0.6469 | 1.7168 |
| 3C | 422 | 243654 | 3 | 64.88 | -2.182 | 1.5251 |
| 4C | 422 | 243654 | 3 | 64.88 | -1.324 | 1.5585 |
| 5C | 422 | 243654 | 3 | 64.88 | -1.245 | 1.6335 |
| 6C | 422 | 243654 | 3 | 64.88 | 0.9741 | 9.9799 |
| 7C | 422 | 243654 | 3 | 64.88 | -0.8438 | 1.9877 |
| 8C | 381 | 243195 | 2 | 51.32 | 0.6573 | 1.0543 |
| 9C | 381 | 243195 | 2 | 51.32 | 0.681 | 1.0543 |

The wind farm was modeled with two equivalent generators (WTGs) connected to Tiffin 138 kV bus through a single circuit transmission line and equivalent GSUs and main 34.5/138 kV step-up transformers. The reactive power range of each of the equivalent generator was set at +32.84 Mvar/ -44 Mvar (0.95 lagging and 0.9 leading power factor). The terminal voltage of each generator was set at 1.000 pu.

Low Voltage Ride-Through (LVRT): The LVRT test for V4-010 was performed by applying a three-phase 9-cycle fault at Tiffin 138 kV bus (POI) using the light and peak load base cases. It is noted that V4-010 stayed connected during these fault conditions.

The voltages at the collector buses and generator terminals are not adequate for simulating low voltage ride through test if the WTGs are dispatched at 0.95 leading power factor using the 2014 Summer Peak base-case. If the nearby reactive resources and taps of the main transformers and GSUs (which should not be) are exploited then voltages become acceptable. Under these conditions, a three-phase 9-cycle fault at the 138 kV tap point resulted in tripping of the WTGs on low voltage, which is primarily due to protection settings of Nordex WTGs. The WTGs stay on-line for a 7-cycle three phase-fault. However, for all the cases simulated, the V4-010 queue project rides through the faults specified in Section A.4.

Based on the above, it is concluded that V4-010 meets the LVRT test specified in FERC order 661 and 661A.

**Note**: While the stability analysis has been performed at extreme system conditions, there is a potential that evaluation at a different level of generator MW and/or MVAR output at different system load levels and operating conditions may disclose unforeseen stability problems. The regional reliability analysis routinely performed to test all system changes will include one such evaluation. Any problems uncovered in that or other operating or planning studies will need to be resolved.

Moreover, when the proposed generating station is designed and plant specific dynamics data for the plant and its controls are available, and if it is different than the data provided for this study, a transient stability analysis at a variety of expected operating conditions using the more accurate data shall be performed to verify impact on the dynamic performance of the system. As more accurate or unit specific dynamics data for the proposed facility, as well as plant layout become available, it must be forwarded to PJM.

## 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

## New System Reinforcements

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

None

## Contribution to Previously Identified System Reinforcements

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

None

### 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. The Melmore-Fostoria Central 138 kV line (from bus 243039 to bus 243006 ckt 1) loads from 65.44% to 110.13% (AC power flow) of its emergency rating (245 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('5149_B2_TOR709_WOMOAB'). This project contributes approximately 110.85 MW to the thermal violation.

2. The Melmore-Fostoria Central 138 kV line (from bus 243039 to bus 243006 ckt 1) loads from 82.04% to 116.22% (AC power flow) of its normal rating (167 MVA) for non-contingency condition. This project contributes approximately 58.42 MW to the thermal violation.

3. The Melmore-Howard 138 kV line (from bus 243039 to bus 243024 ckt 1) loads from 83.06% to 110.17% (AC power flow) of its normal rating (138 MVA) for non-contingency condition. This project contributes approximately 39.19 MW to the thermal violation.

