Generation Interconnection
System Impact Study Report

For

PJM Generation Interconnection Request
Queue Position W3-085

Chatfield – South Tiffin (Honey Creek Wind)
138 kV

April 2013

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

NextEra Energy Honey Creek Wind, LLC proposes to install PJM Project #W3-085, a 185 MW (24 MW capacity) wind generating facility connecting to the American Electric Power (AEP) Howard – Chatfield 138 kV circuit (see Figure 2). The proposed location of the wind generating facility is in Crawford and Seneca Counties, Ohio (see Figure1).

The requested in service date is December 31, 2012.

Attachment Facilities

A new in-line switching station will be located between AEP's Howard and Chatfield stations in Ohio. This new station is to consist of three 138 kV circuit breakers physically configured in a breaker and one half bus arrangement operated as a ring-bus (see Figure 2). The interconnection station will be expandable to accommodate future projects in the area. The station also includes 138 kV metering, SCADA, and associated equipment. NextEra Energy Honey Creek Wind, LLC is expected to obtain, at their cost, a station site for the AEP facilities. NextEra Energy Honey Creek Wind, LLC shall obtain all necessary permits. Ownership of the in-line facilities shall be transferred from NextEra Energy Honey Creek Wind, LLC to AEP upon successful completion of the work.

A 138 kV line extension is required to loop through the proposed station. For the cost estimate, the AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap poles will be required. It is expected that NextEra Energy Honey Creek Wind, LLC will obtain the supplemental easement when the station property is purchased.

