Revised Generation Interconnection System Impact Study Report For

PJM Generation Interconnection Request Queue Position AC2-157

Sullivan 345 kV

July 2022

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

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

The 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

Invenergy Solar Development North America, LLC (Invenergy) proposes to install PJM Project #AC2-157, a 200.0 MW (76.0 MW Capacity) solar generating facility in Sullivan, IN (see Figure 2). The point of interconnection will be a direct connection to AEP's Sullivan 345 kV substation (see Figure 1).

The requested in service date is December 31, 2020.

Attachment Facilities

Point of Interconnection (Sullivan 345 kV)

To accommodate the interconnection at the Sullivan 345 kV substation, the Sullivan substation will have to be expanded requiring two (2) additional 345 kV circuit breaker (see Figure 1). Installation of associated protection and control equipment, 345 kV line risers, SCADA, and 345 kV revenue metering will also be required.

Station Work and Cost:

- Install two (2) new 345 kV circuit breaker and associated bus work. Installation of associated protection and control equipment, 345 kV line risers, SCADA, and 345 kV revenue metering will also be required.
    - **Estimated Station Cost: $3,500,000**

Non-Direct Connection Cost Estimate

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

For AEP building Direct Connection cost estimates:

Description	Estimated Cost
345 kV Revenue Metering	**$350,000**
Total	**$350,000**

Table 1

Interconnection Customer Requirements

It is understood that Invenergy is responsible for all costs associated with this interconnection. The cost of Invenergy's generating plant and the costs for the line connecting the generating plant to the Sullivan 345 kV substation are not included in this report; these are assumed to be Invenergy's responsibility.

The Generation Interconnection Agreement does not in or by itself establish a requirement for American Electric Power to provide power for consumption at the developer's facilities. A separate agreement may be reached with the local utility that provides service in the area to ensure that infrastructure is in place to meet this demand and proper metering equipment is installed. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required.

Requirement from the PJM Open Access Transmission Tariff:

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.

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. The Revenue Metering Requirements may be found within the "Requirements for Connection of New Facilities or Changes to Existing Facilities Connected to the AEP Transmission System" document located at the following link:

http://www.pjm.com/~/media/planning/plan-standards/private-aep/aep-interconnection-requirements.ashx

Network Impacts

The Queue Project AC2-157 was evaluated as a 200.0 MW (Capacity 76.0 MW) injection into the Sullivan 345 kV substation in the AEP area. Project AC2-157 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC2-157 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)

1. (AEP - MISO NIPS) The 05MEADOW-17REYNOLDS 345 kV line (from bus 243878 to bus 255205 ckt 1) loads from 99.15% to 100.66% (AC power flow) of its emergency rating (2627 MVA) for the line fault with failed breaker contingency outage of 'ADD615'. This project contributes approximately 31.91 MW to the thermal violation.

CONTINGENCY 'ADD615'
OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1
OPEN BRANCH FROM BUS 243208 TO BUS 243207 CKT 1
END

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)

1. (AEP - OVEC) The 05JEFRSO-06CLIFTY 345 kV line (from bus 242865 to bus 248000 ckt Z1) loads from 105.9% to 108.36% (AC power flow) of its emergency rating (2045 MVA) for the line fault with failed breaker contingency outage of '1760_C2_05JEFRSO 765-A'. This project contributes approximately 47.58 MW to the thermal violation.

CONTINGENCY '1760_C2_05JEFRSO 765-A'
OPEN BRANCH FROM BUS 243207 TO BUS 243208 CKT 1 / 243207 05GRNTWN 765 243208 05JEFRSO 765 1
OPEN BRANCH FROM BUS 242924 TO BUS 243208 CKT 1 / 242924 05HANGR 765 243208 05JEFRSO 765 1
END

Please refer to Appendix 1 for a table containing the generators having contribution to this flowgate.

2. (AEP - AEP) The 05DEQUIN-05MEADOW 345 kV line (from bus 243217 to bus 243878 ckt 2) loads from 126.35% to 128.32% (AC power flow) of its emergency rating (1304 MVA) for the line fault with failed breaker contingency outage of '4704_C2_05DEQUIN 345-B1'. This project contributes approximately 24.8 MW to the thermal violation.

