System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AC1-053

Brokaw-Lanesville

June 2020

Preface

The intent of the System Impact Study is to determine a plan, with ballpark cost and construction time estimates, to connect the subject generation to the PJM network at a location specified by the Interconnection Customer. The Interconnection Customer may request the interconnection of generation as a capacity resource or as an energy-only resource. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system.

In some instances, a generator interconnection may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection, may also contribute to the need for the same network reinforcement.

Cost allocation rules can be found in PJM Manual 14A, Attachment B. The possibility of sharing the reinforcement costs with other projects may be identified in the feasibility study, but the actual allocation will be deferred until the impact study is performed.

An Interconnection Customer entering the New Services Queue on or after October 1, 2012 with a proposed new Customer Facility that has a Maximum Facility Output equal to or greater than 100 MW shall install and maintain, at its expense, phasor measurement units (PMUs). See Section 8.5.3 of Appendix 2 to the Interconnection Service Agreement as well as section 4.3 of PJM Manual 14D for additional information.

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

Queue AC1-053 project is an Invenergy Wind Development LLC ("Interconnection Customer" or "IC") proposal to connect a 200 MW Energy (26 MW Capacity with a 13% class average capacity factor as specified in PJM Manual 21 Appendix B) windfarm to be located in Logan County, IL, consisting of eighty seven 2.3MW GE wind turbines. The IC will be calling the facility Midland Windfarm.

This Generation Interconnection Feasibility Study provides analysis results to aid the IC in assessing the practicality and cost of incorporating the facility into the PJM system. This study was limited to load flow analyses of probable contingencies. If the IC elects to pursue a System Impact Study, a more comprehensive analysis will be performed.

Point of Interconnection

AC1-053 proposes to interconnect with the ComEd transmission system by tapping into Lanesville-Brokaw 345kV line 20 miles from Lanesville.

Attachment Facilities

The IC AC1-053 generator lead will interconnect to a new 345kV Interconnection Substation. This interconnection would require one 345kV line MOD, a dead-end structure and revenue metering as shown in the one line diagram.

The cost for the attachment facilities is estimated at $1M.

Scope of Work	Cost Estimate
Installation of one 345kV line MOD, one dead-end structures and one set of revenue metering (see notes below on cost estimate)	$1.0M

Direct Connection Network Upgrades

In order to accommodate interconnection of AC1-053, a new 345kV Interconnection Substation would need to be built close to Lanesville-Brokaw 345kV line 20 miles from Lanesville.

The scope of work includes installation of three 345kV circuit breakers in "breaker-and-a-half" bus configuration and tie in the Interconnection Substation to Lanesville-Brokaw 345kV line, as shown in the one line diagram below.

There is a 'yet-to-be-built' Tabor Substation to interconnect AB2-070 Wind Farm approximately 5 miles from this wind farm towards Brokaw. Also, subsequent to this queue request, Mt. Pulaski Substation has been built to interconnect W2-048 Wind Farm approximately 10.6 miles from this wind farm towards Lanesville. If AB2-070 is built before AC1-053, then AC1-053 Interconnection Substation would be tapped into the line between Tabor-Mt. Pulaski substations.

The Interconnection Customer is responsible for constructing all of the facilities on the Interconnection Customer side of the point of interconnection outside of the substation. It will be Interconnection Customer's responsibility to obtain the site for the Interconnection Substation and right-of-way between the Interconnection Substation and the 345kV transmission line.

In the event that the IC exercises the option to build the interconnecting substation, the IC will be required to construct all interconnection facilities that will be turned over to ComEd in accordance with ComEd published standards. The IC will be responsible for the ComEd oversight costs (i.e. costs incurred by the Transmission Owner when engaging in oversight activities to satisfy itself that the Interconnection Customer is complying with the Transmission Owner's standards and specifications for the construction of facilities).

ComEd would design, engineer and construct the tie in of the Interconnection Substation to the Lanesville-Brokaw 345kV line.

The preliminary cost estimate for Direct Connection Network Upgrade is given in the following tables.