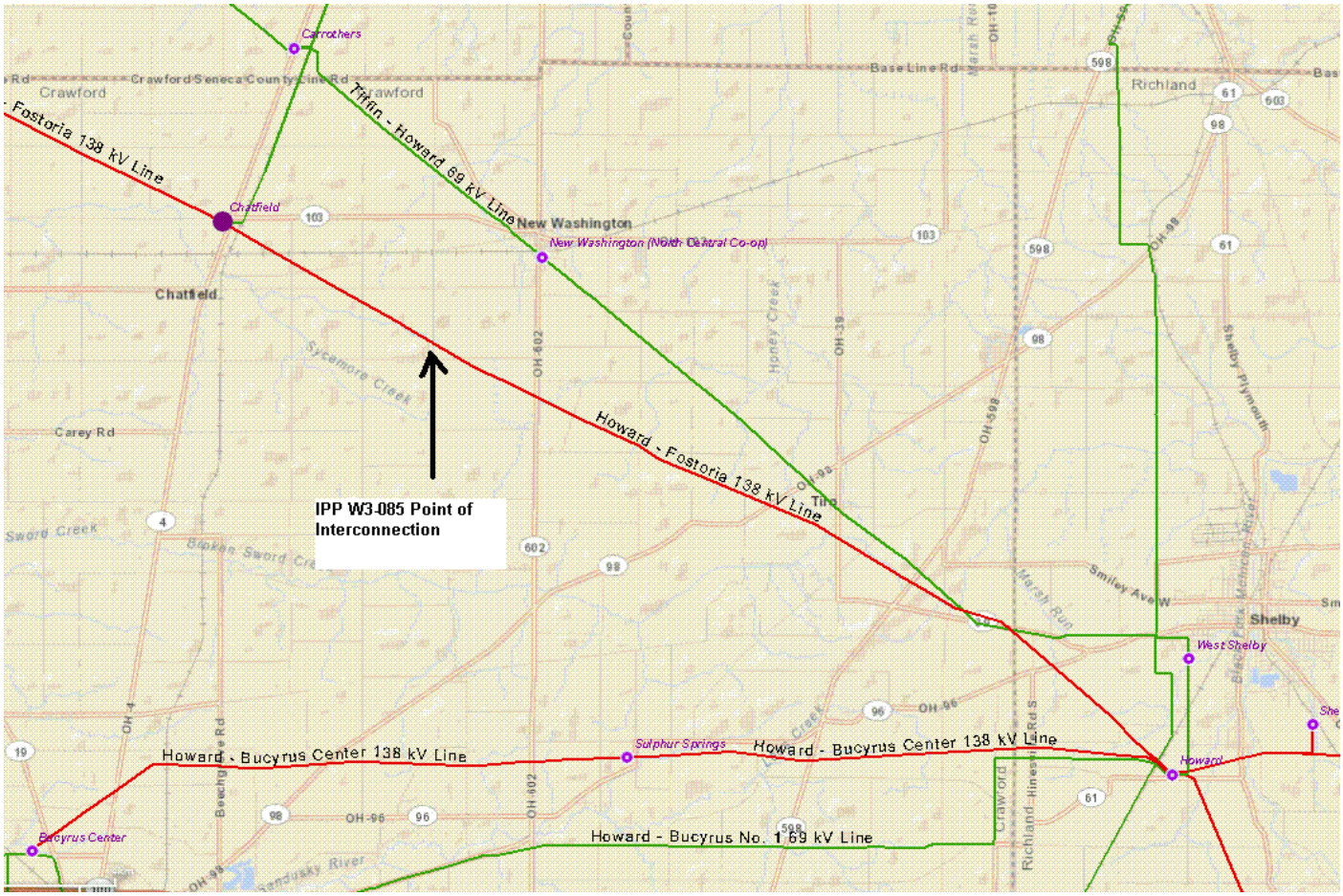

Figure 1: W3-085 Point of Interconnections

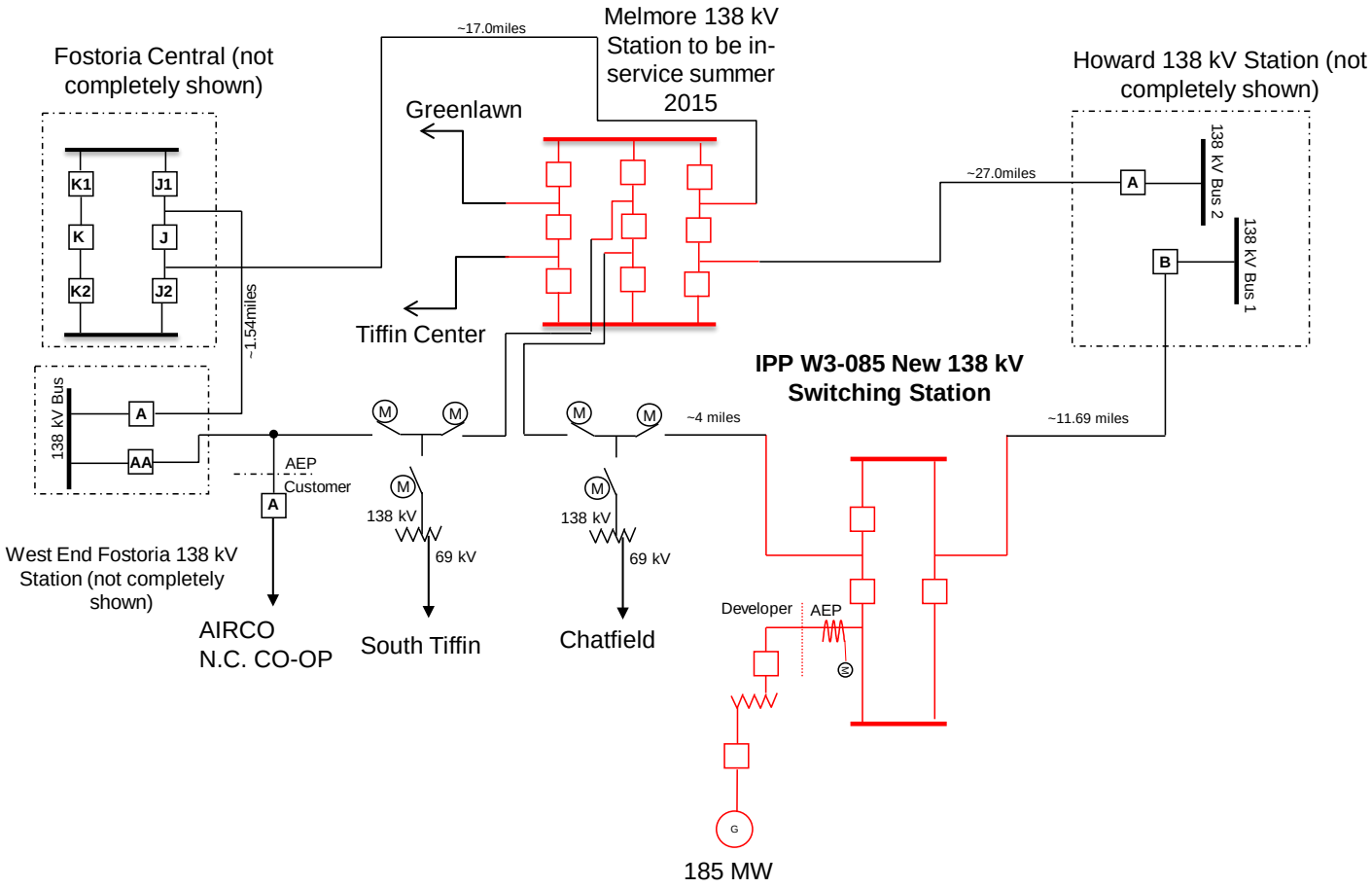

Figure 2: One-Line Diagram of the point of interconnection

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

Direct Connection Cost Estimate

The total preliminary cost estimate for Non-Direct Connection work is given in the Table 1 below:

Description	PJM NUN	Total Cost
W3-085 Interconnect SS: Install a new 3-breaker 138 kV interconnection station laid out in a breaker and one-half arrangement including associated disconnect switches bus work, SCADA and 138 kV revenue metering.	N3690	$5,484,700
	Total	**$5,484,700**

Table 1

Non-Direct Connection Cost Estimate

The total preliminary cost estimate for Non-Direct Connection work is given in the Table 2 below:

Description	PJM NUN	Total Cost
West End Fostoria SS. Modify Relaying	n3691	$613,000
Howard SS. Modify Relaying	n3692	$461,000
South Tiffin SS. Modify Relaying	n3693	$200,000
Chatfield SS. Modify Relaying	n3694	$10,000
	Total	**$1,284,000**

Table 2

It is understood that NextEra Energy Honey Creek Wind, LLC will be responsible for all costs associated with the connection. The costs above are reimbursable to AEP. Cost of the NextEra Energy Honey Creek Wind, LLC collector station for 185 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 NextEra Energy Honey Creek 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 do 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 performance parameters prescribed in the AEP FERC Form 715[1] and Connection Requirements for AEP Transmission System.[2] Therefore, these criteria were used to assess the impact of the proposed facility on the AEP System. The EDP Renewable North America LLC project was studied as a 72 MW (9.36 MW capacity) generating facility consistent with the interconnection application. Project #Y1-006 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

1

https://www.aep.com/about/codeofconduct/oasis/transmissionstudies/GuideLines/2012%20AEP%20PJM%20FERC%20715_Final_Part%204.pdf

2

https://www.aep.com/about/codeofconduct/OASIS/TransmissionStudies/Requirements/AEP_Interconnection_Requirements_rev0.pdf

Revenue Metering and SCADA Requirements

PJM Requirements

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

AEP Requirements

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

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 NextEra Energy Honey Creek Wind, LLC (PJM Project #W3-085) wind generation project connecting to the Howard – Chatfield 138 kV circuit will require additional interconnection charges. Should the developer choose to avoid generation curtailment, additional network upgrades may be required.

Estimated interconnection cost for project W3-085 (2013 Dollars): $6,768,700.

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.

Network Impacts

NextEra Energy Honey Creek Wind, LLC project was studied as a 185 MW (24 MW capacity) generating facility consistent with the interconnection application. Project #W3-085 was evaluated for compliance with reliability criteria for summer peak conditions in 2015.

Potential network impacts were as follows:

Contingency Name	Description
5149_B2_TOR709_WOMOAB	CONTINGENCY '5149_B2_TOR709_WOMOAB' OPEN BRANCH FROM BUS 243008 TO BUS 243130 CKT 1 / 243008 05FREMCT 138 243130 05TIFFIN 138 1 OPEN BRANCH FROM BUS 243008 TO BUS 245614 CKT 1 / 243008 05FREMCT 138 245614 FREMNT C 69.0 1 OPEN BRANCH FROM BUS 243130 TO BUS 245637 CKT 1 / 243130 05TIFFIN 138 245637 TIFFIN C 69.0 1 OPEN BRANCH FROM BUS 245620 TO BUS 245637 CKT 1 / 245620 GREELY 69.0 245637 TIFFIN C 69.0 1 OPEN BRANCH FROM BUS 245648 TO BUS 245637 CKT 1 / 245648 MAULE RD 69.0 245637 TIFFIN C 69.0 1 END
B_LINE2_WR_034	CONTINGENCY 'B_LINE2_WR_034' /* SEG 02KY-HS TO 02W.FREM 138 CK 1 DISCONNECT BRANCH FROM BUS 238871 TO BUS 239154 CKT 1 /* 02KY-HS 138.00 02W.FREM 138.00 END
C2-BRK-SR013	CONTINGENCY 'C2-BRK-SR013' /* GALION B-53 FAILURE TO TRIP DISCONNECT BRANCH FROM BUS 238746 TO BUS 238891 CKT 1 /* 02GALION 138.00 02LESIDE 138.00 DISCONNECT BRANCH FROM BUS 238746 TO BUS 238758 CKT 1 /* 02GALION 138.00 02GM MAN 138.00 END

Contingency Name	Description
C2-BRK-WR136	CONTINGENCY 'C2-BRK-WR136' /* WEST FREMONT B5 BREAKER DISCONNECT BRANCH FROM BUS 239030 TO BUS 239154 CKT 1 /* 02OTTAWA 138.00 02W.FREM 138.00 DISCONNECT BRANCH FROM BUS 239155 TO BUS 239154 CKT 2 /* 02W.FREM 69.00 02W.FREM 138.00 DISCONNECT BUS 239155 /* 02W.FREM 69.00 DISCONNECT BUS 240865 /* GRNSPR 69.00 DISCONNECT BUS 240851 /* CLYDE 69.00 END
C5-TWL-CR040	CONTINGENCY 'C5-TWL-CR040' /* DAVIS BESSE-BEAVER + DAVIS BESSE-HAYES 345KV DISCONNECT BRANCH FROM BUS 238654 TO BUS 239289 CKT 1 /* 02DAV-BE 345.00 02HAYES 345.00 DISCONNECT BRANCH FROM BUS 238654 TO BUS 238569 CKT 1 /* 02DAV-BE 345.00 02BEAVER 345.00 END
C5-TWL-SR063	CONTINGENCY 'C5-TWL-SR063' /* GALION-LEASIDE & GALION-GM COMMON TOWER DISCONNECT BRANCH FROM BUS 238746 TO BUS 238891 CKT 1 /* 02GALION 138.00 02LESIDE 138.00 DISCONNECT BRANCH FROM BUS 238746 TO BUS 238758 CKT 1 /* 02GALION 138.00 02GM MAN 138.00 END

Table 3 – Contingency List

Generator Deliverability

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

None.