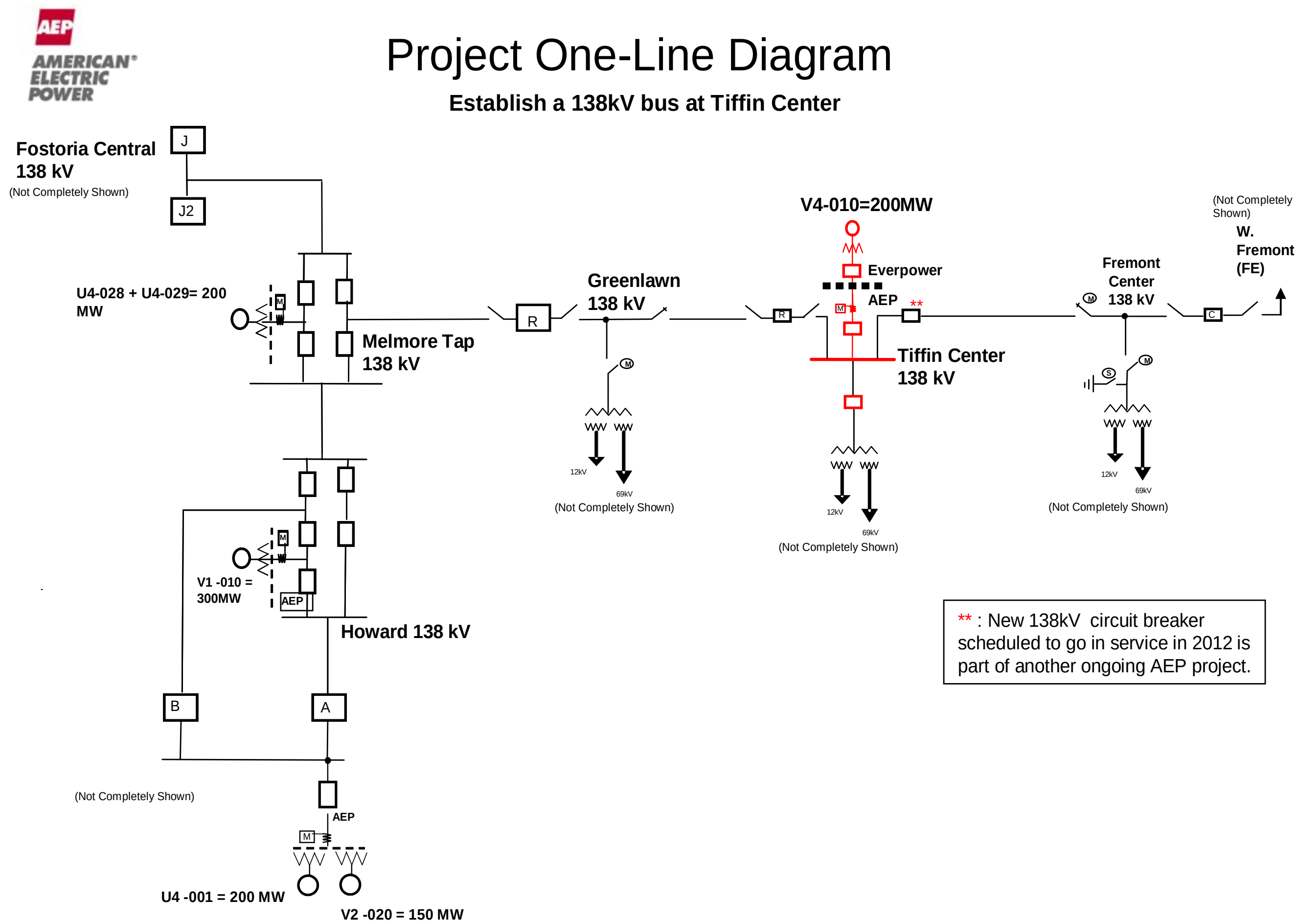
4. The Howard-Brookside 138 kV line (from bus 243024 to bus 238586 ckt 1) loads from 145.11% to 150.01% (AC power flow) of its emergency rating (173 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('911_B2'). This project contributes approximately 18.83 MW to the thermal violation.

5. The Howard-Brookside 138 kV line (from bus 243024 to bus 238586 ckt 1) loads from 168.42% to 174.47% (AC power flow) of its normal rating (133 MVA) for non-contingency condition. This project contributes approximately 17.87 MW to the thermal violation.

## Cost

The V4-010 project is responsible for 100% of the direct connection cost of **$2,300,000.** There are no network upgrades for the project. The total cost responsibility for the V4-010 project is **$2,300,000,** pending the results of the Stability and LVRT analysis**.**

# Figure #1




*Disclaimer:*

*The above one-line diagram shows the requirements for interconnection to the AEP system. The developer is responsible for configuration at the collector station.*

12/28/2010

1

**Sheet 2**

**APPENDIX A**
**V4-010**
**(Tiffin Center 138 kV)**

## A.1) POWER FLOW CONDITIONS

2014 Light and Peak Load Base Cases

## A.2) BREAKER CLEARING TIMES (CYCLES)

Table A.1. AEP Clearing Times (Cycles)

| Station | Primary (3ph/slg) | Stuck Breaker (Total) | Zone 2 (Total) | Re-closing |
|---|---|---|---|---|
| 500 kV | 4 | 14 | 4 | N/A |
| 345 kV | 4 | 15 | 4 | N/A |
| 230 kV | 5 | 15 | 5 | N/A |
| 115kV & 138 kV | 5 | 18 | 63 | N/A |

## A.3) NETWORK CONDITIONS

All facilities in service (base case)

