Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position X1-020

Dumont-Greentown 765 kV

December/2015

Revised December 17, 2015

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

Community Energy Wind, LLC proposes to install PJM Project #X1-020, a 1500 MW (195 MW capacity) wind generating facility connecting to the American Electric Power (AEP) Dumont – Greentown 765 kV Circuit (see Figure 2). The location of the wind generating facility is in Miami County, IN approximately 39 miles from the Dumont and Greentown 765 kV stations (see Figure 1).

The requested in service date is June, 2015.

The objective of this 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.

Attachment Facilities

The point of interconnection is approximately 39 miles from either the Greentown or Dumont 765 kV station via a new in-line 765 kV switching station on the Dumont – Greentown 765 kV line. This new station is to consist of four (4) 765 kV circuit breakers configured in a breaker and one half bus arrangement operated as a ring-bus to accommodate two connections to Community's collector station (Exhibit 2). Protection schemes will need to be modified.

The station also includes 765 kV revenue metering, SCADA, and associated equipment. Community is expected to obtain, at their cost, an 800' x 800' (minimum) station site for the AEP facilities. Community shall obtain all necessary permits. Ownership of the in-line facilities shall be transferred from Community to AEP upon successful completion of the work.

A 765 kV line extension is required to loop through the proposed station. The AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap structures will be required. It is expected that Community will obtain the supplemental easement when the station property is purchased.

Changes to relay equipment at Dumont and Greentown stations are required. However, the Greentown 765 kV station is owned by Duke Energy Indiana and AEP. Therefore, coordination between PJM, MISO and Duke Energy Indiana will be required for any relay upgrades/changes at Greentown station.

The following work is required to connect to the Greentown – Dumont 765 kV line:

- Install a new 4-breaker 765 kV switching station laid out in a breaker and one-half arrangement including associated disconnect switch bus work, SCADA and 765 kV revenue metering. Estimated Cost: $30,092,000

- Modify relaying at Dumont 765 kV Station. Estimate Cost: $554,400

- Modify relaying at Greentown 765 kV Station. Estimated Cost: $727,400 (Based on AEP estimates – may also involve DE-I and MISO)

Total Estimated Point of Interconnection Cost: $31,373,800*

It is understood that Community Energy Wind LLC is responsible for all costs associated with this connection. The costs above are reimbursable to AEP. Cost of the Community Energy Wind LLC collector station for 1500 MW of generation and costs for the line connection from the collector station to the AEP switching station are not included in this report, these are assumed to be Community Energy Wind LLC's responsibility.

The Generation interconnection agreement does <u>not</u> 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. The metering work above and cost indicated below does not include any potential work or cost to address metering requirements of the local service provider. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

Local and Network Impacts

The impact of the proposed generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet required performance criteria in accordance with the AEP FERC Form 715. Therefore, this criterion was used to assess the impact of the proposed facility on

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* The 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.

the AEP System. The Community Energy Wind LLC project was studied as a 1500 MW (195 MW capacity) generating facility consistent with the interconnection application. Project #X1-020 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

Potential network impacts for the points of interconnection were as follows:

<u>Normal System (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Single Contingency (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Multiple Contingency (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Contribution to Previously Identified Overloads (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Normal System (2015 Summer Conditions Full Output)</u>

- No problem identified

<u>Single Contingency (2015 Summer Conditions Full Output)</u>

- No problem identified

<u>Multiple Contingency (2015 Summer Conditions Full Output)</u>

- No problem identified

<u>Contribution to Previously Identified Overloads (2015 Summer Conditions Full Output)</u>

- No problem identified

Light Load Analysis

- No Problem identified

Voltage

- No Problem identified

Short Circuit Analysis

- No Problem identified

Stability Analysis

The concern regarding stability for this project is the N-2 condition involving outage of X1-020 POI to Dumont 765 kV and Greentown-Jefferson 765 kV where the wind generation ends up radial to Greentown 138 kV and 230 kV outlets.

It is found that this condition is of low enough system short circuit ratio (system short circuit MVA/MW generation) as to begin to exhibit signs of wind farm control instability, but it is not to the point of being a stability problem.

This result is sensitive to the wind turbine dynamic modeling data and the line and transformer r+jx values. This study was conducted based on the data available at this time and any small changes in the wind turbine dynamic modeling data and the line and transformer r+jx values may cause wind farm control instability. The complete Stability Analysis can be found in Attachment 1 at the end of this report.

Additional Limitations of Concern

MISO analysis has identified potential overloading of the Sturgis-Howe-LaGrange 69 kV AEP-NIPSCO tieline. AEP owns 2.83 miles of the Howe – Sturgis 69 kV line and the summer emergency rating is 50 MVA. We will have to rebuild 2.83 miles of the existing Howe – Sturgis 69 kV line. Estimated Cost to rebuild is $3.4 Million.

Local/Network Upgrades

- None

Schedule

The standard time required for interconnection station construction is 18 - 24 months after signing an interconnection agreement. The required line upgrades are more significantly affected by availability of construction outages and other details normally addressed in the Facilities Study or when finalizing the ISA/ICSA, but could be expected to take somewhat longer.

Conclusion

Based upon the results of this Impact Study, the construction of the Community Energy Wind LLC (PJM Project #X1-020) wind generation project will require additional interconnection charges. Local network upgrades will also be required for this project.

Network Upgrade Number	Description	Estimate
n4742	Construct Interconnection Substation with Revenue Metering	$30,092,000
n4743	Modify relaying at Dumont 765 kV Station	$554,000
n4744	Modify relaying at Greentown 765 kV Station	$727,400
	Total	**$31,373,400**

Table 1 - Interconnection Costs

Network Upgrade Number	Description	Estimate
~~n4730~~	~~Rebuild/Reconductor approximately 30 miles of the R60/S72 Tap -East Lima 345 kV line section~~	~~$60,000,000~~
n4713	Rebuild 2.83 miles of the existing Howe – Sturgis 69 kV line (AEP portion)	$3,400,000
	Total	**$3,400,000**

Table 2 – Local Network Upgrade Costs

Network Upgrade Number	Description	Estimate
n4740	Rebuild 2.76 miles of the existing Howe – Sturgis 69 kV line (MISO portion)	$2,208,000
n4741	Rebuild of 1.91 miles of 69kV circuit	$1,524,000
	Total	**$3,732,000**

Table 3 – Affected System Upgrade Costs

- **Estimated interconnection cost: $31,373,800.**
- **Estimated local network upgrade cost**: **$3,400,000.**
- **Estimated Affected System upgrade cost**: **$3,732,000.**
- **Total estimated cost for project X1-020: $38,505,400.**

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 refine final construction requirements. Per the PJM Tariff, the customer is responsible for the actual costs incurred.

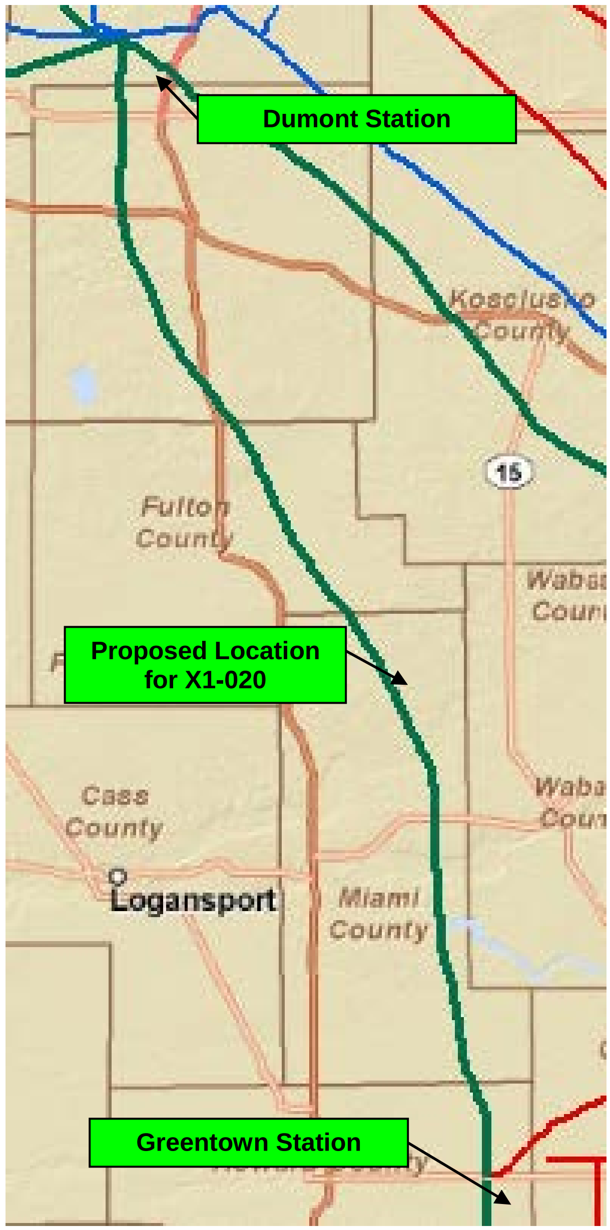

Exhibit 1: Approximate interconnection location of the proposed facilities

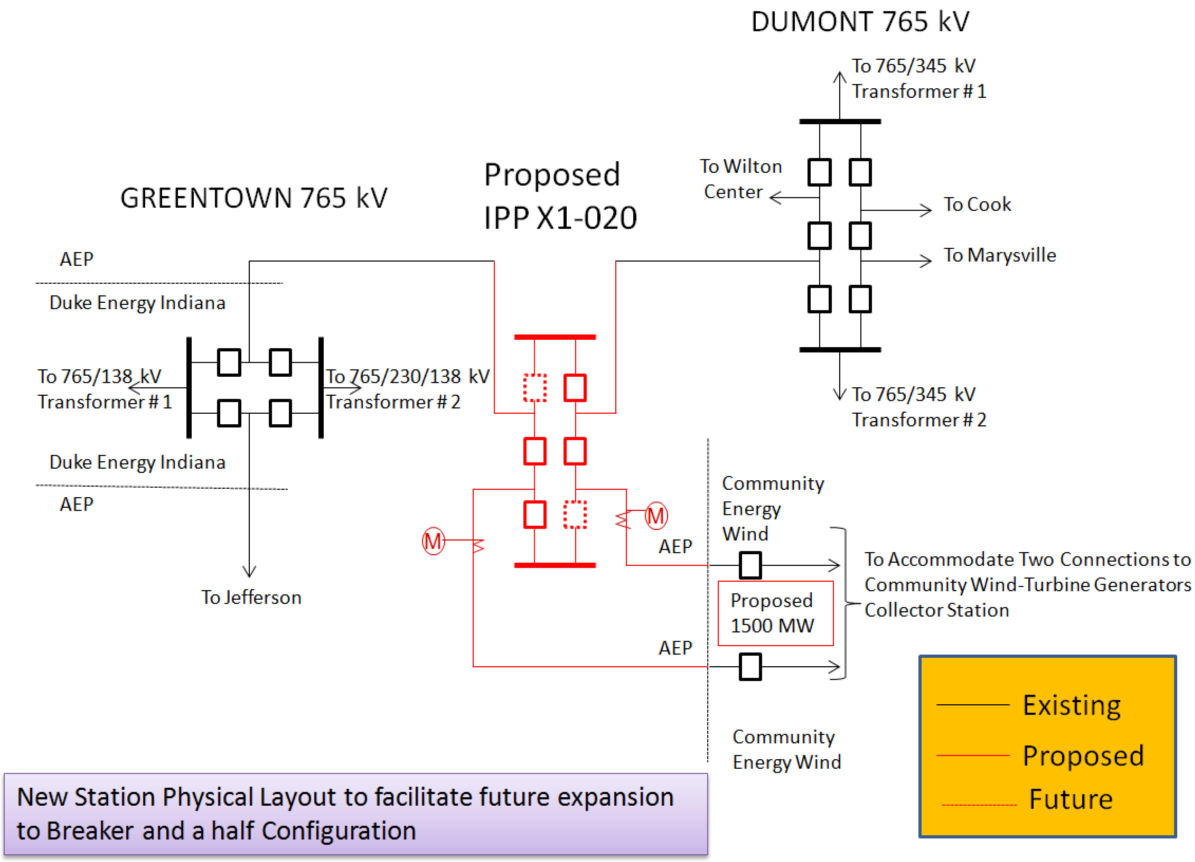

Exhibit 2: Simplified diagram of proposed 765 kV in-line switching station

Attachment 1 – Stability Analysis

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Executive Summary

Generation Interconnection Request X1-020 is for a 1500 MW (maximum facility output) wind farm consisting of 612 × 2.5 MW wind turbine generators with a Point of Interconnection (POI) on the Dumont – Greentown 765 kV circuit in the American Electric Power (AEP) network.

X1-020 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of X1-020 as part of the overall system impact study.

The load flow scenario for analysis was the RTEP 2015 summer peak load case, with the addition of the X1-020 models at maximum power output and unity power factor at the collector buses.

27 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation
b) Three phase faults with normal clearing time
c) Single phase faults with single phase stuck breaker

Selected contingencies were also run under a maintenance outage of the 765 kV Dumont – X1-020 POI circuit. Single phase faults with delayed clearing were omitted as the AEP clearing times indicate that dual primary communication systems are used at 765 kV.

X1-020 was modeled in voltage control mode, per the Impact Study data supplied by the developer. For the intact system, the fault simulations met the fault recovery criteria:

a) X1-020 rode through the faults (except for faults where protective action tripped some machines of X1-020),
b) the system with X1-020 included was found to be transiently stable,
c) a new steady state was reached,
d) voltages at the POI and nearby buses returned to an acceptable range, with system stability being maintained. No mitigations were found to be required.

Several tested under the maintenance outage of the Dumont – X1-020 POI circuit did not run to completion due to non-convergence of the simulation, and inter-tripping of X1-020 would be required for these contingencies. This is the case for contingencies at the X1-020 POI and at Greentown. For these instances, the windfarm is required to be curtailed.

1. Introduction

Generation Interconnection Request X1-020 is for a 1500 MW wind farm consisting of 612 × 2.5 MW wind turbine generators with a Point of Interconnection (POI) on the Dumont – Greentown 765 kV circuit in the American Electric Power (AEP) network.

As the Regional Transmission Operator, PJM Interconnection is responsible for planning the incorporation of generators into the grid. X1-020 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process.

PJM contracted Power Systems Consultants (PSC) to carry out this dynamic simulation analysis of X1-020 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of X1-020 will meet the dynamics requirements of the NERC and PJM reliability standards.

In this report the X1-020 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of the Project

The proposed X1-020 project is specified in the Impact Study data provided in Attachment 1. Attachment 2 shows the one line diagram of the AEP network in the vicinity of X1-020.

X1-020 is connected to the AEP system via the existing 78 mile 765 kV circuit between Greentown 765 kV Substation and Dumont 765 kV Substation, approximately 35 miles from Greentown Substation. The project includes the establishment of a new in-line switching station based on a breaker and one half bus arrangement but configured as a ring bus with four circuit breakers.

Figure 1 shows how X1-020 has been modeled in this study. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the X1-020 load flow model. Attachment 3 provides a diagram of the PSS/E model in the vicinity of X1-020; Attachment 4 gives the X1-020 PSS/E load flow model.

The dynamic model for the X1-020 plant is based on a GEWT 2.5 MW PSS/E model supplied by PJM. The dynamic model of the X1-020 plant is given in Attachment 5.

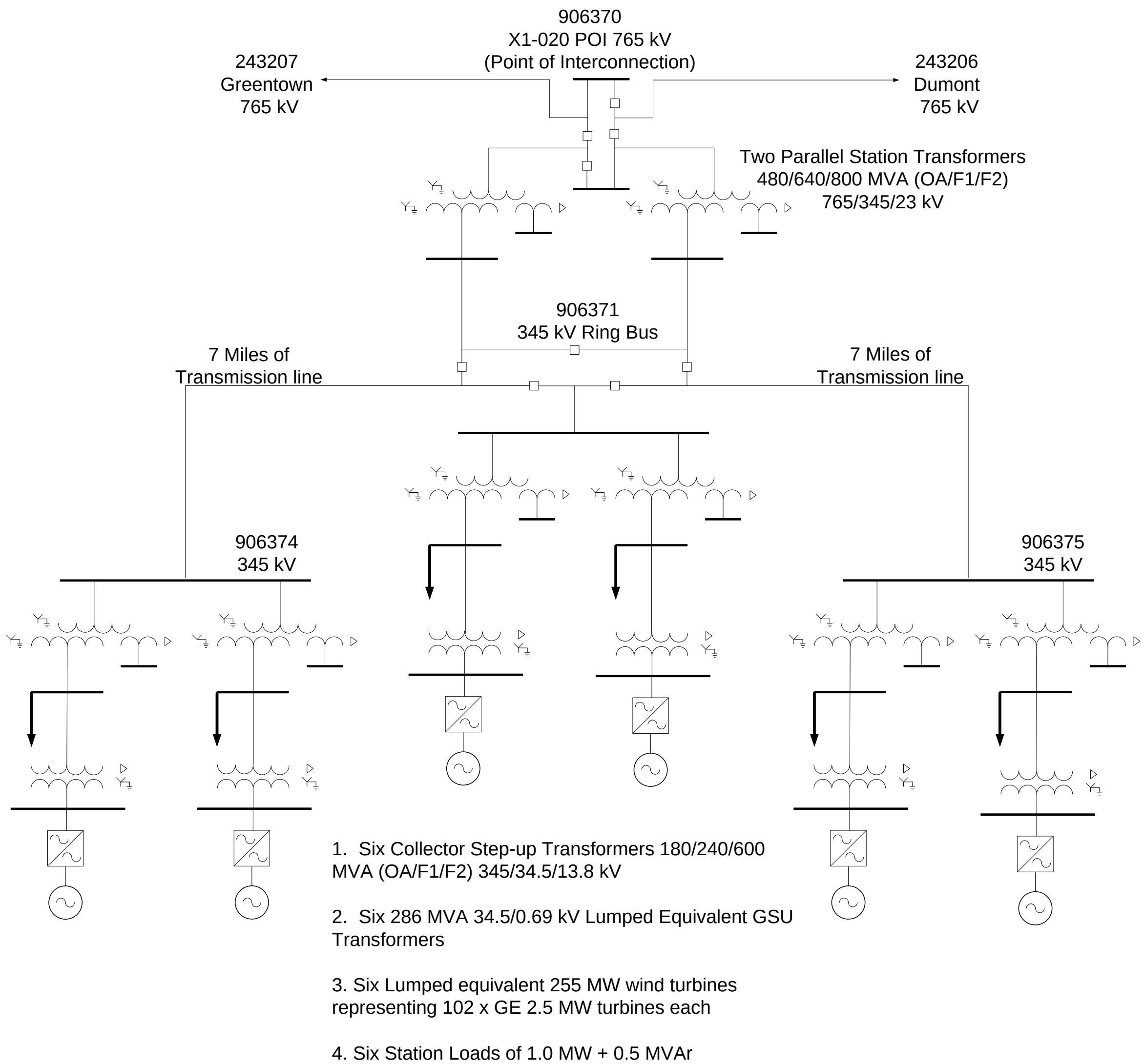

Figure 1: X1-020 Model

Table 1: X1-020 Plant Model

	Impact Study Data	Model
Wind turbine generator	612 x GE 2.5 MW wind turbines MVA base 3.0 MVA Vt = 0.69kV +/- 1.2 MVAr / turbine Saturated subtransient reactance not given – proponent referred to manufacturer specifications.	6 Lumped equivalents representing 102 x 2.5 MW GE Wind Turbines Pgen 255 MW Pmax 255 MW Pmin 0 MW Qgen 15.1 MVAr Qmax 122.4 MVAr* Qmin -122.4 MVAr* Mbase 306 MVA Zsorce[1] 0.0 + j99999 pu
GSU transformer	612 x 2.8 MVA 34.5/0.69 kV 0.8 % + j 6.0 % @ 2.8 MVA Number of taps = 5 Tap Step Size = 2.5 % OA 2.8 MVA	6 Lumped equivalents representing 102 x 2.8 MVA GSU transformers. 285.6 MVA 34.5/0.69 kV 0.008 + j0.06 pu @ 285.6 MVA 5 taps Tap step size = 2.5%

[1] Source reactance of the GE wind turbine model is set to a large number as per the Siemens User Guide – PSS/E Wind Modelling Package for GE 2.5 MW Wind turbines.