Light Load Analysis

Light Load Studies to be conducted during later study phases (applicable to wind, coal, nuclear, and pumped storage projects).

To be performed during the Facilities Study.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)

None.

Short Circuit

(Summary of impacted circuit breakers)

New circuit breakers found to be over-duty:

None.

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

W3-085 Contribution to Previously Identified Overloads										
	Contingency		Facility Description	Bus		Loading		Rating		MW
#	Type	Name		From	To	Initial	Final	Type	MVA	Contr
1	DCTL	C5-TWL-CR040	02OTTAWA-02LAKVEW 138 kV line	239030	238874	100.89	102.3	ER	375	11.73
2	LFFB	C2-BRK-WR136	02KY-HS-02OTTAWA 138 kV line	238871	239030	110.46	112.12	ER	289	10.66
3	LFFB	C2-BRK-WR136	02W.FREM-02KY-HS 138 kV line	239154	238871	111.12	112.78	ER	289	10.66
4	DCTL	C5-TWL-SR063	05HOWARD-02BRKSID 138 kV line	243024	238586	124.53	145.87	ER	173	38.29
5	LFFB	C2-BRK-SR013	05HOWARD-02BRKSID 138 kV line	243024	238586	124.53	145.87	ER	173	38.29

Table 4

Steady-State Voltage Requirements

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

To be determined.

Stability and Reactive Power Requirement for Low Voltage Ride Through

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

None. See attached report

New System Reinforcements

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

All the items in table 4a below will be relieved by the noted baseline projects. All the items except 3a are scheduled to be in service by June 2015. For Item 3a, the overload of the 02OTTAWA-02LAKVEW 138 kV line will be relieved by baseline upgrade **b1959.** The baseline is currently scheduled to go in-service in 2018. If this project chooses to go in-service before the baseline upgrades are in-service, the project may be curtailed until the baseline is in-service. Currently it does

not appear that advancement of this baseline project is capable. However, if the developer would like for PJM to review this again, it will be reviewed as a part of the Facilities Study. If it is found that the baseline project can be advanced and the developer elects to pay for the advancement, then curtailment of this project may be reduced or eliminated.

W3-085 New System Reinforcements					
#	Contingency	Facility Description	Reinforcement	TO	Schedule
1a	C5-TWL-CR040	02OTTAWA-02LAKVEW 138 kV line	**b2122.1** - Reconductor the Howard - Brookside 138 kV line	ATSI	June 2015
2a	C2-BRK-WR136	02KY-HS-02OTTAWA 138 kV line	**b2122.2** - Upgrade terminal equipment at Brookside on the Howard - Brookside 138 kV line to achieve ratings of 252/291 (SN/SE)	ATSI	June 2015
3a	C2-BRK-WR136	02W.FREM-02KY-HS 138 kV line	**b1959** - Build a new West Fremont-Groton-Hayes 138kV line	ATSI	b1959 is required in 2015, but it is not projected to be in-service until June 2018.
4a	C5-TWL-SR063	05HOWARD-02BRKSID 138 kV line	**b2122.3** - Upgrade terminal equipment at Howard on the Howard - Brookside 138 kV line to achieve ratings of 252/291 (SN/SE)	AEP	June 2015
5a	C2-BRK-SR013	05HOWARD-02BRKSID 138 kV line	**b2122.4** - AEP Reconductor the Howard - Brookside 138 kV line	AEP	June 2015

Table 4a

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)

None.

Delivery of Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed, which will study all overload conditions associated with the overloaded element(s) identified.

W3-085 Delivery of Energy Portion of Interconnection Request											
	Contingency			Bus		Loading		Rating		MW
#	Type	Name	Facility Description	From	To	Initial	Final	Type	MVA	Contr
6	N-1	B_LINE2_WR_034	02W.FREM-02OTTAWA 138 kV line	239154	239030	107.68	109.36	ER	289	10.8
7	Non	Non	05HOWARD-02BRKSID 138 kV line	243024	238586	114.17	144.77	NR	133	41.58
8	N-1	5149_B2_TOR709_WOMOAB	05MELMOR-05FOSTOR 138 kV line	243039	243006	143.88	158.4	ER	167	24.67

Table 6

Transient Stability Study

W3-085 (Howard - Melmore Tap 138 kV)

03/20/2012

Description

PJM queue project W3-085 is a new 185 MW interconnection request tapping the existing Howard-Fostoria 138 kV line in the AEP system. This is a GE 1.6 MW xle based wind farm with 116 generators.

Stability analysis for the W3-085 queue project was performed at 2015 peak load conditions. The range of contingencies evaluated was limited to that necessary to assess compliance with the AEP criteria. Simulation time was limited to 10 seconds for all faults.