CONTINGENCY '4704_C2_05DEQUIN 345-B1'
OPEN BRANCH FROM BUS 243217 TO BUS 243878 CKT 1 / 243217 05DEQUIN 345 243878 05MEADOW 345 1
OPEN BRANCH FROM BUS 243217 TO BUS 249525 CKT 1 / 243217 05DEQUIN 345 249525 08WESTWD 345 1
END

Please refer to Appendix 2 for a table containing the generators having contribution to this flowgate.

3. (AEP - MISO NIPS) The 05MEADOW-17REYNOLDS 345 kV line (from bus 243878 to bus 255205 ckt 1) loads from 101.23% to 102.77% (AC power flow) of its emergency rating (2627 MVA) for the line fault with failed breaker contingency outage of '8648_C2_05JEFRSO 765-B1'. This project contributes approximately 35.37 MW to the thermal violation.

CONTINGENCY '8648_C2_05JEFRSO 765-B1'
OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1 / 243208 05JEFRSO 765 243209 05ROCKPT 765 1
OPEN BRANCH FROM BUS 243208 TO BUS 242865 CKT 2 / 243208 05JEFRSO 765 242865 05JEFRSO 345 2
OPEN BRANCH FROM BUS 242865 TO BUS 248000 CKT Z1 / 242865 05JEFRSO 345 248000 06CLIFTY 345 Z1
END

Please refer to Appendix 3 for a table containing the generators having contribution to this flowgate.

4. (AEP - MISO NIPS) The 05MEADOW-17REYNOLDS 345 kV line (from bus 243878 to bus 255205 ckt 1) loads from 101.23% to 102.77% (AC power flow) of its emergency rating (2627 MVA) for the line fault with failed breaker contingency outage of 'ADD614'. This project contributes approximately 35.37 MW to the thermal violation.

CONTINGENCY 'ADD614'
OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1
OPEN BRANCH FROM BUS 243208 TO BUS 242865 CKT 2
END

5. (OVEC - OVEC) The 06CLIFTY-06DEARB1 345 kV line (from bus 248000 to bus 248001 ckt 1) loads from 118.54% to 119.63% (AC power flow) of its emergency rating (956 MVA) for the line fault with failed breaker contingency outage of '1760_C2_05JEFRSO 765-A'. This project contributes approximately 12.19 MW to the thermal violation.

CONTINGENCY '1760_C2_05JEFRSO 765-A'
OPEN BRANCH FROM BUS 243207 TO BUS 243208 CKT 1 / 243207 05GRNTWN 765 243208 05JEFRSO 765 1
OPEN BRANCH FROM BUS 242924 TO BUS 243208 CKT 1 / 242924 05HANGR 765 243208 05JEFRSO 765 1
END

Please refer to Appendix 4 for a table containing the generators having contribution to this flowgate.

6. (LGEE - OVEC) The 7TRIMBLE-06CLIFTY 345 kV line (from bus 324114 to bus 248000 ckt 1) loads from 162.05% to 163.24% (AC power flow) of its emergency rating (1370 MVA) for the line fault with failed breaker contingency outage of 'ADD615'. This project contributes approximately 19.28 MW to the thermal violation.

CONTINGENCY 'ADD615'
OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1
OPEN BRANCH FROM BUS 243208 TO BUS 243207 CKT 1
END

Please refer to Appendix 5 for a table containing the generators having contribution to this flowgate.

7. (LGEE - OVEC) The 7TRIMBLE-06CLIFTY 345 kV line (from bus 324114 to bus 248000 ckt 1) loads from 142.32% to 142.83% (AC power flow) of its emergency rating (1370 MVA) for the single line contingency outage of '363_B2_TOR1682'. This project contributes approximately 5.71 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

Steady-State Voltage Requirements

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

None.