Collector step-up transformer	345/34.5/13.8 kV Yyd 180/240/300 MVA (OA/F1/F2) Collector bus off-nominal turns ratio: 1.0 Impedances (pu @ 180 MVA) HV-MV 0.00167 + j0.10 MV-Tertiary 0.00117 + j0.07 HV-Tertiary 0.003 + j0.18	345/34.5/13.8 kV Yyd 180/240/300 MVA (OA/F1/F2) Positive Sequence pu @ 180 MVA HV-MV 0.00167 + j0.10 MV-Tertiary 0.00117 + j0.07 HV-Tertiary 0.003 + j0.18
Station transformer	765/345/23 kV Yyd 480/640/800 MVA (OA/F1/F2) Number of taps = 5 Tap Step Size = 2.5 % Collector bus off-nominal turns ratio: 1.0 Impedances (pu @ 480 MVA) HV-MV 0.0015 + j0.09 MV-Tertiary 0.00105 + j0.063 HV-Tertiary 0.0027 + j0.162	765/345/23 kV Yyd 480/640/800 MVA (OA/F1/F2) Number of taps = 5 Tap Step Size = 2.5 % Positive Sequence pu @ 480 MVA HV-MV 0.0015 + j0.09 MV-Tertiary 0.00105 + j0.063 HV-Tertiary 0.0027 + j0.162
Collector cables		Not modeled
Station demand	1.0 MW + 0.5 MVAr at low voltage side of GSU	6 × 0.167 MW/0.083 MVAr at 34.5 kV busbars

Transmission line	2 × 7 mile 345 kV 795 kcmil ACSR conductor MVA Base 1000 MVA Z1 = 0.000548+j0.00388 pu/mile Z0 = 0.00520+j0.01407 pu/mile Y1 = 0.00085 pu/mile	MVA Base 100 MVA Z1 = 0.0004+j0.0027 pu Y1 = 0.0595 pu

* Qmax = 15.1MVAr and Qmin = 0 MVAr when running X1-020 study in order to make a conservative assessment of LV ride-through capability by having unity power factor at the collector bus.

3. Load flow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 30.3.1.

The load flow scenario and fault cases for this study are based on PJM's Region Transmission Planning Process[2] and discussions with PJM.

This study is focused on the ability of the plant to ride through faults. The selected load flow scenario is the RTEP 2015 summer peak load case, provided by PJM from the W3-088 study, with the following modifications:

a) Modeling of X1-020 at the Point of Interconnection between Greentown 765 kV Substation and Dumont 765 kV Substation
b) Removal of withdrawn and subsequent queue projects in the vicinity of X1-020
c) Connection and disconnection of some distant generation units in the PJM system in order to maintain slack units within limits
d) Deactivation of bus 243462 (an AEP 242 kV bus connected only to a transformer and solving at > 1.4 pu voltage) to improve load flow convergence

In the load flow the X1-020 generators are set to maximum power output (total 1530 MW) with unity power factor at the collector buses (34.5 kV) and approximately 0.96 and 0.95 pu voltage at the generator buses and collector buses respectively.

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

Generation within the PJM500 system (area 225 in the PSS/E case) and within a 5 bus radius of X1-020 has been dispatched online at maximum output. Exceptions are listed in Table 2.

Table 2: Generation at reduced output within 5-bus radius of X1-020

Bus	**Name**	**Unit**	**PGEN (MW)**	**PMAX (MW)**	**Reason**
248000	06CLIFTY 345.00	A	110	124.715	Initialization issue
248000	06CLIFTY 345.00	B	110	124.715	
243225	05KEYSTN 345.00	1	50	59	GGOV1 Trate=51 MW limits output
243225	05KEYSTN 345.00	2	50	60	
243225	05KEYSTN 345.00	3	50	60	
243225	05KEYSTN 345.00	4	50	59	
243187	05GVG2 26.000	2H	657.2	667	Conflict with governor model

In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV shunt reactors listed in Table 3 were switched out of service.

Table 3: 765 kV Shunt reactors switched out

From Bus Number	**From Bus Name**	**To Bus Number**	**To Bus Name**	**Id**	**Line B From (pu on 100 MVA) Removed**	**Line B To (pu on 100 MVA) Removed**
242509	05AXTON 765.00	242514	05J.FERR 765.00	1	-3	0
242510	05BAKER 765.00	242511	05BROADF 765.00	1	-3	-3
242512	05CLOVRD 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242515	05JOSHUA 765.00	1	-3	0
242924	05HANG R 765.00	243208	05JEFRSO 765.00	1	-3	-3
242928	05MARYSV 765.00	243206	05DUMONT 765.00	1	-3	-3
243206	05DUMONT 765.00	906370	X1-020 MAIN 765.00	1	-3	0

243207	05GRNTWN 765.00	243208	05JEFRSO 765.00	1	-3	-3

Modifications were made to the dynamics case to resolve initialization issues:

1. Removal of several distant generation units from the dynamic simulation to avoid initialization problems, including machines 3 and 5 at bus 345400 (ESST1A exciter models initializing out of limits).

2. Bus 347832 has been netted to avoid the following initialization issue, and a consequent significant DSTATE warning:
```
MNLEX3 AT BUS 347832 [1NEWTON 1   24.000] MACHINE 1
INITIALIZED ABOVE ZERO
```

3. For bus 270000 existing units 1, 2 & 3 and bus 270001 existing units 1 & 2, the saturation factors S(1.0) and S(1.2) were much higher than expected; it was assumed they are % rather than per unit values. These values were thus divided by 100 to set more realistic values.

4. For bus 248000 machine C (+ machine 6), the IEEEG1 governor model was suppressed to avoid initializing out of limits.

4. Fault Cases

Tables 4 – 6 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 10 second simulation time interval. Faults were applied to transmission circuits and transformers connected to the Point of Interconnection or one bus removed[3].

The studied faults included:

a) Steady state operation
b) Three phase faults with normal clearing time
c) Single phase faults with single phase stuck breaker

[3] One bus removed from the POI refers to buses with transmission circuit breakers, not tee-offs or buses with only supply circuit breakers.

Selected faults were also run under a maintenance outage of the 765 kV Dumont – X1-020 POI circuit.

Single phase faults with delayed clearing were omitted as the AEP clearing times indicated that dual primary communication systems are used at 765 kV.

The one line diagram of the AEP network in Attachment 2 shows where faults were applied.

The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case provided by PJM, modified by PSC to ensure that connected generators in the vicinity of X1-020 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

The two 765/345 kV transformers at Dumont had different impedance values in the X1-020 short circuit case. This resulted in different fault admittance for contingencies 1B.13 and 1B.14. The greater of the two fault admittances was used for both contingencies to provide a conservative outcome.

5. Fault Recovery Criteria

The fault recovery criteria applicable to this study are as per PJM's Region Transmission Planning Process:

a) Post-contingency voltages should remain within +/- 0.05 pu of the pre-contingency voltages at transmission level buses.
b) Post-contingency oscillations should be positively damped with a damping margin of at least 3%.
c) The X1-020 generators should maintain their pre-contingent power output following the fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Tables 4 – 7.

For the intact system, the fault simulations met the fault recovery criteria:

a) the system with X1-020 included in voltage control mode was found to be transiently stable,
b) a new steady state was reached,
c) voltages at the POI and nearby buses returned to an acceptable range,
with X1-020 riding through the fault (except for faults where protective action tripped some machines of X1-020) and system stability being maintained. No mitigations were found to be required.

For the system under a maintenance outage of the 765 kV circuit between Dumont and the X1-020 POI, test contingencies involving faults at the X1-020 POI and at Greentown 765 kV did not run to completion. All of the maintenance outage contingencies tested at these locations require inter-tripping of X1-020. A contingency involving the same maintenance outage and a fault on the Jefferson to Hanging Rock 765 kV circuit was found to meet criteria.

Table 4: Steady State Operation

Fault ID	Duration	X1-020 No Mitigation
SS.01	Steady state 20 sec	Stable

Table 5: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X1-020 No Mitigation
3N.01	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 1 circuit.	3.5 / 3.5	Stable
3N.02	Fault at X1-020 765 kV POI on Greentown circuit.	3.5 / 3.5	Stable
3N.03	Fault at X1-020 765 kV POI on Dumont circuit.	3.5 / 3.5	Stable
3N.04	Fault at X1-020 345 kV on circuit to 1/3 of X1-020 turbines.	3.5 / 3.5	Stable
3N.05	Fault at Greentown 765 kV on X1-020 circuit.	3.5 / 3.5	Stable
3N.06	Fault at Greentown 765 kV on Jefferson circuit.	3.5 / 3.5	Stable
3N.07	Fault at Greentown 765 kV on 765/138 kV Transformer 1.	3.5 / 3.5	Stable
3N.08	Fault at Greentown 765 kV on 765/230/138 kV Transformer 2.	3.5 / 3.5	Stable
3N.09	Fault at Dumont 765 kV on X1-020 circuit.	3.5 / 3.5	Stable
3N.10	Fault at Dumont 765 kV on Marysville circuit.	3.5 / 3.5	Stable
3N.11	Fault at Dumont 765 kV on Cook circuit.	3.5 / 3.5	Stable
3N.12	Fault at Dumont 765 kV on Wilton Centre circuit.	3.5 / 3.5	Stable
3N.13	Fault at Dumont 765 kV on 765/345 kV Transformer 1.	3.5 / 3.5	Stable

Table 6: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal / Stuck Breaker (Cycles)	X1-020 No Mitigation
1B.01	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 1 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of 765 kV Dumont circuit.	3.5 / 13	Stable
1B.02	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 2 circuit. Breaker stuck to Greentown circuit. Fault cleared with loss of 765 kV Greentown circuit.	3.5 / 13	Stable
1B.03	Fault at X1-020 765 kV POI on Dumont circuit. Breaker stuck to X1-020 765/345 kV Transformer 1 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.04	Fault at X1-020 765 kV POI on Greentown circuit. Breaker stuck to X1-020 765/345 kV Transformer 2 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 2.	3.5 / 13	Stable
1B.05	Fault at X1-020 345 kV on circuit to 1/3 of X1-020 turbines. Breaker stuck. Fault cleared with the loss of further 1/3 of X1-020 turbines.	3.5 / 13	Stable
1B.06	Fault at Greentown 765 kV on X1-020 circuit. T2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Stable
1B.07	Fault at Greentown 765 kV on Jefferson circuit. S2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Stable
1B.08	Not used	N/A	N/A
1B.09	Fault at Dumont 765 kV on X1-020 circuit. B breaker stuck to 765 kV Wilton circuit. Fault cleared with loss of 765 kV Wilton circuit.	3.5 / 13	Stable
1B.10	Fault at Dumont 765 kV on Marysville circuit. A breaker stuck to 765 kV Cook circuit. Fault cleared with the loss of 765 kV Cook circuit.	3.5 / 13	Stable
1B.11	Fault at Dumont 765 kV on Cook circuit. A1 breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with the loss of Dumont 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.12	Fault at Dumont 765 kV on Wilton Center circuit. B1 breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with the loss of Dumont 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.13	Fault at Dumont 765 kV on 765/345 kV Transformer 1. A1 breaker stuck to Cook. Fault cleared with loss of 765 kV Cook circuit.	3.5 / 13	Stable
1B.14	Fault at Dumont 765 kV on 765/345 kV Transformer 2. B2 breaker stuck to X1-020. Fault cleared with loss of 765 kV X1-020 circuit.	3.5 / 13	Stable

Table 7: Faults under Maintenance Outage of 765 kV Dumont – X1-020 POI circuit

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X1-020 No Mitigation
MA.SS.01	Steady state 20 sec	N/A	Stable

MA.3N.02	Three-phase fault at X1-020 765 kV POI on Greentown circuit.	3.5 / 3.5	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.3N.06	Three-phase fault at Greentown 765 kV on Jefferson circuit.	3.5 / 3.5	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.3N.15	Three-phase fault at Jefferson 765 kV on Hanging Rock circuit.	3.5 / 3.5	Stable
MA.1B.04	SLG fault at X1-020 765 kV POI on Greentown circuit. Breaker stuck to X1-020 765/345 kV Transformer 2 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 2.	3.5 / 13	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.1B.06	SLG fault at Greentown 765 kV on X1-020 circuit. T2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Unstable – PSS/E aborted on non-convergence during fault clearing

Attachment 1. X1-020 Impact Study Data

Attachment 2. AEP One Line Diagram

Attachment 3. PSS/E Model One Line Diagram

Attachment 4. X1-020 PSS/E Case Data

Attachment 5. X1-020 PSS/E Dynamics Data

Attachment 6. Plots from Dynamic Simulations

Attachment 2 – Light Load Analysis

Network Impacts

The queue X1-020 project was studied as a 1500MW injection into AEP system tapping Dumont - Greentown 765kV line. Project X1-020 was evaluated for compliance with reliability criteria for **Light Load conditions** in 2015. Potential network impacts were as follows:

Generator Deliverability

None

Contribution to Previously Identified Overloads

None

Steady-State Voltage Requirements

(Results of the steady-state voltage studies should be inserted here)

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

Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position X1-020

Dumont-Greentown 765 kV

December/2015

Revised December 17, 2015

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

Community Energy Wind, LLC proposes to install PJM Project #X1-020, a 1500 MW (195 MW capacity) wind generating facility connecting to the American Electric Power (AEP) Dumont – Greentown 765 kV Circuit (see Figure 2). The location of the wind generating facility is in Miami County, IN approximately 39 miles from the Dumont and Greentown 765 kV stations (see Figure 1).

The requested in service date is June, 2015.

The objective of this 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.

Attachment Facilities

The point of interconnection is approximately 39 miles from either the Greentown or Dumont 765 kV station via a new in-line 765 kV switching station on the Dumont – Greentown 765 kV line. This new station is to consist of four (4) 765 kV circuit breakers configured in a breaker and one half bus arrangement operated as a ring-bus to accommodate two connections to Community's collector station (Exhibit 2). Protection schemes will need to be modified.

The station also includes 765 kV revenue metering, SCADA, and associated equipment. Community is expected to obtain, at their cost, an 800' x 800' (minimum) station site for the AEP facilities. Community shall obtain all necessary permits. Ownership of the in-line facilities shall be transferred from Community to AEP upon successful completion of the work.

A 765 kV line extension is required to loop through the proposed station. The AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap structures will be required. It is expected that Community will obtain the supplemental easement when the station property is purchased.

Changes to relay equipment at Dumont and Greentown stations are required. However, the Greentown 765 kV station is owned by Duke Energy Indiana and AEP. Therefore, coordination between PJM, MISO and Duke Energy Indiana will be required for any relay upgrades/changes at Greentown station.

The following work is required to connect to the Greentown – Dumont 765 kV line:

- Install a new 4-breaker 765 kV switching station laid out in a breaker and one-half arrangement including associated disconnect switch bus work, SCADA and 765 kV revenue metering. Estimated Cost: $30,092,000

- Modify relaying at Dumont 765 kV Station. Estimate Cost: $554,400

- Modify relaying at Greentown 765 kV Station. Estimated Cost: $727,400 (Based on AEP estimates – may also involve DE-I and MISO)

Total Estimated Point of Interconnection Cost: $31,373,800[*]

It is understood that Community Energy Wind LLC is responsible for all costs associated with this connection. The costs above are reimbursable to AEP. Cost of the Community Energy Wind LLC collector station for 1500 MW of generation and costs for the line connection from the collector station to the AEP switching station are not included in this report, these are assumed to be Community Energy Wind LLC'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. The metering work above and cost indicated below does not include any potential work or cost to address metering requirements of the local service provider. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

Local and Network Impacts

The impact of the proposed generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet required performance criteria in accordance with the AEP FERC Form 715. Therefore, this criterion was used to assess the impact of the proposed facility on

[*] The 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.

the AEP System. The Community Energy Wind LLC project was studied as a 1500 MW (195 MW capacity) generating facility consistent with the interconnection application. Project #X1-020 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

Potential network impacts for the points of interconnection were as follows:

Normal System (2015 Summer Conditions Capacity Level)

- No problem identified

Single Contingency (2015 Summer Conditions Capacity Level)

- No problem identified

Multiple Contingency (2015 Summer Conditions Capacity Level)

- No problem identified

Contribution to Previously Identified Overloads (2015 Summer Conditions Capacity Level)

- No problem identified

Normal System (2015 Summer Conditions Full Output)

- No problem identified

Single Contingency (2015 Summer Conditions Full Output)

- No problem identified

Multiple Contingency (2015 Summer Conditions Full Output)

- No problem identified

Contribution to Previously Identified Overloads (2015 Summer Conditions Full Output)

- No problem identified

Light Load Analysis

- No Problem identified

Voltage

- No Problem identified

Short Circuit Analysis

- No Problem identified

Stability Analysis

The concern regarding stability for this project is the N-2 condition involving outage of X1-020 POI to Dumont 765 kV and Greentown-Jefferson 765 kV where the wind generation ends up radial to Greentown 138 kV and 230 kV outlets.

It is found that this condition is of low enough system short circuit ratio (system short circuit MVA/MW generation) as to begin to exhibit signs of wind farm control instability, but it is not to the point of being a stability problem.

This result is sensitive to the wind turbine dynamic modeling data and the line and transformer r+jx values. This study was conducted based on the data available at this time and any small changes in the wind turbine dynamic modeling data and the line and transformer r+jx values may cause wind farm control instability. The complete Stability Analysis can be found in Attachment 1 at the end of this report.