Three fault types were considered in this study:

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

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

Results

Transient Stability:

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

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

Table-I Maximum angle deviation for type A faults

(2015 Summer Peak Base Case)

Fault	Chan	Bus	ID	Initial Angle	Max Deviation	Time
1A	286	238603	3	42.05	-4.422	0.5500
2A	286	238603	3	42.05	-5.781	0.5667
3A	286	238603	3	42.05	-5.026	0.5625
4A	286	238603	3	42.05	-4.850	0.5584
5A	286	238603	3	42.05	-6.032	0.5792
6A	286	238603	3	42.05	-7.700	0.5875
7A	286	238603	3	42.05	-3.422	0.5625
8A	282	238593	5	35.75	-4.704	9.9841
9A	280	238591	3	33.18	-3.875	0.7167
10A	286	238603	3	42.05	-3.245	0.5584
11A	286	238603	3	42.05	-3.298	0.5584
12A	286	238603	3	42.05	-5.147	0.6209
13A	286	238603	3	42.05	-4.752	0.6251
14A	286	238603	3	42.05	-4.748	0.6251
15A	286	238603	3	42.05	-5.157	0.6251

Table-II Maximum angle deviation for type B faults

(2015 Summer Peak Base Case)

Fault	Chan	Bus	ID	Initial Angle	Max Deviation	Time
1B	286	238603	3	42.05	-5.831	0.7542
2B	286	238603	3	42.05	-4.025	0.6626
3B1	286	238603	3	42.05	-4.868	0.7001
3B2	286	238603	3	42.05	-4.403	0.6917
4B1	286	238603	3	42.05	-6.343	0.7501
4B2	286	238603	3	42.05	-4.752	0.7167
5B1	286	238603	3	42.05	-8.701	0.7584
5B2	286	238603	3	42.05	-8.915	0.7584
6B1	286	238603	3	42.05	-5.278	0.6542
6B2	286	238603	3	42.05	-5.282	0.6542
7B1	300	242940	4	60.45	-4.065	0.9001
7B2	280	238591	3	33.18	-5.104	0.9792
8B	280	238591	3	33.18	-4.864	0.9334
9B	283	238594	D	3.897	-5.039	9.9174
10B	286	238603	3	42.05	-4.252	0.7501
11B	282	238593	5	35.75	-5.325	9.9799

Table-II Maximum angle deviation for type B faults

(2015 Summer Peak Base Case)

Fault	Chan	Bus	ID	Initial Angle	Max Deviation	Time
12B1	286	238603	3	42.05	-6.156	0.7376
12B2	286	238603	3	42.05	-6.512	0.7417
13B1	286	238603	3	42.05	-6.446	0.7667
13B2	286	238603	3	42.05	-5.567	0.7667
13B3	286	238603	3	42.05	-7.019	0.7751
14B1	286	238603	3	42.05	-6.673	0.7709
14B2	286	238603	3	42.05	-6.799	0.7709
14B3	286	238603	3	42.05	-7.216	0.7792
15B1	286	238603	3	42.05	-5.370	0.7626
15B2	287	238670	1	50.49	-4.754	0.8334

Table-III Maximum angle deviation for type C faults

(2015 Summer Peak Base Case)

Fault	Chan	Bus	ID	Initial Angle	Max Deviation	Time
1C	286	238603	3	42.05	-5.005	1.3709
2C	286	238603	3	42.05	-3.498	0.6042
3C	286	238603	3	42.05	-2.45	1.4501
4C	286	238603	3	42.05	-3.697	1.4209
5C	286	238603	3	42.05	-3.55	1.4376
6C	286	238603	3	42.05	-4.216	0.6376
7C	286	238603	3	42.05	-2.105	1.4584
9C	280	238591	3	33.18	-2.959	0.6667
10C	286	238603	3	42.05	-0.9751	1.4501
11C	286	238603	3	42.05	-2.042	1.4626
13C	286	238603	3	42.05	-2.759	1.4001
14C	286	238603	3	42.05	-3.297	1.4168

The wind farm was modeled with an equivalent 185.6 MW generator (WTG) along with GSU, main step-up transformer and 138 kV line section. The reactive power range of the equivalent generator was set at 0.95 lagging and leading power factor. However, the terminal voltages of the equivalent WTG was set at slightly higher than 1.00 p.u. to achieve unity power factor at the 34.5 kV collector bus.

Low Voltage Ride-Through (LVRT): A three-phase 9-cycle self-clearing fault was applied at the 138 kV interconnection bus and it was found that W3-085 rides through the fault.

For all cases studied, the W3-085 queue project rides through the faults specified in Section A.4. Since the terminal voltage of the equivalent WTG was slightly raised to keep unity power factor at the collector bus, the above mentioned LVRT test was repeated with about unity power factor of the equivalent WTG and the terminal voltage was 1.00 p.u. It was found that W3-085 rides through these faults.

Thus, it is concluded that W3-085 meets the LVRT test specified in FERC order 661 and 661A.