For Option to Build Direct Connection cost estimates:

Scope of Work	Cost Estimate
Installation of a new 345kV substation as described above	N/A
Transmission line tie in work (foundations, structures, conductors)	$3,500,000
ComEd oversight and testing	$1,500,000
Total Cost Estimate (see notes below on cost estimate)	$5,000,000

For ComEd building the interconnecting substation cost estimates:

Scope of Work	Cost Estimate
Installation of a new 345kV substation as described above	$20,000,000
Transmission line tie in work (foundations, structures, conductors)	$3,500,000
Total Cost Estimate (see notes below on cost estimate)	$23,500,000

ComEd would take approximately 24-months to construct after the ISA / ICSA are signed.

Non-Direct Connection Network Upgrades

The integration of the new 345kV Interconnection Substation would require relay/communications/SCADA upgrades at substations on both side of the Interconnection Substation. On Brokaw side, it could be Tabor Substation or Brokaw Substation. On Lanesville side, it could be Mt. Pulaski Substation or Lanesville Substation. The ComEd cost at each of these substations is given below:

Scope of Work	Cost Estimate
Relay/communications/SCADA upgrades at Tabor substation (if AB2-070 is built before this wind farm)	$1,000,000
Relay/communications/SCADA upgrades at Brokaw substation (Ameren to provide cost estimate)	0
Relay/communications/SCADA upgrades at Mt. Pulaski substation (if W2-048 is built before this wind farm)	$1,000,000
Total Cost Estimate (see notes below on cost estimate)	$2,000,000

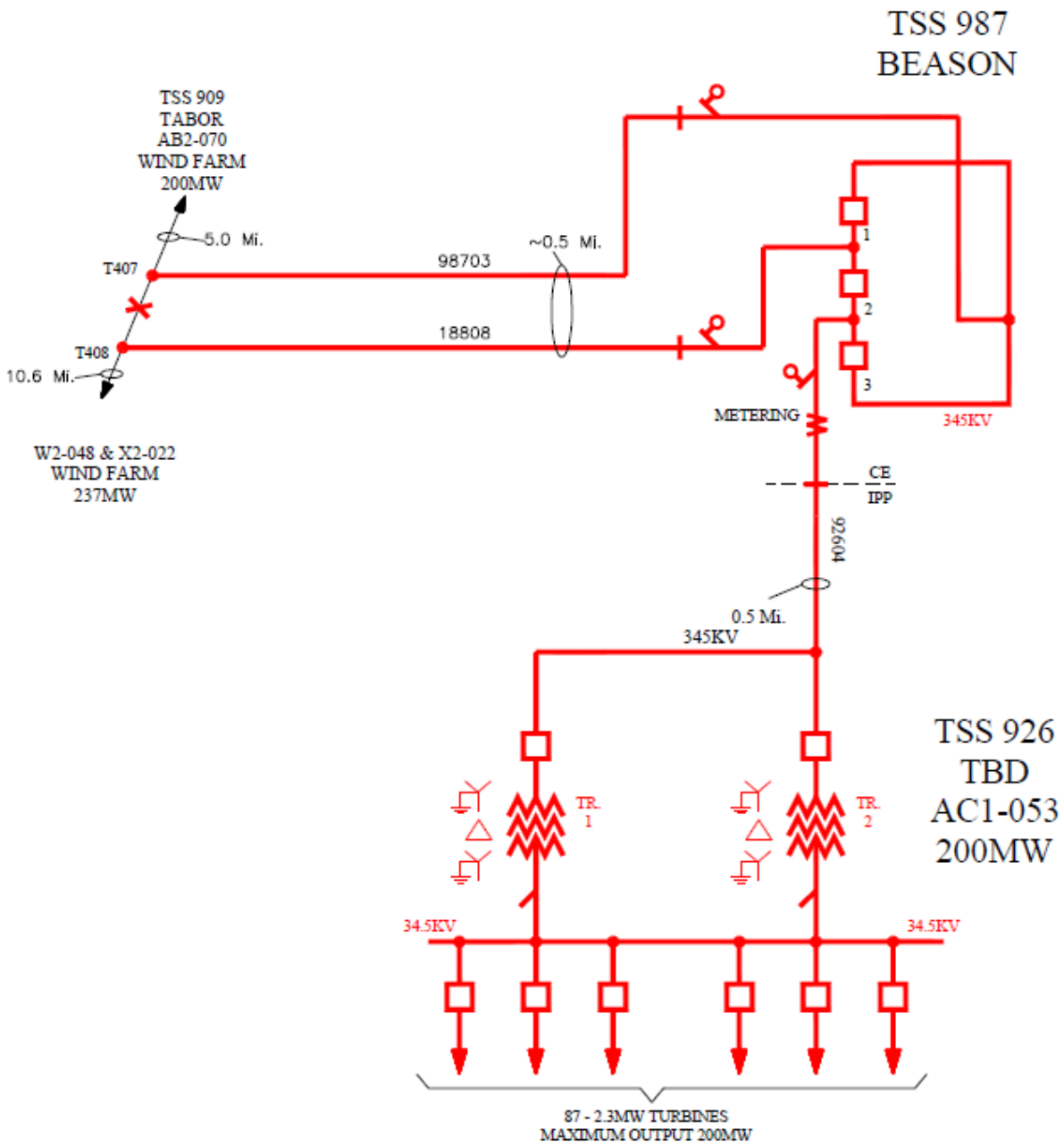
Notes on Cost Estimate:

1) These estimates are Order-of-Magnitude estimates of the costs that ComEd would bill to the customer for this interconnection. These estimates are based on a one-line electrical diagram of the project and the information provided by the Interconnection Customer.

2) There were no site visits performed for these estimates. There may be costs related to specific site related issues that are not identified in these estimates. The site reviews will be performed during the Facilities Study or during detailed engineering.

3) These estimates are not a guarantee of the maximum amount payable by the Interconnection Customer and the actual costs of ComEd's work may differ significantly from these estimates. Per the PJM Tariff, Interconnection Customer will be responsible for paying all actual costs of ComEd's work.

4) The Interconnection Customer is responsible for all engineering, procurement, testing and construction of all equipment on the Interconnection Customer's side of the Point of Interconnection (POI).



Network Impacts

The Queue Project AC1-053 was evaluated as a 200.0 MW (Capacity 26.0 MW) injection into a tap of the W2-048/X2-022 – AB2-070 345 kV line segment (part of the Lanesville – Brokaw 345 kV line) in the ComEd area. Project AC1-053 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-053 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2020

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

None

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

None

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

None

Stability and Steady-State Voltage Requirements
(Results of the stability and steady-state voltage studies should be inserted here)

Generator Interconnection Request AC1-053 is for 200 MW Maximum Facility Output (MFO) wind generating facility. AC1-053 consists of 80 x General Electric 2.5 MW wind turbines with a Point of Interconnection (POI) at a tap of Brokaw – Lanesville 345 kV circuit, in the ComEd transmission system, Logan County, Illinois.
This report describes a dynamic simulation analysis of AC1-053 as part of the overall system impact study.
The load flow scenarios for the analysis were based on the RTEP 2020 Summer Peak case, modified to include applicable queue projects. AC1-053 was dispatched at maximum power output, unity power factor and approximately 1.0 pu voltage at the inverter terminals.
AC1-053 was tested for compliance with NERC, ComEd, PJM and other applicable criteria. 350 contingencies were studied, each with a 20 second simulation time period. Studied scenarios included:

a) Steady state operation (20 seconds);

b) Three-phase faults with normal clearing time on the intact network and with prior outage;

c) Three-phase faults with single-phase delayed clearing due to a stuck breaker (FD clearing time);

d) Three-phase faults with three-phase delayed clearing due to a stuck breaker (GO breakers with A-contact logic);

e) Three-phase faults with three-phase delayed clearing due to a stuck breaker (GO breakers without A-contact logic);

f) Three-phase faults with delayed clearing (Zone 2) at line end closest to AC1-053 POI.

No relevant Bus, or High Speed Reclosing (HSR) contingencies were identified.
For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.
The results indicate that for all contingencies tested on the RTEP 2020 summer peak case:

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

b) The AC1-053 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

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

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

Three instances of non-convergence were observed during fault application for contingencies MG.3N.01 – 03. This non-convergence did not have an adverse effect on the study results.

Mitigation was not required.