Additional Limitations of Concern

MISO analysis has identified potential overloading of the Sturgis-Howe-LaGrange 69 kV AEP-NIPSCO tieline. AEP owns 2.83 miles of the Howe – Sturgis 69 kV line and the summer emergency rating is 50 MVA. We will have to rebuild 2.83 miles of the existing Howe – Sturgis 69 kV line. Estimated Cost to rebuild is $3.4 Million.

Local/Network Upgrades

- None

Schedule

The standard time required for interconnection station construction is 18 - 24 months after signing an interconnection agreement. The required line upgrades are more significantly affected by availability of construction outages and other details normally addressed in the Facilities Study or when finalizing the ISA/ICSA, but could be expected to take somewhat longer.

Conclusion

Based upon the results of this Impact Study, the construction of the Community Energy Wind LLC (PJM Project #X1-020) wind generation project will require additional interconnection charges. Local network upgrades will also be required for this project.

Network Upgrade Number	Description	Estimate
n4742	Construct Interconnection Substation with Revenue Metering	$30,092,000
n4743	Modify relaying at Dumont 765 kV Station	$554,000
n4744	Modify relaying at Greentown 765 kV Station	$727,400
	Total	**$31,373,400**

Table 1 - Interconnection Costs

Network Upgrade Number	Description	Estimate
~~n4730~~	~~Rebuild/Reconductor approximately 30 miles of the R60/S72 Tap -East Lima 345 kV line section~~	~~$60,000,000~~
n4713	Rebuild 2.83 miles of the existing Howe – Sturgis 69 kV line (AEP portion)	$3,400,000
	Total	**$3,400,000**

Table 2 – Local Network Upgrade Costs

Network Upgrade Number	Description	Estimate
n4740	Rebuild 2.76 miles of the existing Howe – Sturgis 69 kV line (MISO portion)	$2,208,000
n4741	Rebuild of 1.91 miles of 69kV circuit	$1,524,000
	Total	**$3,732,000**

Table 3 – Affected System Upgrade Costs

- **Estimated interconnection cost: $31,373,800.**
- **Estimated local network upgrade cost**: **$3,400,000.**
- **Estimated Affected System upgrade cost**: **$3,732,000.**
- **Total estimated cost for project X1-020: $38,505,400.**

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 refine final construction requirements. Per the PJM Tariff, the customer is responsible for the actual costs incurred.

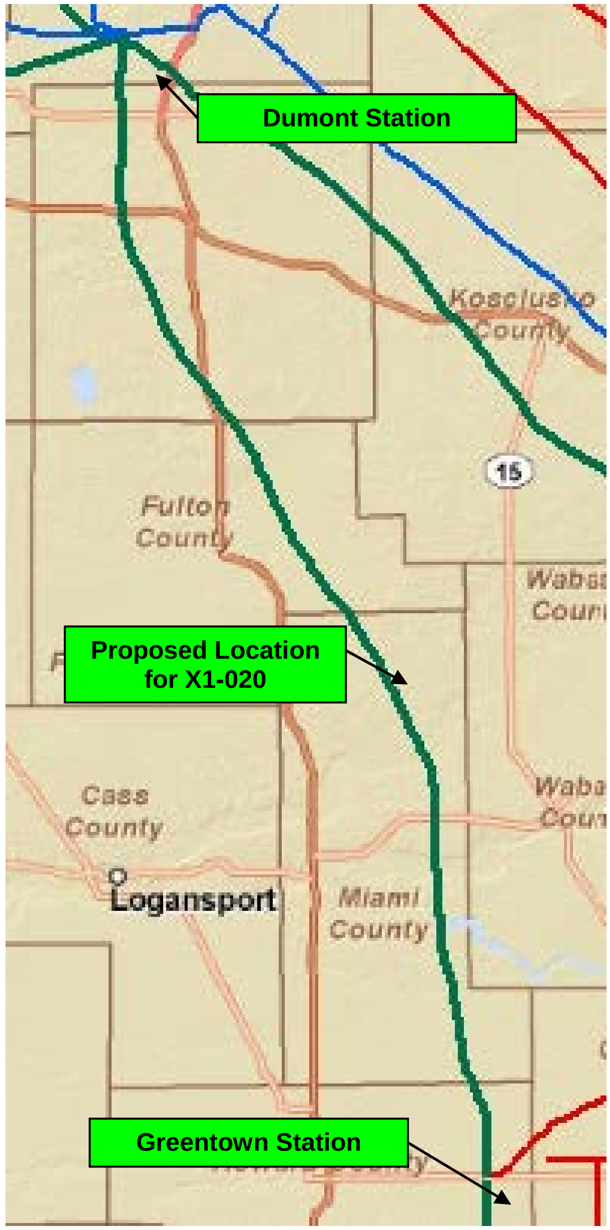

Exhibit 1: Approximate interconnection location of the proposed facilities

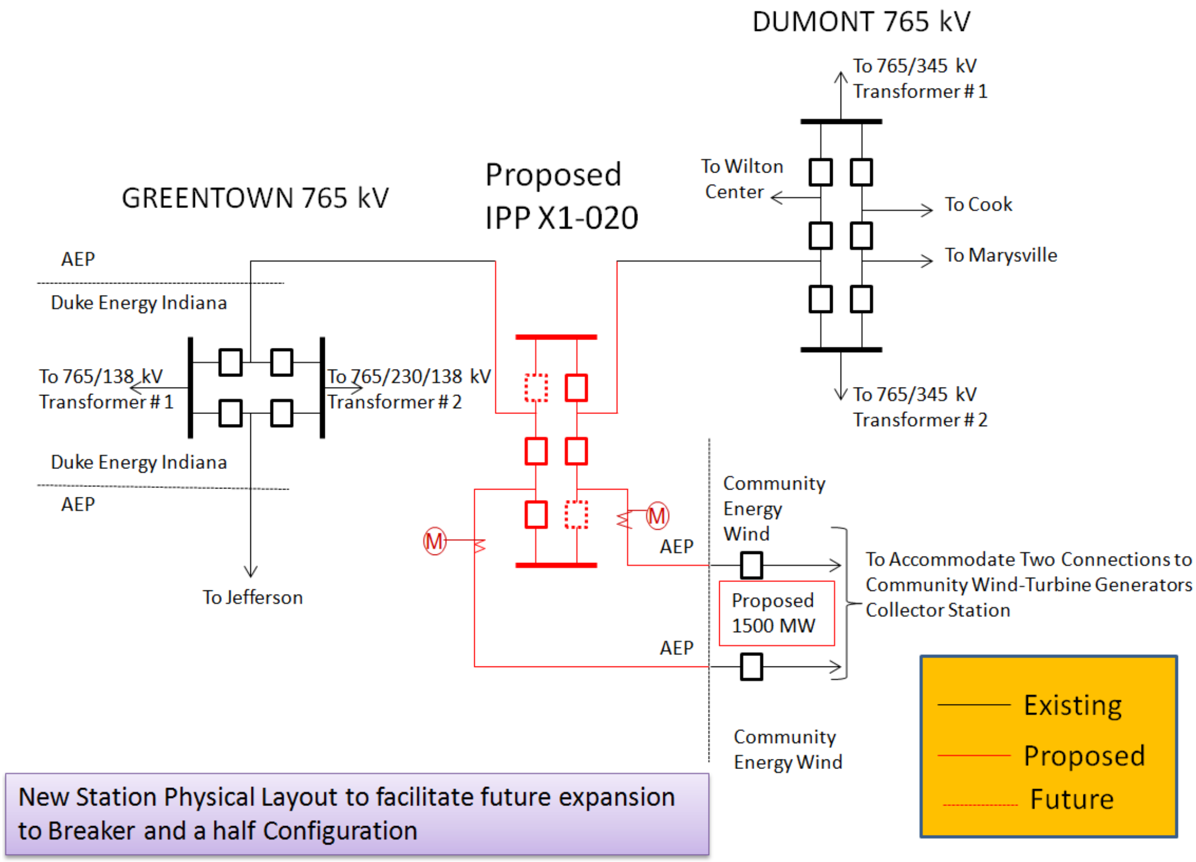

Exhibit 2: Simplified diagram of proposed 765 kV in-line switching station

Attachment 1 – Stability Analysis

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Executive Summary

Generation Interconnection Request X1-020 is for a 1500 MW (maximum facility output) wind farm consisting of 612 × 2.5 MW wind turbine generators with a Point of Interconnection (POI) on the Dumont – Greentown 765 kV circuit in the American Electric Power (AEP) network.

X1-020 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of X1-020 as part of the overall system impact study.

The load flow scenario for analysis was the RTEP 2015 summer peak load case, with the addition of the X1-020 models at maximum power output and unity power factor at the collector buses.

27 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation
b) Three phase faults with normal clearing time
c) Single phase faults with single phase stuck breaker

Selected contingencies were also run under a maintenance outage of the 765 kV Dumont – X1-020 POI circuit. Single phase faults with delayed clearing were omitted as the AEP clearing times indicate that dual primary communication systems are used at 765 kV.

X1-020 was modeled in voltage control mode, per the Impact Study data supplied by the developer. For the intact system, the fault simulations met the fault recovery criteria:

a) X1-020 rode through the faults (except for faults where protective action tripped some machines of X1-020),
b) the system with X1-020 included was found to be transiently stable,
c) a new steady state was reached,
d) voltages at the POI and nearby buses returned to an acceptable range, with system stability being maintained. No mitigations were found to be required.

Several tested under the maintenance outage of the Dumont – X1-020 POI circuit did not run to completion due to non-convergence of the simulation, and inter-tripping of X1-020 would be required for these contingencies. This is the case for contingencies at the X1-020 POI and at Greentown. For these instances, the windfarm is required to be curtailed.

1. Introduction

Generation Interconnection Request X1-020 is for a 1500 MW wind farm consisting of 612 × 2.5 MW wind turbine generators with a Point of Interconnection (POI) on the Dumont – Greentown 765 kV circuit in the American Electric Power (AEP) network.

As the Regional Transmission Operator, PJM Interconnection is responsible for planning the incorporation of generators into the grid. X1-020 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process.

PJM contracted Power Systems Consultants (PSC) to carry out this dynamic simulation analysis of X1-020 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of X1-020 will meet the dynamics requirements of the NERC and PJM reliability standards.

In this report the X1-020 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of the Project

The proposed X1-020 project is specified in the Impact Study data provided in Attachment 1. Attachment 2 shows the one line diagram of the AEP network in the vicinity of X1-020.

X1-020 is connected to the AEP system via the existing 78 mile 765 kV circuit between Greentown 765 kV Substation and Dumont 765 kV Substation, approximately 35 miles from Greentown Substation. The project includes the establishment of a new in-line switching station based on a breaker and one half bus arrangement but configured as a ring bus with four circuit breakers.

Figure 1 shows how X1-020 has been modeled in this study. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the X1-020 load flow model. Attachment 3 provides a diagram of the PSS/E model in the vicinity of X1-020; Attachment 4 gives the X1-020 PSS/E load flow model.

The dynamic model for the X1-020 plant is based on a GEWT 2.5 MW PSS/E model supplied by PJM. The dynamic model of the X1-020 plant is given in Attachment 5.

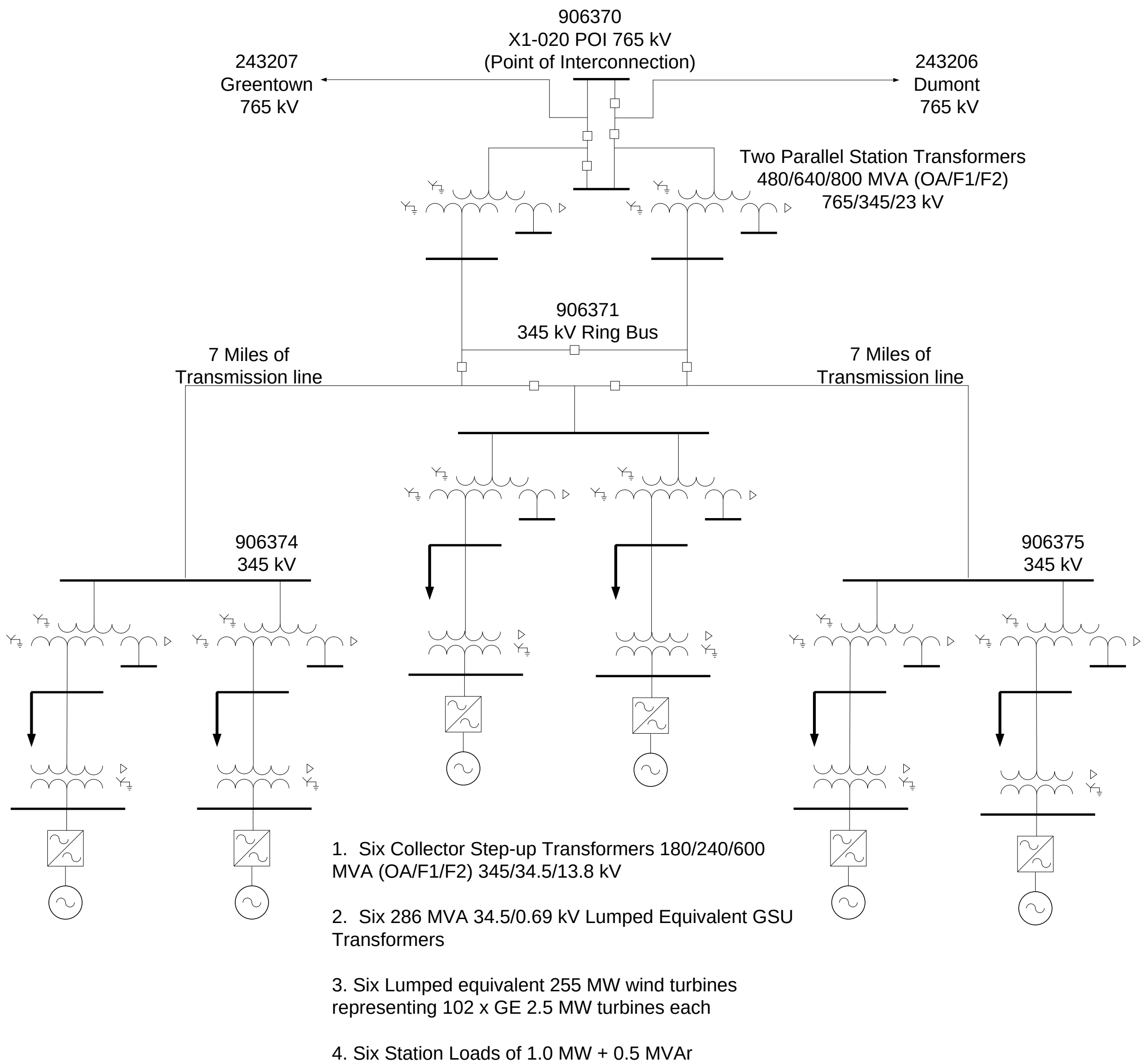

Figure 1: X1-020 Model

Table 1: X1-020 Plant Model

	Impact Study Data	**Model**
Wind turbine generator	612 x GE 2.5 MW wind turbines MVA base 3.0 MVA Vt = 0.69kV +/- 1.2 MVAr / turbine Saturated subtransient reactance not given – proponent referred to manufacturer specifications.	6 Lumped equivalents representing 102 x 2.5 MW GE Wind Turbines Pgen 255 MW Pmax 255 MW Pmin 0 MW Qgen 15.1 MVAr Qmax 122.4 MVAr* Qmin -122.4 MVAr* Mbase 306 MVA Zsorce[1] 0.0 + j99999 pu
GSU transformer	612 x 2.8 MVA 34.5/0.69 kV 0.8 % + j 6.0 % @ 2.8 MVA Number of taps = 5 Tap Step Size = 2.5 % OA 2.8 MVA	6 Lumped equivalents representing 102 x 2.8 MVA GSU transformers. 285.6 MVA 34.5/0.69 kV 0.008 + j0.06 pu @ 285.6 MVA 5 taps Tap step size = 2.5%

[1] Source reactance of the GE wind turbine model is set to a large number as per the Siemens User Guide – PSS/E Wind Modelling Package for GE 2.5 MW Wind turbines.

Collector step-up transformer	345/34.5/13.8 kV Yyd 180/240/300 MVA (OA/F1/F2) Collector bus off-nominal turns ratio: 1.0 Impedances (pu @ 180 MVA) HV-MV 0.00167 + j0.10 MV-Tertiary 0.00117 + j0.07 HV-Tertiary 0.003 + j0.18	345/34.5/13.8 kV Yyd 180/240/300 MVA (OA/F1/F2) Positive Sequence pu @ 180 MVA HV-MV 0.00167 + j0.10 MV-Tertiary 0.00117 + j0.07 HV-Tertiary 0.003 + j0.18
Station transformer	765/345/23 kV Yyd 480/640/800 MVA (OA/F1/F2) Number of taps = 5 Tap Step Size = 2.5 % Collector bus off-nominal turns ratio: 1.0 Impedances (pu @ 480 MVA) HV-MV 0.0015 + j0.09 MV-Tertiary 0.00105 + j0.063 HV-Tertiary 0.0027 + j0.162	765/345/23 kV Yyd 480/640/800 MVA (OA/F1/F2) Number of taps = 5 Tap Step Size = 2.5 % Positive Sequence pu @ 480 MVA HV-MV 0.0015 + j0.09 MV-Tertiary 0.00105 + j0.063 HV-Tertiary 0.0027 + j0.162
Collector cables		Not modeled
Station demand	1.0 MW + 0.5 MVAr at low voltage side of GSU	6 × 0.167 MW/0.083 MVAr at 34.5 kV busbars

Transmission line	2 × 7 mile 345 kV 795 kcmil ACSR conductor MVA Base 1000 MVA Z1 = 0.000548+j0.00388 pu/mile Z0 = 0.00520+j0.01407 pu/mile Y1 = 0.00085 pu/mile	MVA Base 100 MVA Z1 = 0.0004+j0.0027 pu Y1 = 0.0595 pu

* Qmax = 15.1MVAr and Qmin = 0 MVAr when running X1-020 study in order to make a conservative assessment of LV ride-through capability by having unity power factor at the collector bus.

3. Load flow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 30.3.1.

The load flow scenario and fault cases for this study are based on PJM's Region Transmission Planning Process[2] and discussions with PJM.

This study is focused on the ability of the plant to ride through faults. The selected load flow scenario is the RTEP 2015 summer peak load case, provided by PJM from the W3-088 study, with the following modifications:

a) Modeling of X1-020 at the Point of Interconnection between Greentown 765 kV Substation and Dumont 765 kV Substation
b) Removal of withdrawn and subsequent queue projects in the vicinity of X1-020
c) Connection and disconnection of some distant generation units in the PJM system in order to maintain slack units within limits
d) Deactivation of bus 243462 (an AEP 242 kV bus connected only to a transformer and solving at > 1.4 pu voltage) to improve load flow convergence

In the load flow the X1-020 generators are set to maximum power output (total 1530 MW) with unity power factor at the collector buses (34.5 kV) and approximately 0.96 and 0.95 pu voltage at the generator buses and collector buses respectively.