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

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

APPENDIX A

W3-085

(Howard-Melmore Tap 138 kV)

A.1) POWER FLOW CONDITIONS

2015 Summer Peak Load Base Case

A.2) BREAKER CLEARING TIMES (CYCLES)

Table A.1. AEP Clearing Times (Cycles)

Station	Primary (3ph/slg)	Stuck Breaker (Total)	Zone 2 (Total)	Re-closing
500 kV	3.5	13	3.5	N/A
345 kV	3.5	16	60	N/A
230 kV	4.5	17	60	N/A
115kV & 138 kV	4.5	17	60	N/A

A.3) NETWORK CONDITIONS

All facilities in service (base case)

A.4) FAULTS CONSIDERED

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

A faults: *three-phase faults with normal clearing time*

B faults: *slg faults due to stuck breaker with delayed clearing time*

C faults: *slg faults with delayed clearing time due to protection system failure*

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

W3-085 138 kV

1a 3ph fault @ W3-085 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: W3-085 - V1-010 138 kV Ckt-1

1b slg fault @ W3-085 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: W3-085 - V1-010 138 kV Ckt-1

Breaker Failure

slg fault @ W3-085 138 kV Tap

Fault cleared within 138 kV breaker backup clearing time

Loss of: W3-085

1c slg fault @ 80% of W3-085 - V1-010 138 kV Ckt-1

V1-010 breaker tripped within 138 kV primary time

W3-085 breaker tripped within 138 kV secondary time

Loss of: W3-085 - V1-010 138 kV Ckt-1

2a 3ph fault @ W3-085 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: W3-085 - Melmore 138 kV Ckt-1

2b slg fault @ W3-085 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: W3-085 - Melmore 138 kV Ckt-1

Breaker Failure

slg fault @ W3-085 138 kV Tap

Fault cleared within 138 kV breaker backup clearing time

Loss of: W3-085

2c slg fault @ 80% of W3-085 - Melmore 138 kV Ckt-1

V1-010 breaker tripped within 138 kV primary time

W3-085 breaker tripped within 138 kV secondary time

Loss of: W3-085 - Melmore 138 kV Ckt-1

V1-010 138 kV

3a 3ph fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: Chatfield 138 kV

South Tiffin 138 kV

AirCO 138 kV

V1-010 - South Tiffin - West End Fostoria 138 kV Circuit

3b1 slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: AirCo - West End Fostoria 138 kV Circuit

Breaker Failure

slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker backup clearing time

Loss of: Chatfield, South Tiffin and Airco 138 kV

V1-010 - South Tiffin - West End Fostoria 138 kV Circuit

V1-010 - Howard 138 kV Ckt-1

3b2 slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: AirCo - West End Fostoria 138 kV Circuit

Breaker Failure

slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker backup clearing time

Loss of: Chatfield, South Tiffin and Airco 138 kV

V1-010 - South Tiffin - West End Fostoria 138 kV Circuit

V1-010 - W3-085 Tap 138 kV Ckt-1

3c slg fault @ 80% of V1-010 Tap - West End Fostoria 138 kV Ckt-1

West End Fostoria breaker tripped within 138 kV primary time

V1-010 breaker tripped within 138 kV secondary time

Loss of: Chatfield, South Tiffin and Airco 138 kV

V1-010 - South Tiffin - West End Fostoria 138 kV Circuit

4a 3ph fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - V1-010 138 kV Ckt-1

4b1 slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - V1-010 138 kV Ckt-1

Breaker Failure

slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker backup clearing time

Loss of: V1-010

4b2 slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - V1-010 138 kV Ckt-1

Breaker Failure

slg fault @ V1-010 138 kV Tap

Fault cleared within 138 kV breaker backup clearing time

Loss of: V1-010 - Chatfield 138 kV Ckt-1

4c slg fault @ 80% of V1-010 Tap - Howard 138 kV Circuit Ckt-1

Howard breaker tripped within 138 kV primary time

V1-010 breaker tripped within 138 kV secondary time

Loss of: V1-010 Tap - Howard 138 kV Ckt-1

Melmore 138 kV

5a 3ph fault @ Melmore 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Melmore - Fostoria Central 138 kV Ckt-1

5b1 slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Melmore - Fostoria Central 138 kV Ckt-1

Breaker Failure

slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: U4-028 & U4-029

5b2 slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Melmore - Fostoria Central 138 kV Ckt-1

Breaker Failure

slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Melmore - Greenlawn 138 kV Ckt-1

5c slg fault @ 80% of Melmore - Fostoria Central 138 kV Ckt-1

Fostoria breakers tripped within 138 kV primary time

Melmore breakers tripped within 138 kV secondary time.