Short Circuit
(Summary of impacted circuit breakers)

No issues identified

Affected System Analysis & Mitigation

MISO Impacts:

AC1-053 is contingent on MTEP 2237(Kansas-Sugarcreek 345kV line) which is scheduled to be done on 12/15/2020.

Delivery of Energy Portion of Interconnection Request
PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.
Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed, which will study all overload conditions associated with the overloaded element(s) identified.

1. (AEP - AEP) The 05EUGENE-05DEQUIN 345 kV line (from bus 243221 to bus 243217 ckt 1) loads from 147.06% to 147.94% (AC power flow) of its normal rating (971 MVA) for the single line contingency outage of '363_B2_TOR1682'. This project contributes approximately 10.03 MW to the thermal violation.

```
CONTINGENCY '363_B2_TOR1682'
 OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1              / 243208 05JEFRSO 765 243209 05ROCKPT 765 1
 END
```

2. (CE - CE) The BLUEMOUND; B-PONTIAC ; B 345 kV line (from bus 270668 to bus 270852 ckt 1) loads from 110.73% to 112.93% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L8001___-S_A'. This project contributes approximately 32.83 MW to the thermal violation.

```
CONTINGENCY '345-L8001___-S_A'
 TRIP BRANCH FROM BUS 270853 TO BUS 920791 CKT 1              / PONTI; R 345 Z2-087 TAP
 END
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3. (CE - CE) The LORETTO ; B-WILTON ; B 345 kV line (from bus 270704 to bus 270926 ckt 1) loads from 147.88% to 151.27% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L8014_T_-S'. This project contributes approximately 50.72 MW to the thermal violation.

```
CONTINGENCY '345-L8014_T_-S'
 TRIP BRANCH FROM BUS 270853 TO BUS 270717 CKT 1              / PONTIAC ; R 345 DRESDEN ; R 345
 TRIP BRANCH FROM BUS 275210 TO BUS 270853 CKT 1              / PONTIAC ;2M 138 PONTIAC ; R 345
 TRIP BRANCH FROM BUS 275210 TO BUS 272261 CKT 1              / PONTIAC ;2M 138 PONTIAC ; R 138
 TRIP BRANCH FROM BUS 275210 TO BUS 275310 CKT 1              / PONTIAC ;2M 138 PONTIAC ;2C 34.5
 CLOSE BRANCH FROM BUS 272260 TO BUS 272261 CKT 1              / PONTIAC ; B 138 PONTIAC ; R 138
 END
```

4. (CE - CE) The LORETTO ; B-WILTON ; B 345 kV line (from bus 270704 to bus 270926 ckt 1) loads from 108.44% to 110.96% (AC power flow) of its normal rating (1364 MVA) for non-contingency condition. This project contributes approximately 33.37 MW to the thermal violation.

5. (CE - CE) The DRESDEN ; R-COLLINS ; R 345 kV line (from bus 270717 to bus 270697 ckt 1) loads from 80.47% to 81.37% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L1223_TR-S'. This project contributes approximately 15.66 MW to the thermal violation.

```
CONTINGENCY '345-L1223_TR-S'
 TRIP BRANCH FROM BUS 270717 TO BUS 270731 CKT 1              / DRESD; R 345 ELECT;4R 345
 TRIP BRANCH FROM BUS 275180 TO BUS 270717 CKT 1              / DRESD;3M 138 DRESD; R 345
 TRIP BRANCH FROM BUS 275180 TO BUS 271336 CKT 1              / DRESD;3M 138 DRESD; B 138
 TRIP BRANCH FROM BUS 275180 TO BUS 275280 CKT 1              / DRESD;3M 138 DRESD;3C 34.5
 END
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6. (CE - CE) The DRESDEN ; R-ELWOOD ; R 345 kV line (from bus 270717 to bus 270737 ckt 1) loads from 113.83% to 114.84% (AC power flow) of its emergency rating (1479 MVA) for the single line contingency outage of '345-L1223_TR-S'. This project contributes approximately 17.58 MW to the thermal violation.

```
CONTINGENCY '345-L1223_TR-S'
 TRIP BRANCH FROM BUS 270717 TO BUS 270731 CKT 1          / DRESD; R 345 ELECT;4R 345
 TRIP BRANCH FROM BUS 275180 TO BUS 270717 CKT 1          / DRESD;3M 138 DRESD; R 345
 TRIP BRANCH FROM BUS 275180 TO BUS 271336 CKT 1          / DRESD;3M 138 DRESD; B 138
 TRIP BRANCH FROM BUS 275180 TO BUS 275280 CKT 1          / DRESD;3M 138 DRESD;3C 34.5
 END
```