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

Generation within the PJM500 system (area 225 in the PSS/E case) and within a 5 bus radius of X1-020 has been dispatched online at maximum output. Exceptions are listed in Table 2.

Table 2: Generation at reduced output within 5-bus radius of X1-020

Bus	**Name**	**Unit**	**PGEN (MW)**	**PMAX (MW)**	**Reason**
248000	06CLIFTY 345.00	A	110	124.715	Initialization issue
248000	06CLIFTY 345.00	B	110	124.715	
243225	05KEYSTN 345.00	1	50	59	GGOV1 Trate=51 MW limits output
243225	05KEYSTN 345.00	2	50	60	
243225	05KEYSTN 345.00	3	50	60	
243225	05KEYSTN 345.00	4	50	59	
243187	05GVG2 26.000	2H	657.2	667	Conflict with governor model

In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV shunt reactors listed in Table 3 were switched out of service.

Table 3: 765 kV Shunt reactors switched out

From Bus Number	**From Bus Name**	**To Bus Number**	**To Bus Name**	**Id**	**Line B From (pu on 100 MVA) Removed**	**Line B To (pu on 100 MVA) Removed**
242509	05AXTON 765.00	242514	05J.FERR 765.00	1	-3	0
242510	05BAKER 765.00	242511	05BROADF 765.00	1	-3	-3
242512	05CLOVRD 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242515	05JOSHUA 765.00	1	-3	0
242924	05HANG R 765.00	243208	05JEFRSO 765.00	1	-3	-3
242928	05MARYSV 765.00	243206	05DUMONT 765.00	1	-3	-3
243206	05DUMONT 765.00	906370	X1-020 MAIN 765.00	1	-3	0

243207	05GRNTWN 765.00	243208	05JEFRSO 765.00	1	-3	-3

Modifications were made to the dynamics case to resolve initialization issues:

1. Removal of several distant generation units from the dynamic simulation to avoid initialization problems, including machines 3 and 5 at bus 345400 (ESST1A exciter models initializing out of limits).

2. Bus 347832 has been netted to avoid the following initialization issue, and a consequent significant DSTATE warning:

```
MNLEX3 AT BUS 347832 [1NEWTON 1   24.000] MACHINE 1
INITIALIZED ABOVE ZERO
```

3. For bus 270000 existing units 1, 2 & 3 and bus 270001 existing units 1 & 2, the saturation factors S(1.0) and S(1.2) were much higher than expected; it was assumed they are % rather than per unit values. These values were thus divided by 100 to set more realistic values.

4. For bus 248000 machine C (+ machine 6), the IEEEG1 governor model was suppressed to avoid initializing out of limits.

4. Fault Cases

Tables 4 – 6 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 10 second simulation time interval. Faults were applied to transmission circuits and transformers connected to the Point of Interconnection or one bus removed[3].

The studied faults included:

a) Steady state operation
b) Three phase faults with normal clearing time
c) Single phase faults with single phase stuck breaker

[3] One bus removed from the POI refers to buses with transmission circuit breakers, not tee-offs or buses with only supply circuit breakers.

Selected faults were also run under a maintenance outage of the 765 kV Dumont – X1-020 POI circuit.

Single phase faults with delayed clearing were omitted as the AEP clearing times indicated that dual primary communication systems are used at 765 kV.

The one line diagram of the AEP network in Attachment 2 shows where faults were applied.

The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case provided by PJM, modified by PSC to ensure that connected generators in the vicinity of X1-020 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

The two 765/345 kV transformers at Dumont had different impedance values in the X1-020 short circuit case. This resulted in different fault admittance for contingencies 1B.13 and 1B.14. The greater of the two fault admittances was used for both contingencies to provide a conservative outcome.

5. Fault Recovery Criteria

The fault recovery criteria applicable to this study are as per PJM's Region Transmission Planning Process:

a) Post-contingency voltages should remain within +/- 0.05 pu of the pre-contingency voltages at transmission level buses.
b) Post-contingency oscillations should be positively damped with a damping margin of at least 3%.
c) The X1-020 generators should maintain their pre-contingent power output following the fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Tables 4 – 7.

For the intact system, the fault simulations met the fault recovery criteria:

a) the system with X1-020 included in voltage control mode was found to be transiently stable,
b) a new steady state was reached,
c) voltages at the POI and nearby buses returned to an acceptable range,
with X1-020 riding through the fault (except for faults where protective action tripped some machines of X1-020) and system stability being maintained. No mitigations were found to be required.

For the system under a maintenance outage of the 765 kV circuit between Dumont and the X1-020 POI, test contingencies involving faults at the X1-020 POI and at Greentown 765 kV did not run to completion. All of the maintenance outage contingencies tested at these locations require inter-tripping of X1-020. A contingency involving the same maintenance outage and a fault on the Jefferson to Hanging Rock 765 kV circuit was found to meet criteria.

Table 4: Steady State Operation

Fault ID	Duration	X1-020 No Mitigation
SS.01	Steady state 20 sec	Stable

Table 5: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X1-020 No Mitigation
3N.01	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 1 circuit.	3.5 / 3.5	Stable
3N.02	Fault at X1-020 765 kV POI on Greentown circuit.	3.5 / 3.5	Stable
3N.03	Fault at X1-020 765 kV POI on Dumont circuit.	3.5 / 3.5	Stable
3N.04	Fault at X1-020 345 kV on circuit to 1/3 of X1-020 turbines.	3.5 / 3.5	Stable
3N.05	Fault at Greentown 765 kV on X1-020 circuit.	3.5 / 3.5	Stable
3N.06	Fault at Greentown 765 kV on Jefferson circuit.	3.5 / 3.5	Stable
3N.07	Fault at Greentown 765 kV on 765/138 kV Transformer 1.	3.5 / 3.5	Stable
3N.08	Fault at Greentown 765 kV on 765/230/138 kV Transformer 2.	3.5 / 3.5	Stable
3N.09	Fault at Dumont 765 kV on X1-020 circuit.	3.5 / 3.5	Stable
3N.10	Fault at Dumont 765 kV on Marysville circuit.	3.5 / 3.5	Stable
3N.11	Fault at Dumont 765 kV on Cook circuit.	3.5 / 3.5	Stable
3N.12	Fault at Dumont 765 kV on Wilton Centre circuit.	3.5 / 3.5	Stable
3N.13	Fault at Dumont 765 kV on 765/345 kV Transformer 1.	3.5 / 3.5	Stable

Table 6: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal / Stuck Breaker (Cycles)	X1-020 No Mitigation
1B.01	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 1 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of 765 kV Dumont circuit.	3.5 / 13	Stable
1B.02	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 2 circuit. Breaker stuck to Greentown circuit. Fault cleared with loss of 765 kV Greentown circuit.	3.5 / 13	Stable
1B.03	Fault at X1-020 765 kV POI on Dumont circuit. Breaker stuck to X1-020 765/345 kV Transformer 1 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.04	Fault at X1-020 765 kV POI on Greentown circuit. Breaker stuck to X1-020 765/345 kV Transformer 2 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 2.	3.5 / 13	Stable
1B.05	Fault at X1-020 345 kV on circuit to 1/3 of X1-020 turbines. Breaker stuck. Fault cleared with the loss of further 1/3 of X1-020 turbines.	3.5 / 13	Stable
1B.06	Fault at Greentown 765 kV on X1-020 circuit. T2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Stable
1B.07	Fault at Greentown 765 kV on Jefferson circuit. S2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Stable
1B.08	Not used	N/A	N/A
1B.09	Fault at Dumont 765 kV on X1-020 circuit. B breaker stuck to 765 kV Wilton circuit. Fault cleared with loss of 765 kV Wilton circuit.	3.5 / 13	Stable
1B.10	Fault at Dumont 765 kV on Marysville circuit. A breaker stuck to 765 kV Cook circuit. Fault cleared with the loss of 765 kV Cook circuit.	3.5 / 13	Stable
1B.11	Fault at Dumont 765 kV on Cook circuit. A1 breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with the loss of Dumont 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.12	Fault at Dumont 765 kV on Wilton Center circuit. B1 breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with the loss of Dumont 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.13	Fault at Dumont 765 kV on 765/345 kV Transformer 1. A1 breaker stuck to Cook. Fault cleared with loss of 765 kV Cook circuit.	3.5 / 13	Stable
1B.14	Fault at Dumont 765 kV on 765/345 kV Transformer 2. B2 breaker stuck to X1-020. Fault cleared with loss of 765 kV X1-020 circuit.	3.5 / 13	Stable

Table 7: Faults under Maintenance Outage of 765 kV Dumont – X1-020 POI circuit

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X1-020 No Mitigation
MA.SS.01	Steady state 20 sec	N/A	Stable

MA.3N.02	Three-phase fault at X1-020 765 kV POI on Greentown circuit.	3.5 / 3.5	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.3N.06	Three-phase fault at Greentown 765 kV on Jefferson circuit.	3.5 / 3.5	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.3N.15	Three-phase fault at Jefferson 765 kV on Hanging Rock circuit.	3.5 / 3.5	Stable
MA.1B.04	SLG fault at X1-020 765 kV POI on Greentown circuit. Breaker stuck to X1-020 765/345 kV Transformer 2 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 2.	3.5 / 13	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.1B.06	SLG fault at Greentown 765 kV on X1-020 circuit. T2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Unstable – PSS/E aborted on non-convergence during fault clearing

Attachment 1. X1-020 Impact Study Data

Attachment 2. AEP One Line Diagram

Attachment 3. PSS/E Model One Line Diagram

Attachment 4. X1-020 PSS/E Case Data

Attachment 5. X1-020 PSS/E Dynamics Data

Attachment 6. Plots from Dynamic Simulations

Attachment 2 – Light Load Analysis

Network Impacts

The queue X1-020 project was studied as a 1500MW injection into AEP system tapping Dumont - Greentown 765kV line. Project X1-020 was evaluated for compliance with reliability criteria for **Light Load conditions** in 2015. Potential network impacts were as follows:

Generator Deliverability

None

Contribution to Previously Identified Overloads

None

Steady-State Voltage Requirements

(Results of the steady-state voltage studies should be inserted here)

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

Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position X1-020

Dumont-Greentown 765 kV

December/2015

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

Community Energy Wind, LLC proposes to install PJM Project #X1-020, a 1500 MW (195 MW capacity) wind generating facility connecting to the American Electric Power (AEP) Dumont – Greentown 765 kV Circuit (see Figure 2). The location of the wind generating facility is in Miami County, IN approximately 39 miles from the Dumont and Greentown 765 kV stations (see Figure 1).

The requested in service date is June, 2015.

The objective of this 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.

Attachment Facilities

The point of interconnection is approximately 39 miles from either the Greentown or Dumont 765 kV station via a new in-line 765 kV switching station on the Dumont – Greentown 765 kV line. This new station is to consist of four (4) 765 kV circuit breakers configured in a breaker and one half bus arrangement operated as a ring-bus to accommodate two connections to Community's collector station (Exhibit 2). Protection schemes will need to be modified.

The station also includes 765 kV revenue metering, SCADA, and associated equipment. Community is expected to obtain, at their cost, an 800' x 800' (minimum) station site for the AEP facilities. Community shall obtain all necessary permits. Ownership of the in-line facilities shall be transferred from Community to AEP upon successful completion of the work.

A 765 kV line extension is required to loop through the proposed station. The AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap structures will be required. It is expected that Community will obtain the supplemental easement when the station property is purchased.

Changes to relay equipment at Dumont and Greentown stations are required. However, the Greentown 765 kV station is owned by Duke Energy Indiana and AEP. Therefore, coordination between PJM, MISO and Duke Energy Indiana will be required for any relay upgrades/changes at Greentown station.

The following work is required to connect to the Greentown – Dumont 765 kV line:

- Install a new 4-breaker 765 kV switching station laid out in a breaker and one-half arrangement including associated disconnect switch bus work, SCADA and 765 kV revenue metering. Estimated Cost: $30,092,000

- Modify relaying at Dumont 765 kV Station. Estimate Cost: $554,400

- Modify relaying at Greentown 765 kV Station. Estimated Cost: $727,400 (Based on AEP estimates – may also involve DE-I and MISO)

Total Estimated Point of Interconnection Cost: $31,373,800*

It is understood that Community Energy Wind LLC is responsible for all costs associated with this connection. The costs above are reimbursable to AEP. Cost of the Community Energy Wind LLC collector station for 1500 MW of generation and costs for the line connection from the collector station to the AEP switching station are not included in this report, these are assumed to be Community Energy Wind LLC's responsibility.

The Generation interconnection agreement does <u>not</u> 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. The metering work above and cost indicated below does not include any potential work or cost to address metering requirements of the local service provider. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

Local and Network Impacts

The impact of the proposed generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet required performance criteria in accordance with the AEP FERC Form 715. Therefore, this criterion was used to assess the impact of the proposed facility on

* The 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.

the AEP System. The Community Energy Wind LLC project was studied as a 1500 MW (195 MW capacity) generating facility consistent with the interconnection application. Project #X1-020 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

Potential network impacts for the points of interconnection were as follows:

<u>Normal System (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Single Contingency (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Multiple Contingency (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Contribution to Previously Identified Overloads (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Normal System (2015 Summer Conditions Full Output)</u>

- No problem identified

<u>Single Contingency (2015 Summer Conditions Full Output)</u>

- No problem identified

<u>Multiple Contingency (2015 Summer Conditions Full Output)</u>

- No problem identified

<u>Contribution to Previously Identified Overloads (2015 Summer Conditions Full Output)</u>

- No problem identified

Light Load Analysis

- The Maddox – East Lima 345 kV line (from bus 246929 to bus 242935) loads to 110.9% of its normal rating 897 MVA for the single line contingency outage (05MARYSV_05SOREN 765 kV).

CONTINGENCY '05MARYSV _05DUMONT _118_A'

DISCONNECT BRANCH FROM BUS 242928 TO BUS 299951 CKT 1 / 05MARYSV – 05SOREN 765kV*

END

See the Complete Light Load Analysis in Attachment 2 at the end of this report.

Voltage

- No Problem identified

Short Circuit Analysis

- No Problem identified

Stability Analysis

The concern regarding stability for this project is the N-2 condition involving outage of X1-020 POI to Dumont 765 kV and Greentown-Jefferson 765 kV where the wind generation ends up radial to Greentown 138 kV and 230 kV outlets.

It is found that this condition is of low enough system short circuit ratio (system short circuit MVA/MW generation) as to begin to exhibit signs of wind farm control instability, but it is not to the point of being a stability problem.

This result is sensitive to the wind turbine dynamic modeling data and the line and transformer r+jx values. This study was conducted based on the data available at this time and any small changes in the wind turbine dynamic modeling data and the line and transformer r+jx values may cause wind farm control instability. The complete Stability Analysis can be found in Attachment 1 at the end of this report.

Additional Limitations of Concern

MISO analysis has identified potential overloading of the Sturgis-Howe-LaGrange 69 kV AEP-NIPSCO tieline. AEP owns 2.83 miles of the Howe – Sturgis 69 kV line and the summer emergency rating is 50 MVA. We will have to rebuild 2.83 miles of the existing Howe – Sturgis 69 kV line. Estimated Cost to rebuild is $3.4 Million.

Local/Network Upgrades

- The Maddox – East Lima 345 kV overload has one limiting element. The 1275 Conductor Section1 is the limiting element.
    - Reconductoring 30 miles of the Maddox – East Lima 345 kV line will mitigate this overload.
    - Estimated Cost: $60 Million.

Schedule

The standard time required for interconnection station construction is 18 - 24 months after signing an interconnection agreement. The required line upgrades are more significantly affected by availability of construction outages and other details normally addressed in the Facilities Study or when finalizing the ISA/ICSA, but could be expected to take somewhat longer.

Conclusion

Based upon the results of this Impact Study, the construction of the Community Energy Wind LLC (PJM Project #X1-020) wind generation project will require additional interconnection charges. Local network upgrades will also be required for this project.

Network Upgrade Number	Description	Estimate
n4742	Construct Interconnection Substation with Revenue Metering	$30,092,000
n4743	Modify relaying at Dumont 765 kV Station	$554,000
n4744	Modify relaying at Greentown 765 kV Station	$727,400
	Total	**$31,373,400**

Table 1 - Interconnection Costs

Network Upgrade Number	Description	Estimate
n4730	Rebuild/Reconductor approximately 30 miles of the R60/S72 Tap -East Lima 345 kV line section	$60,000,000
n4713	Rebuild 2.83 miles of the existing Howe – Sturgis 69 kV line (AEP portion)	$3,400,000
	Total	**$63,400,000**

Table 2 – Local Network Upgrade Costs

Network Upgrade Number	Description	Estimate
n4740	Rebuild 2.76 miles of the existing Howe – Sturgis 69 kV line (MISO portion)	$2,208,000
n4741	Rebuild of 1.91 miles of 69kV circuit	$1,524,000
	Total	**$3,732,000**

Table 3 – Affected System Upgrade Costs

- **Estimated interconnection cost: $31,373,800.**
- **Estimated local network upgrade cost: $63,400,000.**
- **Estimated Affected System upgrade cost: $3,732,000.**
- **Total estimated cost for project X1-020: $98,505,400.**

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 refine final construction requirements. Per the PJM Tariff, the customer is responsible for the actual costs incurred.