## A.4) FAULTS CONSIDERED

*Note: For simplicity of fault type identification,* PJM *has adopted the following notation:*

A faults: *three-phase faults with normal clearing time*
B faults: *slg faults due to stuck breaker with delayed clearing time*
C faults: *slg faults with delayed clearing time due to protection system failure*

*This notation is for internal purposes only, and does not necessarily correspond with the NERC category definition stated in TPL-001.*

Tiffin Center 138 kV

1a 3ph fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Tiffin Center - Fremont Center 138 kV ckt 1
Fremont Center - Freemont 138 kV ckt 1
Tiffin Center 138 kV
Fremont Center 138 kV
V4-010

1b slg fault @ Tiffin Center 138 kV

Fault cleared within 138 kV breaker primary clearing time
Loss of: Fremont Center - Freemont 138 kV ckt 1
V4-010
Breaker Failure
slg fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Tiffin Center - Fremont Center 138 kV ckt 1
Tiffin Center 138 kV
Fremont Center 138 kV
Greenlawn 138 kV

1c slg fault @ 80% of Tiffin Center - Fremont Center 138 kV ckt 1
Fremont Center breaker tripped within 138 kV primary time
Tiffin Center breaker tripped within 138 kV secondary time
Loss of: Tiffin Center - Fremont Center 138 kV ckt 1
Fremont Center - Freemont 138 kV ckt 1
Tiffin Center 138 kV
Fremont Center 138 kV
V4-010

2a 3ph fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Tiffin Center - Greenlawn 138 kV ckt 1
Greenlawn - Melmore Tap 138 kV ckt 1
Greenlawn 138 kV

2b slg fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Greenlawn - Melmore Tap 138 kV ckt 1
V4-010
Breaker Failure
slg fault @ Tiffin Center 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Freemont Center 138 kV
Tiffin Center 138 kV
Greenlawn 138 kV

2c slg fault @ 80% of Tiffin Center - Greenlawn 138 kV ckt 1
Greenlawn breaker tripped within 138 kV primary time
Tiffin Center breaker tripped within 138 kV secondary time
Loss of: Tiffin Center - Greenlawn 138 kV ckt 1
Greenlawn - Melmore Tap 138 kV ckt 1
Greenlawn 138 kV

Melmore 138 kV

3a 3ph fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Greenlawn 138 kV ckt 1

3b1 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Greenlawn 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melomore - Fostoria Central 138 kV ckt 1

3b2 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Greenlawn 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melomore - V1-010 138 kV ckt 1

3c slg fault @ 80% of Melmore - Greenlawn 138 kV ckt 1
Greenlawn breaker tripped within 138 kV primary time
Melmore breakers tripped within 138 kV secondary time.
Loss of: Melmore - Greenlawn 138 kV ckt 1

4a 3ph fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Fostoria Central 138 kV ckt-1

4b1 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Fostoria Central 138 kV ckt-1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: U4-028 & U4-029

4b2 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - Fostoria Central 138 kV ckt-1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melmore - Greenlawn 138 kV ckt-1

4c slg fault @ 80% of Melmore - Fostoria Central 138 kV ckt-1

Fostoria breakers tripped within 138 kV primary time
Melmore breakers tripped within 138 kV secondary time.
Loss of: Melmore - Fostoria Central 138 kV ckt-1

5a 3ph fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1

5b1 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: Melmore - Greenlawn 138 kV ckt-1

5b2 slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1
Breaker Failure
slg fault @ Melmore 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: U4-028 & U4-029

5c slg fault @ 80% of Melmore - V1-010 138 kV Tap 138 kV ckt 1
V1-010 breakers tripped within 138 kV primary time
Melmore breakers tripped within 138 kV secondary time.
Loss of: Melmore - V1-010 138 kV Tap 138 kV ckt 1

West Freemont 138 kV
(assumed 138 kV line-end breaker at Ottawa)

6a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Freemont Center 138 kV ckt 1
Freemont 138 kV

6b slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: Freemont - Freemont Center 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: West Freemont - Freemont 138 kV ckt 1
Freemont 138 kV
West Freemont CT A18

6c slg fault @ 80% of West Freemont - Freemont Center 138 kV ckt 1
Freemont Center breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Freemont Center 138 kV ckt 1
Freemont 138 kV

7a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Woodville 138 kV ckt 1

7b slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Woodville 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: None (T3)

7c slg fault @ 80% of West Freemont - Woodville 138 kV ckt 1
Woodville breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Woodville 138 kV ckt 1

8a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Lemoyne 138 kV ckt 1

8b slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Lemoyne 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: West Freemont CT A17

8c slg fault @ 80% of West Freemont - Lemoyne 138 kV ckt 1
Lemoyne breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Lemoyne 138 kV ckt 1