7. (CE - MISO AMIL) The KINCAID ; B-7AUSTIN 345 kV line (from bus 270796 to bus 347955 ckt 1) loads from 99.84% to 105.42% (AC power flow) of its emergency rating (797 MVA) for the single line contingency outage of '345-L8014_T_-S'. This project contributes approximately 42.96 MW to the thermal violation.

```
CONTINGENCY '345-L8014_T_-S'
 TRIP BRANCH FROM BUS 270853 TO BUS 270717 CKT 1          / PONTIAC ; R 345 DRESDEN ; R 345
 TRIP BRANCH FROM BUS 275210 TO BUS 270853 CKT 1          / PONTIAC ;2M 138 PONTIAC ; R 345
 TRIP BRANCH FROM BUS 275210 TO BUS 272261 CKT 1          / PONTIAC ;2M 138 PONTIAC ; R 138
 TRIP BRANCH FROM BUS 275210 TO BUS 275310 CKT 1          / PONTIAC ;2M 138 PONTIAC ;2C 34.5
 CLOSE BRANCH FROM BUS 272260 TO BUS 272261 CKT 1          / PONTIAC ; B 138 PONTIAC ; R 138
 END
```

8. (CE - CE) The LATHAM ; T-W4-005 TAP 345 kV line (from bus 270804 to bus 905080 ckt 1) loads from 94.85% to 97.34% (AC power flow) of its emergency rating (1334 MVA) for the single line contingency outage of '345-L8001___-S_A'. This project contributes approximately 32.96 MW to the thermal violation.

```
CONTINGENCY '345-L8001___-S_A'
 TRIP BRANCH FROM BUS 270853 TO BUS 920791 CKT 1          / PONTI; R 345 Z2-087 TAP
 END
```

9. (CE - CE) The PONTIAC ; B-LORETTO ; B 345 kV line (from bus 270852 to bus 270704 ckt 1) loads from 134.83% to 138.2% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L8014_T_-S'. This project contributes approximately 50.78 MW to the thermal violation.

```
CONTINGENCY '345-L8014_T_-S'
 TRIP BRANCH FROM BUS 270853 TO BUS 270717 CKT 1          / PONTIAC ; R 345 DRESDEN ; R 345
 TRIP BRANCH FROM BUS 275210 TO BUS 270853 CKT 1          / PONTIAC ;2M 138 PONTIAC ; R 345
 TRIP BRANCH FROM BUS 275210 TO BUS 272261 CKT 1          / PONTIAC ;2M 138 PONTIAC ; R 138
 TRIP BRANCH FROM BUS 275210 TO BUS 275310 CKT 1          / PONTIAC ;2M 138 PONTIAC ;2C 34.5
 CLOSE BRANCH FROM BUS 272260 TO BUS 272261 CKT 1          / PONTIAC ; B 138 PONTIAC ; R 138
 END
```

10. (CE - CE) The PONTIAC ; B-LORETTO ; B 345 kV line (from bus 270852 to bus 270704 ckt 1) loads from 97.04% to 99.54% (AC power flow) of its normal rating (1364 MVA) for non-contingency condition. This project contributes approximately 33.44 MW to the thermal violation.

11. (CE - CE) The PONTIAC ; R-DRESDEN ; R 345 kV line (from bus 270853 to bus 270717 ckt 1) loads from 156.82% to 160.46% (AC power flow) of its emergency rating (1481 MVA) for the single line contingency outage of '345-L11212_B-S'. This project contributes approximately 52.72 MW to the thermal violation.

```
CONTINGENCY '345-L11212_B-S'
 TRIP BRANCH FROM BUS 270926 TO BUS 270704 CKT 1          / WILTO; B 345 LORET; B 345
 END
```

12. (CE - CE) The PONTIAC ; R-DRESDEN ; R 345 kV line (from bus 270853 to bus 270717 ckt 1) loads from 109.78% to 112.51% (AC power flow) of its normal rating (1334 MVA) for non-contingency condition. This project contributes approximately 34.9 MW to the thermal violation.