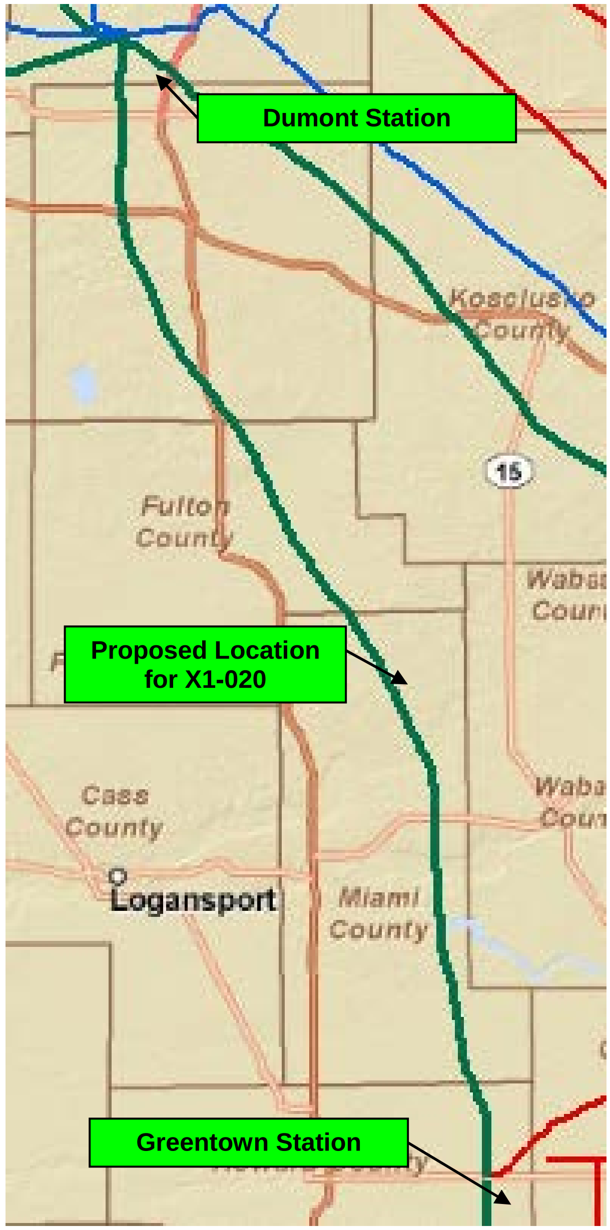

Exhibit 1: Approximate interconnection location of the proposed facilities

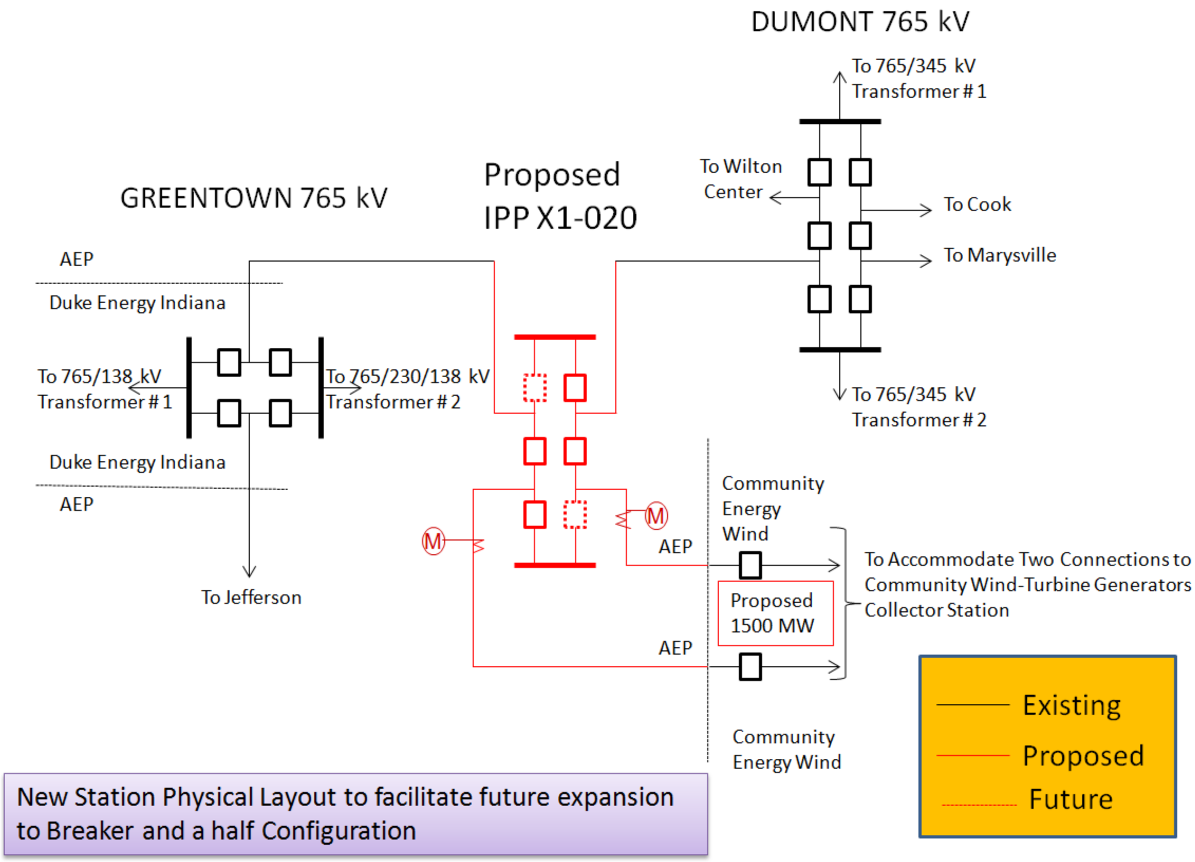

Exhibit 2: Simplified diagram of proposed 765 kV in-line switching station

Attachment 1 – Stability Analysis

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Executive Summary

Generation Interconnection Request X1-020 is for a 1500 MW (maximum facility output) wind farm consisting of 612 × 2.5 MW wind turbine generators with a Point of Interconnection (POI) on the Dumont – Greentown 765 kV circuit in the American Electric Power (AEP) network.

X1-020 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of X1-020 as part of the overall system impact study.

The load flow scenario for analysis was the RTEP 2015 summer peak load case, with the addition of the X1-020 models at maximum power output and unity power factor at the collector buses.

27 contingencies were studied, each with a 10 second simulation time period. Studied faults included:

a) Steady state operation
b) Three phase faults with normal clearing time
c) Single phase faults with single phase stuck breaker

Selected contingencies were also run under a maintenance outage of the 765 kV Dumont – X1-020 POI circuit. Single phase faults with delayed clearing were omitted as the AEP clearing times indicate that dual primary communication systems are used at 765 kV.

X1-020 was modeled in voltage control mode, per the Impact Study data supplied by the developer. For the intact system, the fault simulations met the fault recovery criteria:

a) X1-020 rode through the faults (except for faults where protective action tripped some machines of X1-020),
b) the system with X1-020 included was found to be transiently stable,
c) a new steady state was reached,
d) voltages at the POI and nearby buses returned to an acceptable range, with system stability being maintained. No mitigations were found to be required.

Several tested under the maintenance outage of the Dumont – X1-020 POI circuit did not run to completion due to non-convergence of the simulation, and inter-tripping of X1-020 would be required for these contingencies. This is the case for contingencies at the X1-020 POI and at Greentown. For these instances, the windfarm is required to be curtailed.

1. Introduction

Generation Interconnection Request X1-020 is for a 1500 MW wind farm consisting of 612 × 2.5 MW wind turbine generators with a Point of Interconnection (POI) on the Dumont – Greentown 765 kV circuit in the American Electric Power (AEP) network.

As the Regional Transmission Operator, PJM Interconnection is responsible for planning the incorporation of generators into the grid. X1-020 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process.

PJM contracted Power Systems Consultants (PSC) to carry out this dynamic simulation analysis of X1-020 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of X1-020 will meet the dynamics requirements of the NERC and PJM reliability standards.

In this report the X1-020 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of the Project

The proposed X1-020 project is specified in the Impact Study data provided in Attachment 1. Attachment 2 shows the one line diagram of the AEP network in the vicinity of X1-020.

X1-020 is connected to the AEP system via the existing 78 mile 765 kV circuit between Greentown 765 kV Substation and Dumont 765 kV Substation, approximately 35 miles from Greentown Substation. The project includes the establishment of a new in-line switching station based on a breaker and one half bus arrangement but configured as a ring bus with four circuit breakers.

Figure 1 shows how X1-020 has been modeled in this study. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the X1-020 load flow model. Attachment 3 provides a diagram of the PSS/E model in the vicinity of X1-020; Attachment 4 gives the X1-020 PSS/E load flow model.

The dynamic model for the X1-020 plant is based on a GEWT 2.5 MW PSS/E model supplied by PJM. The dynamic model of the X1-020 plant is given in Attachment 5.

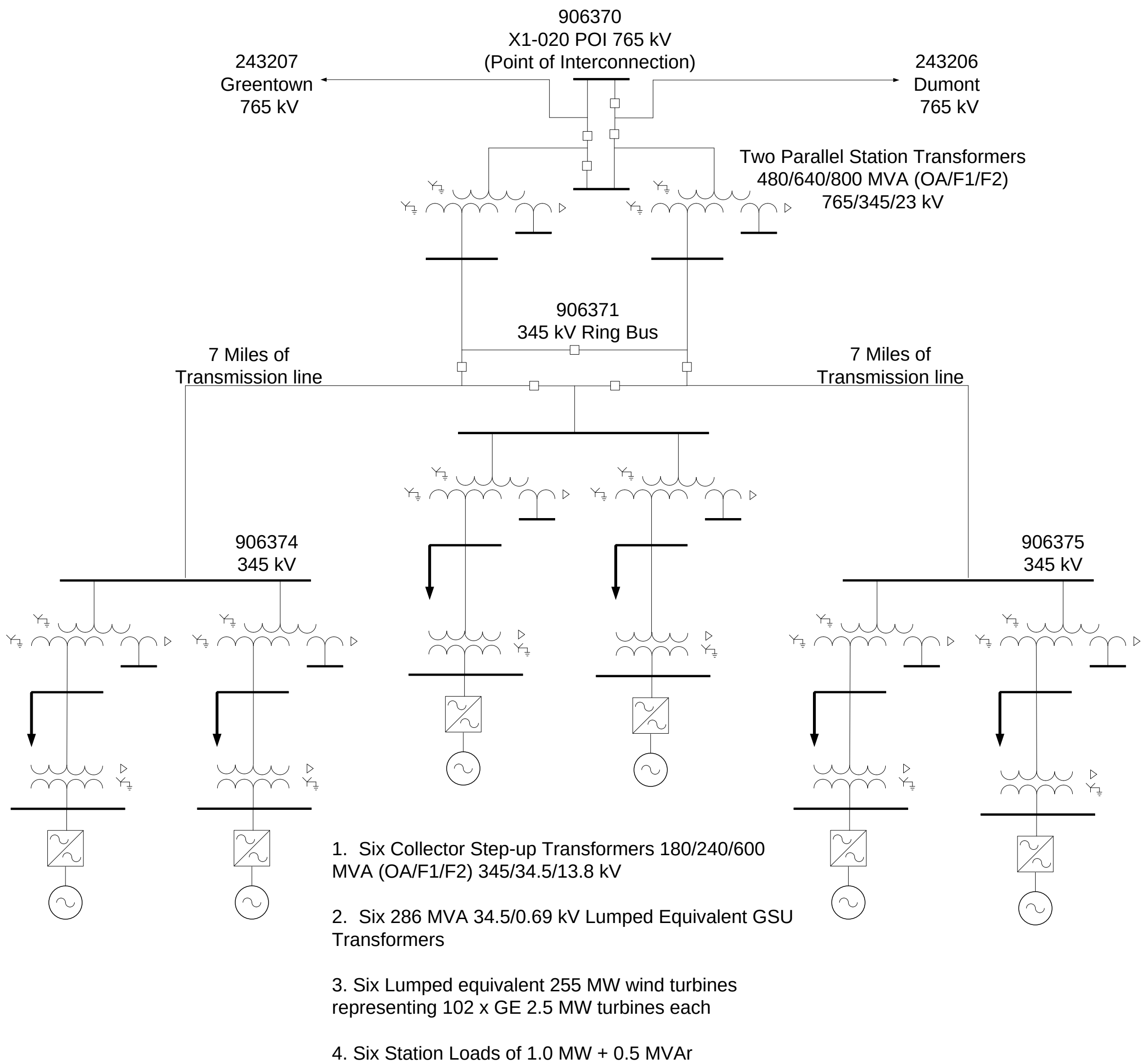

Figure 1: X1-020 Model

Table 1: X1-020 Plant Model

	Impact Study Data	Model
Wind turbine generator	612 x GE 2.5 MW wind turbines MVA base 3.0 MVA Vt = 0.69kV +/- 1.2 MVAr / turbine Saturated subtransient reactance not given – proponent referred to manufacturer specifications.	6 Lumped equivalents representing 102 x 2.5 MW GE Wind Turbines Pgen 255 MW Pmax 255 MW Pmin 0 MW Qgen 15.1 MVAr Qmax 122.4 MVAr* Qmin -122.4 MVAr* Mbase 306 MVA Zsorce[1] 0.0 + j99999 pu
GSU transformer	612 x 2.8 MVA 34.5/0.69 kV 0.8 % + j 6.0 % @ 2.8 MVA Number of taps = 5 Tap Step Size = 2.5 % OA 2.8 MVA	6 Lumped equivalents representing 102 x 2.8 MVA GSU transformers. 285.6 MVA 34.5/0.69 kV 0.008 + j0.06 pu @ 285.6 MVA 5 taps Tap step size = 2.5%

[1] Source reactance of the GE wind turbine model is set to a large number as per the Siemens User Guide – PSS/E Wind Modelling Package for GE 2.5 MW Wind turbines.

Collector step-up transformer	345/34.5/13.8 kV Yyd 180/240/300 MVA (OA/F1/F2) Collector bus off-nominal turns ratio: 1.0 Impedances (pu @ 180 MVA) HV-MV 0.00167 + j0.10 MV-Tertiary 0.00117 + j0.07 HV-Tertiary 0.003 + j0.18	345/34.5/13.8 kV Yyd 180/240/300 MVA (OA/F1/F2) Positive Sequence pu @ 180 MVA HV-MV 0.00167 + j0.10 MV-Tertiary 0.00117 + j0.07 HV-Tertiary 0.003 + j0.18
Station transformer	765/345/23 kV Yyd 480/640/800 MVA (OA/F1/F2) Number of taps = 5 Tap Step Size = 2.5 % Collector bus off-nominal turns ratio: 1.0 Impedances (pu @ 480 MVA) HV-MV 0.0015 + j0.09 MV-Tertiary 0.00105 + j0.063 HV-Tertiary 0.0027 + j0.162	765/345/23 kV Yyd 480/640/800 MVA (OA/F1/F2) Number of taps = 5 Tap Step Size = 2.5 % Positive Sequence pu @ 480 MVA HV-MV 0.0015 + j0.09 MV-Tertiary 0.00105 + j0.063 HV-Tertiary 0.0027 + j0.162
Collector cables		Not modeled
Station demand	1.0 MW + 0.5 MVAr at low voltage side of GSU	6 × 0.167 MW/0.083 MVAr at 34.5 kV busbars

Transmission line	2 × 7 mile 345 kV 795 kcmil ACSR conductor MVA Base 1000 MVA Z1 = 0.000548+j0.00388 pu/mile Z0 = 0.00520+j0.01407 pu/mile Y1 = 0.00085 pu/mile	MVA Base 100 MVA Z1 = 0.0004+j0.0027 pu Y1 = 0.0595 pu

* Qmax = 15.1MVAr and Qmin = 0 MVAr when running X1-020 study in order to make a conservative assessment of LV ride-through capability by having unity power factor at the collector bus.

3. Load flow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 30.3.1.

The load flow scenario and fault cases for this study are based on PJM's Region Transmission Planning Process[2] and discussions with PJM.

This study is focused on the ability of the plant to ride through faults. The selected load flow scenario is the RTEP 2015 summer peak load case, provided by PJM from the W3-088 study, with the following modifications:

a) Modeling of X1-020 at the Point of Interconnection between Greentown 765 kV Substation and Dumont 765 kV Substation
b) Removal of withdrawn and subsequent queue projects in the vicinity of X1-020
c) Connection and disconnection of some distant generation units in the PJM system in order to maintain slack units within limits
d) Deactivation of bus 243462 (an AEP 242 kV bus connected only to a transformer and solving at > 1.4 pu voltage) to improve load flow convergence

In the load flow the X1-020 generators are set to maximum power output (total 1530 MW) with unity power factor at the collector buses (34.5 kV) and approximately 0.96 and 0.95 pu voltage at the generator buses and collector buses respectively.

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

Generation within the PJM500 system (area 225 in the PSS/E case) and within a 5 bus radius of X1-020 has been dispatched online at maximum output. Exceptions are listed in Table 2.

Table 2: Generation at reduced output within 5-bus radius of X1-020

Bus	**Name**	**Unit**	**PGEN (MW)**	**PMAX (MW)**	**Reason**
248000	06CLIFTY 345.00	A	110	124.715	Initialization issue
248000	06CLIFTY 345.00	B	110	124.715	
243225	05KEYSTN 345.00	1	50	59	GGOV1 Trate=51 MW limits output
243225	05KEYSTN 345.00	2	50	60	
243225	05KEYSTN 345.00	3	50	60	
243225	05KEYSTN 345.00	4	50	59	
243187	05GVG2 26.000	2H	657.2	667	Conflict with governor model

In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV shunt reactors listed in Table 3 were switched out of service.

Table 3: 765 kV Shunt reactors switched out

From Bus Number	**From Bus Name**	**To Bus Number**	**To Bus Name**	**Id**	**Line B From (pu on 100 MVA) Removed**	**Line B To (pu on 100 MVA) Removed**
242509	05AXTON 765.00	242514	05J.FERR 765.00	1	-3	0
242510	05BAKER 765.00	242511	05BROADF 765.00	1	-3	-3
242512	05CLOVRD 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242515	05JOSHUA 765.00	1	-3	0
242924	05HANG R 765.00	243208	05JEFRSO 765.00	1	-3	-3
242928	05MARYSV 765.00	243206	05DUMONT 765.00	1	-3	-3
243206	05DUMONT 765.00	906370	X1-020 MAIN 765.00	1	-3	0

243207	05GRNTWN 765.00	243208	05JEFRSO 765.00	1	-3	-3

Modifications were made to the dynamics case to resolve initialization issues:

1. Removal of several distant generation units from the dynamic simulation to avoid initialization problems, including machines 3 and 5 at bus 345400 (ESST1A exciter models initializing out of limits).

2. Bus 347832 has been netted to avoid the following initialization issue, and a consequent significant DSTATE warning:
```
MNLEX3 AT BUS 347832 [1NEWTON 1   24.000] MACHINE 1
INITIALIZED ABOVE ZERO
```

3. For bus 270000 existing units 1, 2 & 3 and bus 270001 existing units 1 & 2, the saturation factors S(1.0) and S(1.2) were much higher than expected; it was assumed they are % rather than per unit values. These values were thus divided by 100 to set more realistic values.

4. For bus 248000 machine C (+ machine 6), the IEEEG1 governor model was suppressed to avoid initializing out of limits.

4. Fault Cases

Tables 4 – 6 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 10 second simulation time interval. Faults were applied to transmission circuits and transformers connected to the Point of Interconnection or one bus removed[3].

The studied faults included:

a) Steady state operation
b) Three phase faults with normal clearing time
c) Single phase faults with single phase stuck breaker

[3] One bus removed from the POI refers to buses with transmission circuit breakers, not tee-offs or buses with only supply circuit breakers.

Selected faults were also run under a maintenance outage of the 765 kV Dumont – X1-020 POI circuit.

Single phase faults with delayed clearing were omitted as the AEP clearing times indicated that dual primary communication systems are used at 765 kV.

The one line diagram of the AEP network in Attachment 2 shows where faults were applied.

The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case provided by PJM, modified by PSC to ensure that connected generators in the vicinity of X1-020 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

The two 765/345 kV transformers at Dumont had different impedance values in the X1-020 short circuit case. This resulted in different fault admittance for contingencies 1B.13 and 1B.14. The greater of the two fault admittances was used for both contingencies to provide a conservative outcome.