9a 3ph fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Ottawa 138 kV ckt 1

9b slg fault @ West Freemont 138 kV

Fault cleared within 138 kV breaker primary clearing time
Loss of: West Freemont - Ottawa 138 kV ckt 1
Breaker Failure
slg fault @ West Freemont 138 kV
Fault cleared within 138 kV breaker backup clearing time
Loss of: West Freemont ST A16

9c slg fault @ 80% of West Freemont - Ottawa 138 kV ckt 1
Ottawa breaker tripped within 138 kV primary time
West Freemont breakers tripped within 138 kV secondary time.
Loss of: West Freemont - Ottawa 138 kV ckt 1

### A.4.1) Maintenance outage faults

No faults with outages due to maintenance were studied.

### A.5) Reinforcements

The following reinforcements were considered in the study:

None

## Appendix B

## PROJECT DATA

### B.1) Wind farm and wind turbine data for U1-060

Queue Letter/Position/Unit ID: ______________________________ V4-010

**Wind farm data**

Primary Fuel Type: ______________________________ Wind

Maximum Net MW Output: ______________________________ 200

Maximum Gross MW Output: ______________________________ 200

Station Service Load in MW/MVAR: ______________________________ 5/1

**Wind turbine data**

Wind Turbine Type: ______________________________ Nordex N90

MW Size: ______________________________ 2.5

MVA Base: ______________________________ 2.5

Nominal Power Factor: ______________________________ 0.95-0.95 at gen. Term.

Terminal Voltage (kV): ______________________________ 0.66

Control Mode: ______________________________ Power Factor

Number of Turbines (total): ______________________________ 80

Positive Sequence Impedance R1 (on MVA base): ______________________________ .0074

Saturated Sub-Transient Reactance X’’d(v): ______________________________ 0.316

**Wind farm capacitors**

Queue Letter/Position/Unit ID: ______________________________ V4-010

Additional Capacitor: ______________________________ N/A

Location of Additional Capacitor: ______________________________ N/A

Type of Additional Capacitor: ______________________________ N/A

Steps of Switching Shunt: ______________________________ N/A

**Unit GSU data**

Queue Letter/Position/Unit ID:____________________ V4-010

Generator Step-up Transformer MVA Base: ____________________ 2.75

Generator Step-up Transformer Impedance (R+jX, on MVA Base):__________ 0.575+jX5.75

Generator Step-up Transformer Reactance-to-Resistance Ratio (X/R):__________10

Generator Step-up Transformer Rating (MVA): ____________________ 2.75

Generator Step-up Transformer Low-side Voltage (kV):________________ 0.66

Generator Step-up Transformer High-side Voltage (kV): ________________ 34.5

Generator Step-up Transformer Off-nominal Turns Ratio: _______________ 52.27

Generator Step-up Transformer Number of Taps and Step Size:____________5/2.5%

**Main transformer data**

Queue Letter/Position/Unit ID:____________________ V4-010

Generator Step-up Transformer MVA Base: ____________________2-60

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): H-L _____0.283+j8.5

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): H-L _____0.283+j8.5

Generator Step-up Transformer Imp.(R+jX, in p.u, on Xfmr MVA Base): L-L _____0.283+j8.5

Generator Step-up Transformer Reactance-to-Resistance Ration (X/R):__________30

Generator Step-up Transformer Rating (MVA): ________________ 60/80/100

Generator Step-up Transformer Low-side Voltage (kV):________________ 34.5

Generator Step-up Transformer High-side Voltage (kV): ________________138

Generator Step-up Transformer Tertiary Voltage (kV):________________ 13.8

Generator Step-up Transformer Off-nominal Turns Ratio: ________________4

Generator Step-up Transformer Number of Taps: ____________________5

Generator Step-up Transformer Step Size:____________________ 0.025

**Transmission line data:**

Queue Letter/ ID: ________________________ V4-010

Transmission Line MVA Base: ______________________100MVA

Transmission Line kV Base:________________________ 138kV

Transmission Line length (mi):________________________ 7.6

Conductor Type: ______________________________________________________ ACSR

Transmission Line Positive Seq. Impedance (R+jX, p.u. on MVA Base): _____ 0.00059+j0.0036

Transmission Line Zero Seq. Impedance (R+jX, p.u. on MVA Base): _______ 0.00288+j0.01163

Transmission Line Positive Seq. Charging Admittance (B, p.u. on MVA Base): _________ .1619

**Wind project cable:**

Queue Letter/ ID: _____________________________________________________ V4-010

Cable Type:____________________________________________________ 1000 kcmil AL

Cable Impedance: ________________________________________________ 0.1274+j.20302