13. (MISO AMIL - AEP) The 7CASEY-05SULLIVAN 345 kV line (from bus 346809 to bus 247712 ckt 1) loads from 134.55% to 136.44% (AC power flow) of its normal rating (1334 MVA) for the single line contingency outage of '695_B2'. This project contributes approximately 25.73 MW to the thermal violation.

```
CONTINGENCY '695_B2'
 OPEN BRANCH FROM BUS 243206 TO BUS 270644 CKT 1              / 243206 05DUMONT 765 270644 WILTO; 765 1
 END
```

14. (MISO AMIL - CE) The 7BROKAW-AB2-047 TAP 345 kV line (from bus 348847 to bus 924040 ckt 1) loads from 117.44% to 121.72% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L8002___-S'. This project contributes approximately 65.06 MW to the thermal violation.

```
CONTINGENCY '345-L8002___-S'
 TRIP BRANCH FROM BUS 270852 TO BUS 270668 CKT 1              / PONTI; B 345 BLUEM; B 345
 END
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15. (CE - CE) The W4-005 TAP-BLUEMOUND; B 345 kV line (from bus 905080 to bus 270668 ckt 1) loads from 107.5% to 110.0% (AC power flow) of its emergency rating (1334 MVA) for the single line contingency outage of '345-L8001___-S_A'. This project contributes approximately 32.91 MW to the thermal violation.

```
CONTINGENCY '345-L8001___-S_A'
 TRIP BRANCH FROM BUS 270853 TO BUS 920791 CKT 1              / PONTI; R 345 Z2-087 TAP
 END
```

16. (CE - CE) The Z2-087 TAP-PONTIAC ; R 345 kV line (from bus 920791 to bus 270853 ckt 1) loads from 136.51% to 140.82% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L8002___-S'. This project contributes approximately 65.06 MW to the thermal violation.

```
CONTINGENCY '345-L8002___-S'
 TRIP BRANCH FROM BUS 270852 TO BUS 270668 CKT 1              / PONTI; B 345 BLUEM; B 345
 END
```

17. (CE - CE) The Z2-087 TAP-PONTIAC ; R 345 kV line (from bus 920791 to bus 270853 ckt 1) loads from 112.89% to 117.5% (AC power flow) of its normal rating (1334 MVA) for non-contingency condition. This project contributes approximately 61.0 MW to the thermal violation.

18. (CE - CE) The AB2-047 TAP-Z2-087 TAP 345 kV line (from bus 924040 to bus 920791 ckt 1) loads from 127.85% to 132.15% (AC power flow) of its emergency rating (1528 MVA) for the single line contingency outage of '345-L8002___-S'. This project contributes approximately 65.06 MW to the thermal violation.

```
CONTINGENCY '345-L8002___-S'
 TRIP BRANCH FROM BUS 270852 TO BUS 270668 CKT 1              / PONTI; B 345 BLUEM; B 345
```

END

19. (CE - CE) The AB2-047 TAP-Z2-087 TAP 345 kV line (from bus 924040 to bus 920791 ckt 1) loads from 101.78% to 106.38% (AC power flow) of its normal rating (1334 MVA) for non-contingency condition. This project contributes approximately 61.0 MW to the thermal violation.

Light Load Analysis - 2020

Light Load Studies to be conducted during later study phases (as required by PJM Manual 14B).

The Queue Project AC1-053 was evaluated as a 200.0 MW (Capacity 26.0 MW) injection at the AB2-070 project which taps the Brokaw-W2-048 345kV line substation in the ComEd area. Project AC1-053 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-053 was studied with a commercial probability of 100%. Potential network impacts were as follows:

None

System Reinforcements

Short Circuit

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

None required.

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

No mitigation was required.

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

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

Generator Deliverability

None

Multiple Facility Contingency

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

None

Contribution to Previously Identified 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

Light Load Load Flow Analysis Reinforcements

New System Reinforcements

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

None