Loss of: Melmore - Fostoria Central 138 kV Ckt-1

6a 3ph fault @ Melmore 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Melmore - Greenlawn 138 kV Ckt-1

6b1 slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Melmore - Greenlawn 138 kV Ckt-1

Breaker Failure

slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Melomore - Fostoria Central 138 kV Ckt-1

6b2 slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Melmore - Greenlawn 138 kV Ckt-1

Breaker Failure

slg fault @ Melmore 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Melomore - W3-085 138 kV Ckt-1

6c slg fault @ 80% of Melmore - Greenlawn 138 kV Ckt-1

Greenlawn breaker tripped within 138 kV primary time

Melmore breakers tripped within 138 kV secondary time.

Loss of: Melmore - Greenlawn 138 kV Ckt-1

Howard 138 kV

7a 3ph fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - BuCyrus Center 138 kV Ckt-1

Sulphur Springs 138 kV

7b1 slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - BuCyrus Center 138 kV Ckt-1

Breaker Failure

slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Howard 138 kV Bus #2

Sulphur Springs 138 kV

7b2 slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - BuCyrus Center 138 kV Ckt-1

Breaker Failure

slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Howard 138 kV Bus #1

Sulphur Springs 138 kV

7c slg fault @ 80% of Howard - Sulphur Springs - BuCyrus 138 kV Ckt-1

BuCyrus 138 kV breaker tripped within 138 kV primary time.

Howard breaker tripped within 138 kV secondary time

Loss of: Howard - Sulphur Springs - BuCyrus 138 kV Ckt-1

Sulphur Springs 138 kV

8a 3ph fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: U4-001

8b slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: U4-001

Breaker Failure

slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Howard 138 kV Bus #1

9a 3ph fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - Brookside 138 kV Ckt-1

9b slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time.

Loss of: Howard - Brookside 138 kV Ckt-1

Breaker Failure

slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Howard 138 kV Bus #1

9c slg fault @ 80% of Howard - Brookside 138 kV Ckt-1

Brookside 138 kV breaker tripped within 138 kV primary time.

Howard breaker tripped within 138 kV secondary time

Loss of: Howard - Brookside 138 kV Ckt-1

10a 3ph fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - Academia 138 kV Ckt-1

(assumed taps at 243061 & 242955)

10b slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - Academia 138 kV Ckt-1

Breaker Failure

slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Howard 138 kV Bus #2

10c slg fault @ 80% of Howard - Academia 138 kV Ckt-1

Academia 138 kV breaker tripped within 138 kV primary time.

Howard breaker tripped within 138 kV secondary time

Loss of: Howard - Academia 138 kV Ckt-1

11a 3ph fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - North Bellville 138 kV Ckt-1

11b slg fault @ Howard 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Howard - North Bellville 138 kV Ckt-1

Breaker Failure

slg fault @ Howard 138 kV

Fault cleared within 230 kV breaker backup clearing time

Loss of: Howard 138 kV Bus #1

11c slg fault @ 80% of Howard - North Bellville 138 kV Ckt-1

North Bellville 138 kV breaker tripped within 138 kV primary time.

Howard breaker tripped within 138 kV secondary time

Loss of: Howard - North Bellville 138 kV Ckt-1

Fostoria Central 138 kV

12a 3ph fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Fostoria 345/138 kV transformer

12b1 slg fault @ Fostoria 138 kV

Fault cleared within 345 kV breaker primary clearing time

Loss of: Fostoria 345/138 kV transformer

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Findley Tap 138 kV ckt 1

12b2 slg fault @ Fostoria 138 kV

Fault cleared within 345 kV breaker primary clearing time

Loss of: Fostoria 345/138 kV transformer

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria – Buckley Road 138 kV ckt 1

Buckley Road 138 kV

Rising Sun 138 kV

13a 3ph fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Fostoria - Marion - Findlay Center 138 kV ckt 1

Fostoria - New Liberty 138 kV ckt 1

13b1 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV (& 34 kV) breaker primary clearing time

Loss of: Fostoria - New Liberty 138 kV ckt 1

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria 345/138 kV transformer

Fostoria - Marion - Findlay Center 138 kV ckt 1

13b2 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV (& 34 kV) breaker primary clearing time

Loss of: Fostoria - New Liberty 138 kV ckt 1

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Melomore 138 kV ckt 1

Fostoria - Marion - Findlay Center 138 kV ckt 1

13b3 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV (& 34 kV) breaker primary clearing time

Loss of: Fostoria - New Liberty 138 kV ckt 1

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Marion - Findlay Center 138 kV ckt 1

V4-015 and W2-001

13c slg fault @ 80% of Fostoria - New Liberty 138 kV ckt 1

New Liberty breaker tripped within 138 kV primary time

Fostoria breakers tripped within 138 kV secondary time

Loss of: Fostoria - New Liberty 138 kV ckt 1

Fostoria - Marion - Findlay Center 138 kV ckt 1

14a 3ph fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Fostoria - Northeast Findlay - North Findlay 138 kV ckt 1

Northeast Findlay 138 kV

North Findlay 138/34 kV transformer #2 (50% load)

14b1 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV (& 34 kV) breaker primary clearing time

Loss of: Northeast Findlay - North Findlay 138 kV ckt 1

North Findlay 138/34 kV transformer #2 (50% load)