5. Fault Recovery Criteria

The fault recovery criteria applicable to this study are as per PJM's Region Transmission Planning Process:

a) Post-contingency voltages should remain within +/- 0.05 pu of the pre-contingency voltages at transmission level buses.
b) Post-contingency oscillations should be positively damped with a damping margin of at least 3%.
c) The X1-020 generators should maintain their pre-contingent power output following the fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Tables 4 – 7.

For the intact system, the fault simulations met the fault recovery criteria:

a) the system with X1-020 included in voltage control mode was found to be transiently stable,
b) a new steady state was reached,
c) voltages at the POI and nearby buses returned to an acceptable range,
   with X1-020 riding through the fault (except for faults where protective action tripped some machines of X1-020) and system stability being maintained. No mitigations were found to be required.

For the system under a maintenance outage of the 765 kV circuit between Dumont and the X1-020 POI, test contingencies involving faults at the X1-020 POI and at Greentown 765 kV did not run to completion. All of the maintenance outage contingencies tested at these locations require inter-tripping of X1-020. A contingency involving the same maintenance outage and a fault on the Jefferson to Hanging Rock 765 kV circuit was found to meet criteria.

Table 4: Steady State Operation

Fault ID	Duration	X1-020 No Mitigation
SS.01	Steady state 20 sec	Stable

Table 5: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X1-020 No Mitigation
3N.01	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 1 circuit.	3.5 / 3.5	Stable
3N.02	Fault at X1-020 765 kV POI on Greentown circuit.	3.5 / 3.5	Stable
3N.03	Fault at X1-020 765 kV POI on Dumont circuit.	3.5 / 3.5	Stable
3N.04	Fault at X1-020 345 kV on circuit to 1/3 of X1-020 turbines.	3.5 / 3.5	Stable
3N.05	Fault at Greentown 765 kV on X1-020 circuit.	3.5 / 3.5	Stable
3N.06	Fault at Greentown 765 kV on Jefferson circuit.	3.5 / 3.5	Stable
3N.07	Fault at Greentown 765 kV on 765/138 kV Transformer 1.	3.5 / 3.5	Stable
3N.08	Fault at Greentown 765 kV on 765/230/138 kV Transformer 2.	3.5 / 3.5	Stable
3N.09	Fault at Dumont 765 kV on X1-020 circuit.	3.5 / 3.5	Stable
3N.10	Fault at Dumont 765 kV on Marysville circuit.	3.5 / 3.5	Stable
3N.11	Fault at Dumont 765 kV on Cook circuit.	3.5 / 3.5	Stable
3N.12	Fault at Dumont 765 kV on Wilton Centre circuit.	3.5 / 3.5	Stable
3N.13	Fault at Dumont 765 kV on 765/345 kV Transformer 1.	3.5 / 3.5	Stable

Table 6: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal / Stuck Breaker (Cycles)	X1-020 No Mitigation
1B.01	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 1 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of 765 kV Dumont circuit.	3.5 / 13	Stable
1B.02	Fault at X1-020 765 kV POI on X1-020 765/345 kV Transformer 2 circuit. Breaker stuck to Greentown circuit. Fault cleared with loss of 765 kV Greentown circuit.	3.5 / 13	Stable
1B.03	Fault at X1-020 765 kV POI on Dumont circuit. Breaker stuck to X1-020 765/345 kV Transformer 1 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.04	Fault at X1-020 765 kV POI on Greentown circuit. Breaker stuck to X1-020 765/345 kV Transformer 2 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 2.	3.5 / 13	Stable
1B.05	Fault at X1-020 345 kV on circuit to 1/3 of X1-020 turbines. Breaker stuck. Fault cleared with the loss of further 1/3 of X1-020 turbines.	3.5 / 13	Stable
1B.06	Fault at Greentown 765 kV on X1-020 circuit. T2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Stable
1B.07	Fault at Greentown 765 kV on Jefferson circuit. S2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Stable
1B.08	Not used	N/A	N/A
1B.09	Fault at Dumont 765 kV on X1-020 circuit. B breaker stuck to 765 kV Wilton circuit. Fault cleared with loss of 765 kV Wilton circuit.	3.5 / 13	Stable
1B.10	Fault at Dumont 765 kV on Marysville circuit. A breaker stuck to 765 kV Cook circuit. Fault cleared with the loss of 765 kV Cook circuit.	3.5 / 13	Stable
1B.11	Fault at Dumont 765 kV on Cook circuit. A1 breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with the loss of Dumont 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.12	Fault at Dumont 765 kV on Wilton Center circuit. B1 breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with the loss of Dumont 765/345 kV Transformer 1.	3.5 / 13	Stable
1B.13	Fault at Dumont 765 kV on 765/345 kV Transformer 1. A1 breaker stuck to Cook. Fault cleared with loss of 765 kV Cook circuit.	3.5 / 13	Stable
1B.14	Fault at Dumont 765 kV on 765/345 kV Transformer 2. B2 breaker stuck to X1-020. Fault cleared with loss of 765 kV X1-020 circuit.	3.5 / 13	Stable

Table 7: Faults under Maintenance Outage of 765 kV Dumont – X1-020 POI circuit

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X1-020 No Mitigation
MA.SS.01	Steady state 20 sec	N/A	Stable

MA.3N.02	Three-phase fault at X1-020 765 kV POI on Greentown circuit.	3.5 / 3.5	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.3N.06	Three-phase fault at Greentown 765 kV on Jefferson circuit.	3.5 / 3.5	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.3N.15	Three-phase fault at Jefferson 765 kV on Hanging Rock circuit.	3.5 / 3.5	Stable
MA.1B.04	SLG fault at X1-020 765 kV POI on Greentown circuit. Breaker stuck to X1-020 765/345 kV Transformer 2 circuit. Fault cleared with the loss of X1-020 765/345 kV Transformer 2.	3.5 / 13	Unstable – PSS/E aborted on non-convergence during fault clearing
MA.1B.06	SLG fault at Greentown 765 kV on X1-020 circuit. T2 breaker stuck. Fault cleared with the loss of 765/230/138 kV Greentown Transformer 2.	3.5 / 13	Unstable – PSS/E aborted on non-convergence during fault clearing

Attachment 1. X1-020 Impact Study Data

Attachment 2. AEP One Line Diagram

Attachment 3. PSS/E Model One Line Diagram

Attachment 4. X1-020 PSS/E Case Data

Attachment 5. X1-020 PSS/E Dynamics Data

Attachment 6. Plots from Dynamic Simulations

Attachment 2 – Light Load Analysis

Network Impacts

The queue X1-020 project was studied as a 1500MW injection into AEP system tapping Dumont - Greentown 765kV line. Project X1-020 was evaluated for compliance with reliability criteria for **Light Load conditions** in 2015. Potential network impacts were as follows:

Generator Deliverability

None

Contribution to Previously Identified Overloads

1. The R60_S72_TAP - 05E LIMA 345kV line (from bus 99202 to bus 242935 ckt 1) loads to 107.89% of its emergency rating (897MVA) for the Single contingency 361_B2. This project contributes approximately 73.16 MW to the thermal violation.

CONTINGENCY '361_B2A' /
OPEN BRANCH FROM BUS 242928 TO BUS 299951 CKT 1 / 242928 05MARYSV 765 299951 05SORENS 765 1
END

Steady-State Voltage Requirements

(Results of the steady-state voltage studies should be inserted here)

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)

1. To alleviate thermal violations on R60/S72 Tap – East Lima 345kV the following upgrade is needed:

[n4730] Rebuild/Reconductor approximately 30 miles of the line section. Estimated Cost for the line rebuild $60,000,000.

Queue	Impact, MW	Impact, %	Cost
U3-026	3	2.03%	1.2158
V3-007	9.7	6.55%	3.9311
V3-008	9.7	6.55%	3.9311
V3-009	9.7	6.55%	3.9311
V4-033	13.95	9.42%	5.6535
W3-046	11.61	7.84%	4.7052
W4-005	17.23	11.64%	6.9828
X1-020	73.16	49.42%	29.6494

Appendix 1

Bus #	Name	Pmax	Pgen	DFAX	50/50 MW	Adder MW	50/50|Adder
905072	W4-005 E	305.4	0	0.07359		15.2826	Adder
905071	W4-005 C	45.6	0	0.07359		2.2819	Adder
903432	W3-046	207.5	0	0.10756	17.855		80/20
902352	W2-048 E	62.5	0	0.06182		2.6274	Adder
900091	V4-049	20	0	0.12744	2.5488		80/20
900081	V4-048	20	0	0.12717	2.5434		80/20
900071	V4-047	20	0	0.10348	2.0696		80/20
900061	V4-046	20	0	0.10347	2.0694		80/20
892031	V1-025	20	0	0.1223	2.446		80/20
892021	V1-024	20	0	0.12229	2.4458		80/20
90728	U3-026	246	0	0.11228	27.6209		80/20
90729	U3-026	246	0	0.11228	27.6209		80/20
885741	T-148	100	0	0.10502	8.4016		80/20
885721	T-143	250	0	0.09907	19.814		80/20
885631	T-099	100	0	0.10502	8.4016		80/20
290732	S-058	219	0	0.11228	19.6715		80/20
90727	S-057 2E	219	0	0.11228	19.6715		80/20
90726	S-057 2C	219	0	0.11228	19.6715		80/20
290731	S-057	219	0	0.11228	19.6715		80/20
290298	S-037OP1	175	0	0.12028	16.8392		80/20
290294	S-036	175	0	0.12028	16.8392		80/20
296128	R-030 3	166	0	0.08801		9.9346	Adder
296272	R-030 2	166	0	0.08801		9.9346	Adder
296309	R-030 1	168	0	0.08801		10.0543	Adder
290100	Q50E	20	0	0.11105	2.221		80/20
290000	Q49E	20	0	0.11529	2.3058		80/20
290090	Q39E	75.6	0	0.09514	5.7541		80/20
290089	Q39C	29.4	0	0.09514		1.902	Adder
94762	P46C	100.5	40.6	0.10264	4.0894		80/20
94666	P36_2GEN	119.7	48.3	0.09946	4.7198		80/20
94664	P36 GEN	119.7	48.3	0.09946	4.7198		80/20
4481	P20_GEN2	105	0	0.09858	8.2807		80/20
4479	P20_GEN1	105	0	0.09858	8.2807		80/20
99912	P11_UNIT	201	81.1	0.09514	7.5812		80/20
94391	P10_GEN	190.5	76.9	0.11863	8.9592		80/20
93932	O51 U2	150	60.5	0.09785	5.8187		80/20
93931	O51 U1	150	60.5	0.09785	5.8187		80/20
290021	O50E	160	64.6	0.11119	7.0529		80/20
290020	O50C	40	16.1	0.11119	1.7633		80/20
93771	O35_GEN	74	29.9	0.09702	2.8463		80/20
93712	O29_SUZL	224.7	0	0.09681	17.4026		80/20
93641	O22_2	150.1	60.6	0.10756	6.4005		80/20
93644	O22_1	150.1	60.6	0.10756	6.4005		80/20
93513	O09 SUZL	210	0	0.09681	16.2641		80/20
293191	O-003 E	6.2	2.5	0.10485	0.2577		80/20

Bus #	Name	Pmax	Pgen	DFAX	50/50 MW	Adder MW	50/50|Adder
293190	O-003 C	1.8	0.7	0.10485	0.0749		80/20
293161	N25 E	8.8	3.6	0.10485	0.3658		80/20
293160	N25 C	2.2	0.9	0.10485	0.0914		80/20
293151	N24 E	8.8	3.6	0.10485	0.3658		80/20
293150	N24 C	2.2	0.9	0.10485	0.0914		80/20
293141	N23 E	8.8	3.6	0.10485	0.3658		80/20
293140	N23 C	2.2	0.9	0.10485	0.0914		80/20
293131	N22 E	8.8	3.6	0.10485	0.3658		80/20
293130	N22 C	2.2	0.9	0.10485	0.0914		80/20
293121	N21 E	4.8	1.9	0.10485	0.1995		80/20
293120	N21 C	1.2	0.5	0.10485	0.0499		80/20
21003	N15	150	60.5	0.11863	7.0545		80/20
274850	M HIL;RU	50.4	20.3	0.10485	2.095		80/20
274872	LEEDK;1U	240	100.9	0.10697	9.746		80/20
274849	CRESC;1U	54.5	22	0.09702	2.0943		80/20
292536	CE23EL12	16	0	0.10485	1.3421		80/20
292535	CE23CL12	4	0	0.10485	0.3355		80/20

Appendix 2

Bus #	Name	Pmax	Pgen	DFAX	50/50 MW	Adder MW	50/50|Adder
905072	W4-005 E	305.4	0	0.39171	95.7026		80/20
905071	W4-005 C	45.6	0	0.39171	14.2896		80/20
902352	W2-048 E	62.5	0	0.29306	14.653		80/20
274854	TWING;U2	198	79.9	0.44402	34.8534		80/20
274853	TWING;U1	198	79.9	0.44402	34.8534		80/20
296128	R-030 3	166	0	0.51288	68.1105		80/20
296272	R-030 2	166	0	0.51288	68.1105		80/20
296309	R-030 1	168	0	0.51288	68.9311		80/20
93932	O51 U2	150	60.5	0.69357	41.2438		80/20
93931	O51 U1	150	60.5	0.69357	41.2438		80/20

Appendix 3

Bus #	Name	Pmax	Pgen	DFAX	50/50 MW	Adder MW	50/50|Adder
905072	W4-005 E	305.4	0	0.06137		12.7448	Adder
905071	W4-005 C	45.6	0	0.06137		1.903	Adder
905042	W4-004 E	78.3	0	0.05029		2.6776	Adder
905041	W4-004 C	11.7	0	0.05029		0.4001	Adder
903432	W3-046	207.5	0	0.06992	11.6067		80/20
902352	W2-048 E	62.5	0	0.05775		2.4544	Adder
900091	V4-049	20	0	0.07191	1.4382		80/20
900081	V4-048	20	0	0.07191	1.4382		80/20
900071	V4-047	20	0	0.06659	1.3318		80/20
900061	V4-046	20	0	0.06659	1.3318		80/20
900031	V4-033	300	0	0.05812		11.8565	Adder
894531	V3-015	300	0	0.09077	21.7848		80/20
894521	V3-009	200	0	0.06067		8.2511	Adder
894511	V3-008	200	0	0.06067		8.2511	Adder
894501	V3-007	200	0	0.06067		8.2511	Adder
892031	V1-025	20	0	0.07148	1.4296		80/20
892021	V1-024	20	0	0.07148	1.4296		80/20
90728	U3-026	246	0	0.07303	17.9654		80/20
90729	U3-026	246	0	0.07303	17.9654		80/20
885741	T-148	100	0	0.06712	5.3696		80/20
885721	T-143	250	0	0.06609	13.218		80/20
885701	T-131	150	0	0.05591		5.7028	Adder
885631	T-099	100	0	0.06712	5.3696		80/20
90883	S-072	240	0	0.54761	105.1411		80/20
290787	S-071	120	0	0.06215		5.0714	Adder
290732	S-058	219	0	0.07303	12.7949		80/20
90727	S-057 2E	219	0	0.07303	12.7949		80/20
90726	S-057 2C	219	0	0.07303	12.7949		80/20
290731	S-057	219	0	0.07303	12.7949		80/20
290298	S-037OP1	175	0	0.07203	10.0842		80/20
290294	S-036	175	0	0.07203	10.0842		80/20
90881	R-060	350	0	0.54761	153.3308		80/20
296145	R-048	48	0	0.05241		1.7107	Adder
296128	R-030 3	166	0	0.06523	8.6625		80/20
296272	R-030 2	166	0	0.06523	8.6625		80/20
296309	R-030 1	168	0	0.06523	8.7669		80/20
290100	Q50E	20	0	0.06962	1.3924		80/20
290000	Q49E	20	0	0.07063	1.4126		80/20
290090	Q39E	75.6	0	0.06482		3.3323	Adder
290089	Q39C	29.4	0	0.06482		1.2959	Adder
94762	P46C	100.5	40.6	0.0663	2.6415		80/20
94666	P36_2GEN	119.7	48.3	0.06519	3.0935		80/20
94664	P36 GEN	119.7	48.3	0.06519	3.0935		80/20
4481	P20_GEN2	105	0	0.0649	5.4516		80/20

Bus #	Name	Pmax	Pgen	DFAX	50/50 MW	Adder MW	50/50|Adder
4479	P20_GEN1	105	0	0.0649		4.6339	Adder
94391	P10_GEN	190.5	76.9	0.0707	5.3394		80/20
93932	O51 U2	150	60.5	0.06846	4.071		80/20
93931	O51 U1	150	60.5	0.06846	4.071		80/20
290021	O50E	160	64.6	0.06949	4.4078		80/20
290020	O50C	40	16.1	0.06949	1.102		80/20
93771	O35_GEN	74	29.9	0.06543	1.9195		80/20
93712	O29_SUZL	224.7	0	0.06471		9.8874	Adder
93641	O22_2	150.1	60.6	0.06992	4.1607		80/20
93644	O22_1	150.1	60.6	0.06992	4.1607		80/20
93513	O09 SUZL	210	0	0.06471		9.2406	Adder
293191	O-003 E	6.2	2.5	0.06716	0.1651		80/20
293190	O-003 C	1.8	0.7	0.06716	0.048		80/20
293161	N25 E	8.8	3.6	0.06716	0.2343		80/20
293160	N25 C	2.2	0.9	0.06716	0.0586		80/20
293151	N24 E	8.8	3.6	0.06716	0.2343		80/20
293150	N24 C	2.2	0.9	0.06716	0.0586		80/20
293141	N23 E	8.8	3.6	0.06716	0.2343		80/20
293140	N23 C	2.2	0.9	0.06716	0.0586		80/20
293131	N22 E	8.8	3.6	0.06716	0.2343		80/20
293130	N22 C	2.2	0.9	0.06716	0.0586		80/20
293121	N21 E	4.8	1.9	0.06716	0.1278		80/20
293120	N21 C	1.2	0.5	0.06716	0.032		80/20
21003	N15	150	60.5	0.0707	4.2042		80/20
885691	ML4_5	200	0	0.0625		8.5	Adder
885681	ML3_4	200	0	0.0625		8.5	Adder
274850	M HIL;RU	50.4	20.3	0.06716	1.3419		80/20
274872	LEEDK;1U	240	100.9	0.06789	6.1855		80/20
889101	HEADWATERS	200	0	0.06067		8.2511	Adder
890501	GRANDWIND	200	0	0.0634		8.6224	Adder
274849	CRESC;1U	54.5	22	0.06543	1.4124		80/20
90999	CLR_1	202	0	0.0625		8.585	Adder
292536	CE23EL12	16	0	0.06716	0.8596		80/20
292535	CE23CL12	4	0	0.06716	0.2149		80/20

Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position X1-020

Dumont-Greentown (Harvest Wind) 765 kV

December/2012

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

General

Community Energy Wind, LLC proposes to install PJM Project #X1-020, a 1500 MW (195 MW capacity) wind generating facility connecting to the American Electric Power (AEP) Dumont – Greentown 765 kV Circuit (see Figure 2). The location of the wind generating facility is in Miami County, IN approximately 39 miles from the Dumont and Greentown 765 kV stations (see Figure 1).

The requested in service date is June, 2015.

The objective of this 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.

Attachment Facilities

The point of interconnection is approximately 39 miles from either the Greentown or Dumont 765 kV station via a new in-line 765 kV switching station on the Dumont – Greentown 765 kV line (Figure 1). This new station is to consist of four (4) 765 kV circuit breakers configured in a breaker and one half bus arrangement operated as a ring-bus to accommodate two connections to Community's collector station (Figure 2). Protection schemes will need to be modified.

The station also includes 765 kV revenue metering, SCADA, and associated equipment. Community is expected to obtain, at their cost, an 800' x 800' (minimum) station site for the AEP facilities. Community shall obtain all necessary permits. Ownership of the in-line facilities shall be transferred from Community to AEP upon successful completion of the work.

A 765 kV line extension is required to loop through the proposed station. The AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap structures will be required. It is expected that Community will obtain the supplemental easement when the station property is purchased.

Changes to relay equipment at Dumont and Greentown stations are required. However, the Greentown 765 kV station is owned by Duke Energy Indiana and AEP. Therefore, coordination between PJM, MISO and Duke Energy Indiana will be required for any relay upgrades/changes at Greentown station.

The following work is required to connect to the Greentown – Dumont 765 kV line:

- Install a new 4-breaker 765 kV switching station laid out in a breaker and one-half arrangement including associated disconnect switch bus work, SCADA and 765 kV revenue metering. Estimated Cost (2012 Dollars): $30,092,000 (n3528)

- Modify relaying at Dumont 765 kV Station. Estimate Cost (2012 Dollars): $554,400 (n3529)

- Modify relaying at Greentown 765 kV Station. Estimated Cost (2012 Dollars): $727,400 (n3530) (Based on AEP estimates – may also involve DE-I and MISO)

Total Estimated Point of Interconnection Cost (2012 Dollars): $31,373,800

It is understood that Community Energy Wind LLC is responsible for all costs associated with this connection. The costs above are reimbursable to AEP. Cost of the Community Energy Wind LLC collector station for 1500 MW of generation and costs for the line connection from the collector station to the AEP switching station are not included in this report, these are assumed to be Community Energy Wind LLC's responsibility.

The Generation interconnection agreement does not in or by itself establishes 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. The metering work above and cost indicated below does not include any potential work or cost to address metering requirements of the local service provider. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

The 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 - Approximate interconnection location of the proposed facilities

Community Energy LLC is required to construct all connection facilities in accordance with the AEP published standards.

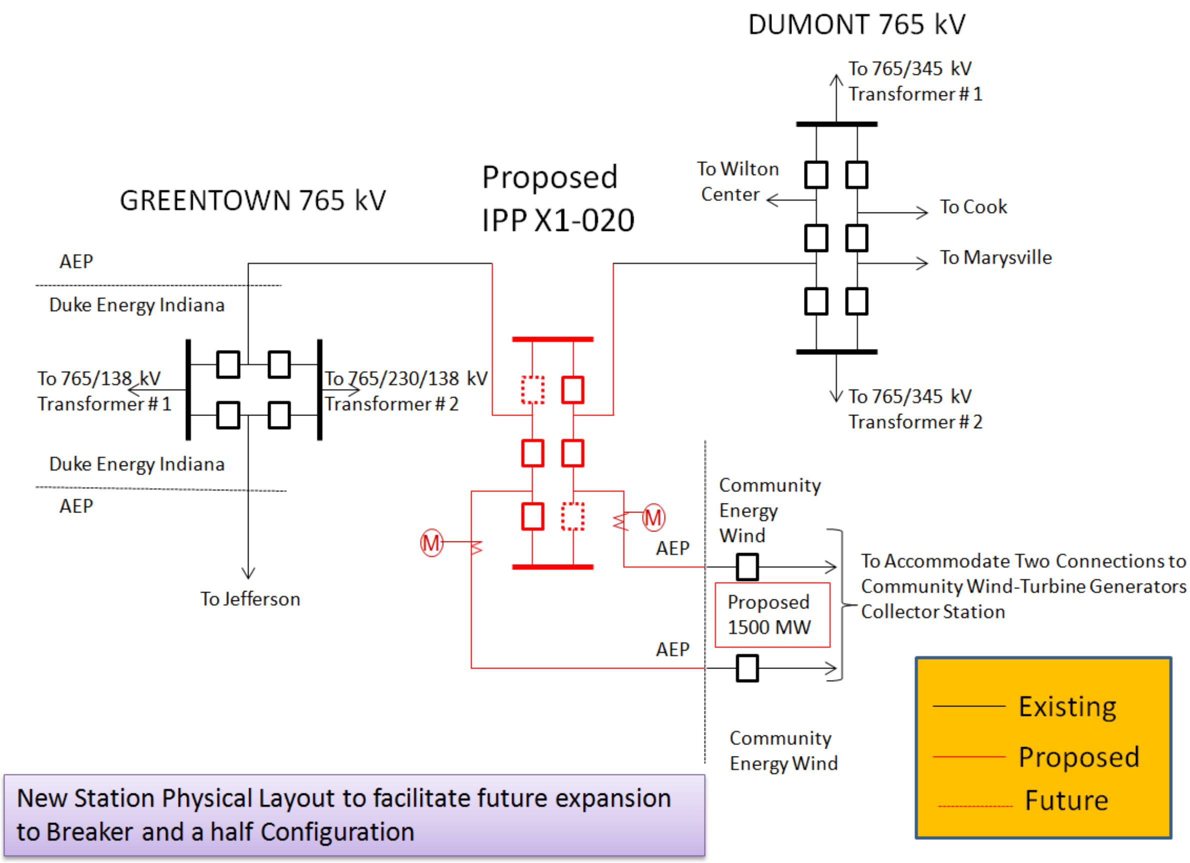

Figure 2. Simplified diagram of proposed 765 kV in-line switching station

Revenue Metering and SCADA Requirements

For PJM: IC will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for IC's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

For AEP: The Interconnection Customer will be required to comply with all AEP Revenue Metering Requirements for Generation Interconnection Customers.

Local and Network Impacts

The impact of the proposed generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet required performance criteria in accordance with the AEP FERC Form 715. Therefore, this criterion was used to assess the impact of the proposed facility on the AEP System. The Community Energy Wind LLC project was studied as a 1500 MW (195 MW capacity) generating facility consistent with the interconnection application. Project #X1-020 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

Potential network impacts for the points of interconnection were as follows:

<u>Normal System (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Single Contingency (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Multiple Contingency (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Contribution to Previously Identified Overloads (2015 Summer Conditions Capacity Level)</u>

- No problem identified

<u>Normal System (2015 Summer Conditions Full Output – provided for information only)</u>

1. The DEER CREEK – GRANT TAP 138 KV line (from bus 243274 to bus 243303 ckt 1) Overloads from 99% to 106% of its normal rating 191MVA for non-contingency condition.

    a. The Deer Creek Riser and Bus are the limiting element.

b. RTEP 2017 has identified the Deer Creek riser and bus as the limiting elements and will be replaced as a baseline project. In-service Date: 6/1/2017

c. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC can choose to pay the incremental cost to advance these upgrades.

2. The WINDSOR – TILTONSVILLE 138 kV line (from bus 235428 to bus 243131 ckt 1) overloads from 96.1% to 105.1% of its normal rating 205MVA for non-contingency condition.

    a. The 556.5 ACSR Conductor Section1 is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV line to mitigate this overload.

Single Contingency (2015 Summer Conditions Full Output – provided for information only)

3. The DRESDEN – DRESDEN8 69 kV line (from bus 245322 to bus 245323 ckt1) loads from 96.9% to 101.6% of its emergency rating 56MVA for single line contingency outage of CONTINGENCY DESCRIPTION (5162_B2_TOR736).

    a. The COPPER 4/0 Conductor Section2, 54MVA summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

4. The LAWTON PARK – THREE RIVERS 34.5 kV line (from bus 246569 to bus 246572 ckt1) overloads from 98.8% to 104.2% of its emergency rating 26MVA for single line outage of CONTINGENCY DESCRIPTION (5524_B2_TOR1737C_MOAB).

    a. The underground CU 500 MCM Conductor Section1 is the limiting element.

b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 34.5 kV line to mitigate this overload.

c. Rather than requiring the Community Energy Wind, LLC project to fix this overload, they could curtail. However, the 34.5 kV facilities do not currently have SCADA to provide monitoring capability. There is no way to know in real time if the lines in question would be overloaded. Therefore AEP will require adding SCADA to the Lawton Park 34.5 kV Station. Estimated Cost (2012 Dollars) for the SCADA: $250,000. (n3531)

5. The WEST PHILO (NORTH PHILO SWITCH) - ZANESVILLE 138 kV line (from bus 243159 to bus 243161 ckt1) overloads from 98.4% to 105.4% of its emergency rating 150MVA for single line outage of CONTINGENCY DESCRIPTION (5164_B2_TOR739A_MOAB).

    a. The 336.4 ACSR Conductor Section1 is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV line to mitigate this overload.

6. The TILTONSVILLE – WEST BELLAIRE 138 kV line (from bus 243131 to bus 243143 ckt1) overloads from 98.6% to 106.8% of its emergency rating 251MVA for single line outage of CONTINGENCY DESCRIPTION (AMOS_WELTONSP).

    a. The 795 ACSR Conductor Section2 is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV line to mitigate this overload.

7. The WOLF CREEK M – WOLF CREEK L 138 kV transformer (from bus 243463 to bus 243589 ckt2) overloads from 98.5% to 115.4% of its emergency rating 215MVA for single line outage of CONTINGENCY DESCRIPTION (37_B2_TOR12_WOMOP).

    a. The Wolf Creek CT, 215MVA summer emergency rating, and the Wolf Creek 138 kV transformer, 229MVA summer emergency rating, are the limiting elements.

b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV limiting elements to mitigate this overload.

8. The MUSKINGUM – WOLF CREEK M 138 kV line (from bus 243045 to bus 243463 ckt1) overloads from 97.6% to 114.8% of its emergency rating 205MVA for single line outage of CONTINGENCY DESCRIPTION (01BELMNT_05BELMON_067).

   a. The 556.5 ACSR Conductor Section2, 205MVA summer emergency rating, the ACSR 636 Conductor Section1, 223MVA summer emergency rating, and the Wolf Creek Risers Sub-conductor 556.5 ACSR, 227MVA summer emergency rating, are the limiting elements.

   b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV limiting elements to mitigate this overload.

9. The LAYMAN – WOLF CREEK L 138 kV line (from bus 243533 to bus 243589 ckt1) overloads from 98.8% to 117.4% of its emergency rating 205MVA for single line outage of CONTINGENCY DESCRIPTION (37_B2_TOR12_WOMOP).

   a. The 556.5 ACSR Conductor Section1, 205MVA summer emergency rating, the Layman Line Risers Sub-conductor 556.5 ACSR, 227MVA summer rating, and the Wolf Creek line Risers Sub-conductor 556.5 ACSR, 227MVA emergency rating, are the limiting element.

   b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV limiting elements to mitigate this overload.

10. The AMHERST COAL – CLIFFORD 69 kV line (from bus 242862 to bus 242867 ckt1) loads from 90.8% to 101.2% of its emergency rating 53MVA for single line contingency outage of CONTINGENCY DESCRIPTION (5401_B2_TOR94A_MOAB).

   a. Conductor Section1, 53 MVA summer emergency rating, is the limiting element.

   b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

Multiple Contingency (2015 Summer Conditions Full Output)

PJM identified overloads:

11. The Dumont 765/345 kV transformer (from bus 243206 to bus 243219 ckt2) loads from 89.05% to 102% of its emergency rating 1752 MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (1750_C2).

12. The Wolf Creek L – Layman 138 kV line (from bus 243589 to bus 243533 ckt1) loads from 95.33% to 100.62% of its emergency rating 205 MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (5031_C2_05Kammer 765-PP2).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

13. The WOLF CREEK M – WOLF CREEK L 138 kV line (from bus 243463 to bus 243589 ckt2) overloads from 97.25% to 102.29% of its emergency rating of 215 MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (5031_C2_05KAMMER 765-PP2).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

14. The Rock Creek – Huntington Junction 138 kV line (from bus 243367 to bus 243313 ckt1) loads from 95.5% to 104.94% of its emergency rating of 167 MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2979_C2_X1-020).

AEP identified overloads:

15. The EAST LIMA – NORTH WOODCOCK 138 kV line (from bus 242989 to bus 243067 ckt1) overloads from 96.7% to 100.7% of its emergency rating of 167MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (3141_C2_05FOSTOR 345-B2).

    a. The 397.5 ACSR Conductor Section1 is the limiting element.

16. The EAST LIMA – NEW LIBERTY 138 kV line (from bus 242989 to bus 243057 ckt1) overloads from 96.9% to 101.5% of its emergency rating of 150MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (3141_C2_05FOSTOR 345-B2).

a. The 336.4 ACSR Conductor Section2 is the limiting element.

17. The BUCKHORN8 – SOUTH MILLERSBURG 138 kV line (from bus 242973 to bus 243105 ckt1) overloads from 95.7% to 101.8% of its emergency rating 184MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4831_C2_05KAMMER 765-NN).

    a. The South Millersburg Risers Sub-conductor 477 AAC 19 strand, 184MVA summer emergency rating, and the 477 ACSR Conductor Section1, 185MVA summer emergency rating, are the limiting elements.

    b. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid

18. The BUCKHORN8 – WEST COSHOCTON 138 kV line (from bus 242973 to bus 243145 ckt1) loads from 96.7% to 102.8% of its emergency rating 185MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4831_C2_05KAMMER 765-NN).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

19. The WINDSOR - TILTON 138 kV line (from bus 235428 to bus 243131 ckt1) overloads from 95.1% to 104.1% of its emergency rating 284MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4743_C2).

    a. The 556.5 ACSR Conductor Section1 is the limiting element.

20. The BETHEL Z- WEST DOVER 138 kV line (from bus 242972 to bus 243135 ckt1) overloads from 95.8% to 106.2% of its emergency rating 185MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4831_C2_05KAMMER 765-NN).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

21. The WOLF CREEK M – WOLF CREEK L 138 kV line (from bus 243463 to bus 243589 ckt2) overloads from 99.5% to 116.9% of its emergency rating 215MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2942_C2_05KAMMER 765-PP).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

Contribution to Previously Identified Overloads (2015 Summer Conditions Full Output)

22. The CONSOL COAL IRELAND – GEORGE WASHINGTON 69 kV line (from bus 245922 to bus 245935 ckt 1) overloads from 109.1% to 112.1% of its emergency rating 41MVA for single line contingency outage of CONTINGENCY DESCRIPTION (5213_B2_TOR773).

    a. The 176.9 ACSR Conductor Section2, 41MVA summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

23. The CONSOL COAL IRELAND – KAMMER 69 kV line (from bus 245922 to bus 245938 ckt 1) overloads from 167.8% to 170.9% of its emergency rating 41MVA for single line contingency outage of CONTINGENCY DESCRIPTION (5213_B2_TOR773).

    a. The 176.9 ACSR Conductor Section2, 41MVA summer emergency rating, the 167.8 ACSR Conductor Section1, 44MVA summer emergency rating, and the 211.6 ACSR Conductor Section4, 50MVA summer emergency rating, are limiting elements.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV limiting elements to mitigate this overload.

24. The MAGLEY – R03 138 kV line (from bus 243334 to bus 295882 ckt1) overloads from 101.8% to 106.6% of its emergency rating 205MVA for single line contingency outage of CONTINGENCY DESCRIPTION (05DUMONT_O5GRTWN_120-X1-020A).

    a. The 556.5 ACSR Conductor Section1 is the limiting element.

b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 138 kV line to mitigate this overload.

25. The SYCAMOR Z – EAST TIFFIN 2 69 kV line (from bus 245635 to bus 245646 ckt1) overloads from 100.2% to 106.0% of its emergency rating 31MVA for single line outage of CONTINGENCY DESCRIPTION (5242_B2_TOR4783B_MOAB).

    a. The COPPER #1 Conductor Section1, 31MVA summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

    c. Rather than requiring this overload be fixed, the contributing generators could curtail. However, the 69 kV facilities do not currently have SCADA to provide monitoring capability. There is no way to know in real time if the lines in question would be overloaded. AEP will require adding SCADA to the East Tiffin 69 kV Station. Estimated Cost (2012 Dollars) for the SCADA: $250,000.

26. The NEWCOMERSTOWN EQ – NEWCOMERSTOWN 69 kV line (from bus 245252 to bus 245253 ckt1) overloads from 113.2% to 119.4 % of its emergency rating 61.8MVA for single line outage of CONTINGENCY DESCRIPTION (5161_B2_TOR732).

    a. Conductor Section1, 61.8 summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

27. The NEWCOMERSTOWN 8 – NEWCOMERSTOWN 69 kV line (from bus 245239 to bus 245253 ckt1) overloads from 100.7% to 107.5% of its emergency rating 46MVA for single line outage of CONTINGENCY DESCRIPTION (5161_B2_TOR732).

    a. The copper 3/0 Conductor Section2, 46MVA summer emergency rating, and Newcomerstown Relay Compliance Trip 393A, 47MVA summer emergency rating, are the limiting elements.

b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV limiting elements to mitigate this overload.

28. The NEWCOMERSTOWN – NEWCOMERSTOWN EQ 138/999 kV transformer (from bus 243056 to bus 245252 ckt1) overloads from 114.1% to 122.2% of its emergency rating 69.2MVA for single line outage of CONTINGENCY DESCRIPTION (5161_B2_TOR732).

    a. The Newcomerstown 138/999 kV transformer, 69.2MVA summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the transformer to mitigate this overload.

29. The MONROE A - REUSENS 69 kV line (from bus 242876 to bus 242882 ckt1) loads from 132.9% to 143.7% of its emergency rating 53MVA for the single line contingency outage of CONTINGENCY DESCRIPTION (5401_B2_TOR94A_MOAB).

    a. Conductor Section1, 53MVA summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

30. The MONROE A – WALTON PARK 69 kV line (from bus 242876 to bus 242887 ckt1) loads from 110.1% to 120.6% of its emergency rating 53MVA for single line contingency outage of CONTINGENCY DESCRIPTION (5401_B2_TOR94A_MOAB).

    a. Conductor Section1, 53MVA summer emergency rating, is the limiting element.

    b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

31. The AMHERST COAL – WALTON PARK 69 kV line (from bus 242862 to bus 242887 ckt1) loads from 114.1% to 125.2% of its emergency rating 50MVA for single line contingency outage of CONTINGENCY DESCRIPTION (5401_B2_TOR94A_MOAB).

a. Conductor Section1, 50MVA summer emergency rating, is the limiting element.

b. The overload on this line will expose project X1-020 to curtailment for summer peak conditions. Community Energy Wind, LLC may choose to upgrade the 69 kV line to mitigate this overload.