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Northeast Findlay 138 kV ckt 1

Northeast Findlay 138 kV

Fostoria - Buckley Road - Rising Sun 138 kV ckt 1

14b2 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV (& 34 kV) breaker primary clearing time

Loss of: Northeast Findlay - North Findlay 138 kV ckt 1

North Findlay 138/34 kV transformer #2 (50% load)

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Northeast Findlay 138 kV ckt 1

Northeast Findlay 138 kV

Fostoria - West End Fostoria 138 kV ckt 1

14b3 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV (& 34 kV) breaker primary clearing time

Loss of: Northeast Findlay - North Findlay 138 kV ckt 1

North Findlay 138/34 kV transformer #2 (50% load)

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Northeast Findlay 138 kV ckt 1

Northeast Findlay 138 kV

V4-015 and W2-001

14c slg fault @ 80% of Fostoria - North Findlay 138 kV ckt 1

North Findlay breaker tripped within 138 kV (& 34 kV) primary time

Fostoria breakers tripped within 138 kV secondary time

Loss of: Fostoria - Northeast Findlay - North Findlay 138 kV ckt 1

Northeast Findlay 138 kV

North Findlay 138/34 kV transformer #2 (50% load)

15a 3ph fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Fostoria - West End Fostoria 138 kV ckt 1

15b1 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Fostoria - West End Fostoria 138 kV ckt 1

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Northeast Findlay 138 kV ckt 1

15b2 slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker primary clearing time

Loss of: Fostoria - West End Fostoria 138 kV ckt 1

Breaker Failure

slg fault @ Fostoria 138 kV

Fault cleared within 138 kV breaker backup clearing time

Loss of: Fostoria - Melmore 138 kV ckt 1

Notes.

Howard Bus #1 :	Howard - V1-010 138 kV line
	Howard - Bucyrus 138 kV line
	Howard - Brookside 138 kV line
	Howard - U4-001 138 kV line
	Howard - North Bellville 138 kV line
	Howard - Shelby 138 kV line
Howard Bus #2	
	Howard - Academia 138 kV line
	Howard - Shelby 138 kV line
	Howard 138/69 kV transformer
	Howard - Sulphur Springs - Bucyrus 138 kV
	Howard - V1-010 138 kV

A.4.1) Maintenance outage faults

No faults with outages due to maintenance were studied.

A.5) Reinforcements

The following reinforcements were considered in the study:

None

APPENDIX B

Project Data

B.1.1) Wind farm and wind turbine data

Queue Letter/Position/Unit ID: _____ W3-085/Wind Farm

Wind farm data

Primary Fuel Type: _____ Wind

Maximum Net MW Output: _____185

Maximum Gross MW Output: _____185

Station Service Load in MW/MVAR: _____ 9.0/1.0

Number of Turbines: _____116

Wind turbine data

MW Size: _____ 1.6

MVA Base: _____ 1.78

Nominal Power Factor: _____ N/A

Terminal Voltage (kV): _____ 0.69

Type of Turbine: _____ GE 1.6MW xle

Control Mode: _____ Power Factor (±0.90)

Additional Capacitor: _____ N/A

B.1.2) Generator data

Loadflow information

Rg	0.00000	Generator Resistance in Loadflow (pu)

Xg	0.80000	Generator Reactance in Loadflow (pu)

Dynamic data

- Due to confidentiality agreement, dynamic data has not been included.

B.1.3) Unit GSU data

Generator Step-up Transformer MVA Base: 1.85
Generator Step-up Transformer Impedance (R+jX, or %, on transformer MVA Base): 5.75%
Generator Step-up Transformer Reactance-to-Resistance Ratio (X/R): 7.5
Generator Step-up Transformer Rating (MVA): 1.85
Generator Step-up Transformer Low-side Voltage (kV): 0.69
Generator Step-up Transformer High-side Voltage (kV): 34.5
Generator Step-up Transformer Off-nominal Turns Ratio: N/A
Generator Step-up Transformer Number of Taps and Step Size: 5 taps of 2½%
Transformer Low-side Voltage Winding Connection: N/A
Transformer High-side Voltage Winding Connection: N/A
Transformer Tertiary-side Voltage Winding Connection: N/A

B.1.4) Main transformer data

Transformer MVA Base: 123

Transformer Impedance (R+jX, or Z in %): 9.0%

Transformer Reactance-to-Resistance Ratio (X/R): 40

Transformer Rating (MVA): 123/164/205

Transformer Low-side Voltage (kV): 34.5

Transformer High-side Voltage (kV): 138

Transformer Tertiary Voltage (kV): 13.8

Transformer Off-nominal Turns Ratio: N/A

Transformer Number of Taps and Step Size: 2, ±2.5%

Transformer Low-side Voltage Winding Connection: Wye gnd

Transformer High-side Voltage Winding Connection: Wye gnd

Transformer Tertiary-side Voltage Winding Connection: Delta

(Note: Two identical main transformers not in parallel)