32. The CARBONDALE – KANAWH 138 kV line (from bus 242580 to bus 242689 ckt1) loads from 107.1% to 118.7% of its emergency rating 251MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (5031_C2_05KAMMER 765-PP2).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

33. The REYNOL – 17 REYNOLDS 345/138 kV transformer (from bus 243230 to bus 255173 ckt1) overload from 107.1% to 112.3% of its emergency rating of 318MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2978_C2-X1-020A).

    a. The Reynolds 345/138 kV transformer, 350MVA summer emergency rating, the Reynolds 345 kV relaying CT 400A, 318MVA summer emergency rating, are the limiting elements. **This equipment is owned by NIPSCO. Coordination with MISO and NIPSCO will be needed confirm this result and determine mitigation plans.**

34. The OHIO CENTRAL 138/69 kV transformer (from bus 243070 to bus 245338 ckt1) overloads from 109.0% to 114.5% of its emergency rating 77MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (478).

    a. The OHIO CENTRAL 138/69 kV transformer, 77MVA summer emergency rating, is the limiting element.

35. The DRESDEN 8 – OHIO CENTRAL 69 kV line (from bus 245323 to bus 245338 ckt1) overloads from 109.4% to 114.9% of its emergency rating 76MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (478).

    a. The 336.4 ACSR Conductor Section1, 73MVA summer emergency rating, is the limiting element.

36. The SUMMIT – WALLEN 138 kV line (from bus 243381 to bus 243389 ckt1) loads from 107.7% to 113.6% of its emergency rating 257MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2884_C2_05ROB PK 345-LM_WOMOAB).

    a. The 795 ACSR Conductor Section2, 257MVA summer emergency rating, is the limiting element.

37. The INDUSTRIAL PARK - SUMMIT 138 kV line (from bus 243316 to bus 243381 ckt1) overloads from 122.6% to 128.7% of its emergency rating 251MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2884_C2_05ROB PK 345-LM_WOMOAB).

    a. The 795 ACSR Conductor Section1, 251MVA summer emergency rating, is the limiting element.

38. The OHIO CENTRAL – WEST COSHOCTON 138 kV line (from bus 243070 to bus 243145 ckt1) overloads from 108.3% to 114.6% of its emergency rating 185MVA for the line Bus fault contingency outage of CONTINGENCY DESCRIPTION (6404_C1_05OHIOCT 138-2).

    a. The 477 ACSR Conductor Section2, 185MVA summer emergency rating, and the 556.5 ACSR Conductor Section1, 200MVA summer emergency rating, are the limiting element.

39. The WEST PHILO (NORTH PHILO SWITCH) - ZANESVILLE 138 kV line (from bus 243159 to bus 243161 ckt1) overloads from 104.6% to 111.0% of its emergency rating 150MVA for the Bus fault contingency outage of CONTINGENCY DESCRIPTION (6404_C1_05OHIOCT 138-2).

    a. The 336.4 ACSR Conductor Section1, 150MVA summer emergency rating, is the limiting element.

40. The NORTH COSHOCTON – ROBINSON RUN 69 kV line (from bus 245337 to bus 245377 ckt1) loads from 102.7% to 109.9% of its emergency rating 56MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (478).

    a. Conductor Section1, 56MVA summer emergency rating, is the limiting element.

41. The CONESVILLE - DRESDEN 69 kV line (from bus 245318 to bus 245322 ckt1) overloads from 132.9% to 140.3% of its emergency rating 56MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (478).

    a. The COPPER 4/0 conductor section one, 54MVA summer emergency rating, and 336.4 ACSR conductor section 2, 73MVA summer emergency rating, are the limiting elements.

42. The DRESDEN – DRESDEN8 69 kV line (from bus 245322 to bus 245323 ckt1) loads from 144.4% to 151.9% of its emergency rating 56MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (478).

    a. The COPPER 4/0 conductor section 2, 54MVA summer emergency rating, and 336.4 ACSR conductor section1, 73MVA summer emergency rating, are the limiting elements.

43. The OHIO CENTRAL – SOUTH COSHOCTON 138 kV line (from bus 243070 to bus 243094 ckt1) overloads from 111.0% to 119.6% of its emergency rating 185MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4831_C2_05KAMMER 765-NN).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

44. The TILTONSVILLE – WEST BELLAIRE 138 kV line (from bus 243131 to bus 243143 ckt1) overloads from 108.3% to 116.9% of its emergency rating 251MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4743_C2).

    a. The 795 ACSR Conductor Section2, 251 summer emergency rating, is the limiting element.

45. The BRIDGEVILLE - CHANDLERSVILLE 138 kV line (from bus 242965 to bus 242983 ckt1) overloads from 106.0% to 116.5% of its emergency rating 185MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (4831_C2_05KAMMER 765-NN).

    a. The 477 ACSR Conductor Section2, 185MVA summer emergency rating, is the limiting element.

b. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

46. The HUMMEL CREEK – ROCK CREEK 138 kV line (from bus 243312 to bus 243367 ckt1) overloads from 107.3% to 122.7% of its emergency rating 184MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2979_C2-X1-020).

    a. The Rock Creek Riser (1 ph) Sub-conductor 477 AAC 19 strand and Bus, 184MVA summer emergency rating, the Rock Creek switch 600A, 192MVA summer emergency rating, and the Hummel Creek – Rock Creek 138 kV Override, 184MVA summer emergency rating, are the limiting elements.

47. The HUNTINGTON JUNCTION – ROCK CREEK 138 kV line (from bus 243313 to bus 243367 ckt1) overloads from 116.4% to 133.3% of its emergency rating 167MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2979_C2-X1-020).

    a. The Rock Creek Riser and Bus Sub-conductor 477 ACC 19 strand, 184MVA summer emergency rating, and the Rock Creek Switch 600A, 192MVA summer emergency rating, are the limiting elements.

48. The WOLF CREEK M – WOLF CREEK L 138 kV transformer (from bus 243463 to bus 243589 ckt2) overloads from 119.5% to 142.6% of its emergency rating 215MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (5031_C2_05KAMMER 765-PP2).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

49. The MUSKINGUM – WOLF CREEK M 138 kV line (from bus 243045 to bus 243463 ckt1) overloads from 123.7% to 148.2% of its emergency rating 205MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (5031_C2_05KAMMER 765-PP2).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

50. The LAYMAN – WOLF CREEK L 138 kV line (from bus 243533 to bus 243589 ckt1) overloads from 121.8% to 147.1% of its emergency rating 205MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (5031_C2_05KAMMER 765-PP2).

    a. Additional 765 kV circuit breakers at Kammer (b1962) will mitigate this overload. In-Service date is 6/1/2015. This contingency will no longer be valid.

51. The HUNTINGTON JUNCTION - SORENS 138 kV line (from bus 243313 to bus 243377 ckt1) overloads from 116.5% to 144.5% of its emergency rating 208MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (2979_C2-X1-020).

    a. The 397.5 ACSR Conductor Section1, 245MVA summer emergency rating, and the 795 AAC Sub-conductor Sorenson Riser (ph3), 255MVA summer emergency rating, are the limiting elements.

Voltage

- No Problem identified

Short Circuit Analysis

- No Problem identified

Stability Analysis

AEP Portion of Stability Analysis: The concern regarding stability for this project is the N-2 condition involving outage of X1-020 POI to Dumont 765 kV and Greentown-Jefferson 765 kV where the wind generation ends up radial to Greentown 138 kV and 230 kV outlets.

It is found that this condition is of low enough system short circuit ratio (system short circuit MVA/MW generation) as to begin to exhibit signs of wind farm control instability, but it is not to the point of being a stability problem.

This result is sensitive to the wind turbine dynamic modeling data and the line and transformer r+jx values. This study was conducted based on the data available at this time and any small changes in the wind turbine dynamic modeling data and the line and transformer r+jx values may cause the wind farm control instability.

PJM Portion of Stability Analysis: To be performed during the Facilities Study

MISO Impacts

Impacts on the MISO system will be determined in the Facilities Study.

Duke Integration

Due to the recent integration of the Duke Transmission area into PJM, PJM is reviewing contingencies in the Duke territory for all the queue projects in T, U, V, W1, W2, W3 queues that could affect Duke Facilities. Several violations due to contingencies in the Duke area have been found. PJM is currently working with Duke in resolving these issues. Queue project X1-020 could have some cost responsibility for the fixes to these violations. This analysis is ongoing and will be completed during the Facilities Study

Light Load Analysis

Due to extreme loading from wind projects causing congestion during light load conditions an analysis is being done to determine what impacts each wind project may have under these conditions. This analysis will be completed during the Facilities Study.

Additional Limitations of Concern

- None

Local/Network Upgrades

Upgrades	Overload	Contingency	Description	Cost
A	15	EAST LIMA – NORTH WOODCOCK 138 kV line	The 396.5 ACSR Conductor Section1 is the limiting element for the EAST LIMA – NORTH WOODCOCK 138 kV line. A sag check will be required for the 396.5 ACSR Conductor Section1 to determine if the line section can be operated above its emergency rating of 167MVA. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 11.48 miles section of the line would need to be rebuilt.	$45,920
B	16	EAST LIMA – NEW LIBERTY 138 kV line.	The 336.4 ACSR Conductor Section2 is the limiting element for the EAST LIMA – NEW LIBERTY 138 kV line. A sag check will be required for the 336.4 ACSR Conductor Section1 to determine if the line section can be operated above its emergency rating of 150MVA. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 23.69 mile section of the line would need to be rebuilt.	$94,760
C	17,18	OHIO CENTRAL – SOUTH MILLERSBURG 138 kV line	The 477 ACSR Conductor Section1 and the South Millersburg Risers sub conductor 477 AAC 19 strand are the limiting element for the Buckhorn8 – South Millersburg 138 kV line.	$263,000
			▪ The 477 ACSR Conductor Section2 is the limiting element for the Ohio Central – West Coshocton 138 kV line. ▪ The 477 ACSR conductor sections 1 is the limiting element for the West Coshocton – Buckhorn8 138 kV line. ▪ A sag check will be required for the 477 ACSR conductor section 2 and the two 477 ACSR conductor section 1, listed above, to determine if the line sections can be operated above its emergency rating of 184 MVA. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 34.16 mile sections of the Ohio Central – South Millersburg line would need to be rebuilt.	$136,640

Upgrades	Overload	Contingency	Description	Cost
D	20	BETHEL Z – WEST DOVER 138 kV line	The 477 ACSR Conductor Section1 is the limiting element for the BETHEL Z – WEST DOVER 138 kV line. A sag check will be required for the 477 ACSR Conductor Section1 to determine if the line sections can be operated above its emergency rating of 185MVA. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 35.66 mile sections of the BETHEL Z – WEST DOVER 138 kV line would need to be rebuilt.	A sag study request has been submitted with a completion date of 12/31/2013.
E	7,21	Wolf Creek M – Wolf Creek L 138 kV transformer	The WOLF CREEK 138 kV transformer and the WOLF CREEK CT are the limiting elements for the Wolf Creek M – Wolf Creek L 138 kV transformer. Estimated Cost (2012 Dollars) to upgrade the Wolf Creek transformer and CT's including, foundations, bus jumpers, surge arresters, associated equipment and the existing one phase line riser with 200MCM aluminum:	$3,236,000.00
F	33	REYNOLDS 345/138 kV transformer	The REYNOLDS 345/138 kV transformer, the REYNOLDS 345 kV Relaying CT 318A, and the TRF override, 318MVA summer emergency rating, are the limiting element for the Reynolds 345/138 kV transformer.	The transformer is owned by NIPSCO, in the MISO area. PJM will have to contact NIPSCO and MISO to confirm the results and get cost estimates.
G	34	OHIO CENTRAL 138/69 kV transformer	The OHIO CENTRAL 138/69 kV transformer is the limiting element for the Ohio Central 138/69 kV transformer.	$2,171,000
H	36, 37	INDUSTRIAL PARK – WALLEN 138 kV line	The INDUSTRIAL PARK – WALLEN 138 kV line has two limiting elements. The 795 ACSR Conductor Section1 is the limiting element for INDUSTRIAL PARK – SUMMIT 138 kV line and the 795 ACSR Conductor Section2 is the limiting element for SUMMIT – WALLEN 138 kV line. A sag check will be required for both the 795 ACSR conductor section 1 and 2 to determine if the line sections can be operated above its emergency rating of 251MVA and 257MVA, respectively. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 3.24 mile section of the line would need to be rebuilt.	$12,900
I	5, 39	WEST PHILO – ZANESVILLE 138 kV line	The 336.4 ACSR Conductor Section1 is the limiting element for the WEST PHILO – ZANESVILLE 138 kV line. A sag check will be required for the 336.4 ACSR Conductor Section1 to determine if the line section can be operated above its emergency rating of 150MVA. The	$50,160

Upgrades	Overload	Contingency	Description	Cost
			results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 12.54 mile section of the line would need to be rebuilt.	
J	38, 43	Ohio Central – South Coshocton 138 kV line	The 477 ACSR Conductor Section3 and the 556.5 ACSR Conductor Section2 are the limiting element for the Ohio Central – South Coshocton 138 kV line. A sag check will be required for both 477 ACSR Conductor Section3 and 556.5 ACSR Conductor Section2 to determine if the line sections can be operated above its emergency rating of 185MVA and 200MVA, respectively. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 16.37 mile section of the line would need to be rebuilt.	$65,480
K	6, 44	TILTONSVILLE – WEST BELLAIRE 138 kV line	The 795 ACSR Conductor Section2 is the limiting element for the TILTONSVILLE – WEST BELLAIRE 138 kV line. A sag check will be required for the 795 ACSR Conductor Section2 to determine if the line section can be operated above its emergency rating of 251MVA. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 11.99 mile section of the line would need to be rebuilt.	A sag study request has been submitted with a completion date of 12/31/2013.
L	45	BRIDGEVILLE – CHANDLERSVILLE 138 kV line	The 477 ACSR Conductor Section2 is the limiting element for the BRIDGEVILLE – CHANDLERSVILLE 138 kV line. A sag check will be required for the 477 ACSR Conductor Section2 to determine if the line section can be operated above its emergency rating of 185MVA. The results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 6.51 miles section of the line would need to be rebuilt.	A sag study request has been submitted with a completion date of 12/31/2013.
M	46, 47	Rock Creek Risers 477 ACC 19 strand	The Rock Creek Risers 477 ACC 19 strand, the Rock Creek Bus 477 ACC 19 strand, the Rock Creek Override and the Rock Creek Switch 600A are the limiting elements for HUMMEL CREEK – ROCK CREEK 138 kV line.	RTEP 2015 has identified these elements and will be replaced as a baseline project. In-Service Date: 6/1/2015

Upgrades	Overload	Contingency	Description	Cost
N	1	DEER CREEK – GRANT TAP 138 kV line	The 636 ACSR Conductor Section1, the Deer Creek Risers, Bus, Wave-trap and Relay Compliance trip are the limiting element for the DEER CREEK – GRANT TAP 138 kV line. A sag check will be required for the 636 ACSR Conductor Section1 to determine if the 636 ACSR line section can be operated above its emergency rating of 223MVA. In addition to upgrading the Deer Creek Risers, Bus, Wave-trap and the Relay Compliance Trip, the results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 3.9 mile section of the line would need to be rebuilt. PJM project U4-038 is the driver queue for the upgrades to this facility.	$15,600 $782,000 $300,000.00
O	8, 49	MUSKINGUM – WOLF CREEK M 138 kV line	The 556.5 ACSR conductor section 2, the 636 ACSR conductor section 1 and the Wolf Creek Risers sub conductor 556.5 ACSR are the limiting elements for the MUSKINGUM – WOLF CREEK M 138 kV line. A sag check will be required for the 556.5 ACSR Conductor Section2 and the 636 ACSR Conductor Section1 to determine if the line sections can be operated above its emergency rating of 205MVA and 223MVA, respectively. In addition to upgrading the Wolf Creek Risers, the results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 4.4 mile section of the line would need to be rebuilt.	$17,600 The Wolf Creek Risers will be replaced as part of the Generation Retirement Project. In-Service Date: 6/1/2013
P	9, 12, 13, 50	LAYMAN – WOLF CREEK L 138 kV line	The 556.5 ACSR Conductor Section1, the Layman line Risers sub conductor 556.5 ACSR, the Layman line Switcher 1200A and the Wolf Creek Risers sub conductor 556.5 ACSR are the limiting elements for the LAYMAN – WOLF CREEK L 138 kV line. A sag check will be required for the 556.5 ACSR Conductor Section1 to determine if the line section can be operated above its emergency rating of 205MVA. In addition to upgrading the Layman Line Risers and Switch and the Wolf Creek Risers the results of the sag study could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 8.72 mile section of the line would need to be rebuilt.	The Sag Study and replacing the Layman Risers and Switches will be part of the Generation Retirement Project for the area. In-Service Date: 6/1/2013
Q	51	HUNTINGTON JUNCTION – SORENSON 138 kV line	The 397.5 ACSR Conductor Section1 and the Sorenson Risers (ph3) sub conductor 795 AAC 37 strand are the limiting elements for the HUNTINGTON JUNCTION – SORENSON 138 kV line. The entire 6.15 mile of the Huntington junction – Sorenson 138 kV need to be rebuilt.	$10,455,000 $462,000.00

Upgrades	Overload	Contingency	Description	Cost
R	32	CARBONDALE – KANAWHA RIVER 138 kV line	The 795 ACSR Conductor Section 2 is the limiting element for the CARBONDALE – KANAWHA RIVER 138 kV line. The entire 7.67 mile of the Carbondale – Kanawha River 138 kV needs to be rebuilt.	$13,039,000
S	11	Dumont 765/345 kV transformer	The Dumont 765/345 kV transformer (from bus 243206 to bus 243219 ckt2) loads from 89.05% to 102% of its emergency rating 1752 MVA for the line fault with failed breaker contingency outage of CONTINGENCY DESCRIPTION (1750_C2).	$20,000,000
			Total	**$51,147,060**

Schedule

The standard time required for construction is 18 months after signing an interconnection agreement.

Conclusion

Based upon the results of this Impact Study, the construction of the Community Energy Wind LLC (PJM Project #X1-020) wind generation project will require additional interconnection charges. Local network upgrades will also be required for this project.

- **Lawnton Park 34.5 kV Substation SCADA cost (2012 Dollars): $250,000**
- **Estimated interconnection cost (2012 Dollars): $31,373,800.**
- **Estimated local network upgrade cost (2012 Dollars)**: **$51,147,060.**
- **Total estimated cost for project X1-020 (2012 Dollars): $82,770,860.**