Short Circuit

(Summary of impacted circuit breakers)

None

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

No mitigations were found to be required due to instability; however, it was observed that the AC2-157 plant is deficient in lagging power factor requirement at the high-voltage side of the main transformer by 5.46 MVAr. This may need to be addressed through reactive compensation.

See Attachment 1.

Affected System Analysis & Mitigation

LGEE Impacts:

A potential constraint was identified by PJM on the Trimble – Clifty 345 kV line (LG&E/OVEC tie line). The upgrade (LG&E) on the Trimble – Clifty 345 kV line, if determined to be a constraint by LG&E, is to reconductor the line with a high temperature conductor and upgrade necessary terminal equipment to achieve ratings of 2610/2610 MVA SN/SE. Cost estimate is $17.4M with a time estimate of 18 months. An LG&E affected system study is required to determine if the AC2-157 queue project causes any impacts on the LG&E system, including the Trimble-Clifty LG&E-OVEC tie line. Final LG&E Impacts and necessary LG&E system upgrade(s) will be determined once the LG&E affected system study is completed by LG&E.

Update (July 2022): LG&E KU determined that there are no impacts to the system as a result of the AC2-157 project.

MISO Impacts:

None

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

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.

Note: Only the most severely overloaded conditions are listed below. 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 shall study all overload conditions associated with the overloaded element(s) identified.

1. (AEP - AEP) The 05DEQUIN-05MEADOW 345 kV line (from bus 243217 to bus 243878 ckt 2) loads from 121.8% to 123.77% (AC power flow) of its normal rating (1304 MVA) for the single line contingency outage of '6472_B2_TOR15258'. This project contributes approximately

24.54 MW to the thermal violation.

CONTINGENCY '6472_B2_TOR15258'
OPEN BRANCH FROM BUS 243217 TO BUS 243878 CKT 1 / 243217 05DEQUIN 345 243878 05MEADOW 345 1
END

2. (LGEE - OVEC) The 7TRIMBLE-06CLIFTY 345 kV line (from bus 324114 to bus 248000 ckt 1) loads from 135.69% to 136.62% (AC power flow) of its emergency rating (1370 MVA) for the single line contingency outage of '363_B2_TOR1682'. This project contributes approximately 15.03 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

Light Load Analysis

Not Applicable

New System Reinforcements

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

None

Contribution to Previously Identified System Reinforcements

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

1. To relieve the Jefferson – Clifty 345 kV line overloads: Clifty-end SE rating is 2045 MVA SE. There is a 2018 baseline upgrade B2878 to replace the Clifty riser and increase the SE rating to match the Jefferson-end SE rating of 2354 MVA SE which would be sufficient for AC2-157. Baseline upgrade B2878 is now in-service. AEP will need to confirm the new SE rating during the Facilities Study to ensure no additional upgrade is required for AC2-157.

2. To relieve the Trimble – Clifty 345 kV line overload:

A potential constraint was identified by PJM on the Trimble – Clifty 345 kV line (LG&E/OVEC tie line). The upgrade (LG&E) on the Trimble – Clifty 345 kV line, if determined to be a constraint by LG&E, is to reconductor the line with a high temperature conductor and upgrade necessary terminal equipment to achieve ratings of 2610/2610 MVA SN/SE. Cost estimate is $17.4M with a time estimate of 18 months. An LG&E affected system study is required to determine if the AC2-157 queue project causes any impacts on the LG&E system, including the Trimble-Clifty LG&E-OVEC tie line. Final LG&E Impacts and necessary LG&E system upgrade(s) will be determined once the LG&E affected system study is completed by LG&E.
AC2-157 will be required to sign onto an LG&E Affected System Study.

No OVEC end upgrades are required.

3. To relieve the Clifty – Dearborn 345 kV line overload:

   There is a planned 2018 baseline upgrade, B2943, to perform a LIDAR study on the line. LIDAR study results show that various mitigations are required involving various structures. The new expected SE rating is 1251 MVA SE. Expected completion date of the B2943 work is 4/15/2020.
   The LIDAR study and results of the LIDAR study should be confirmed during the Facilities Study phase of AC2-157 in order to conclude that no additional work scope is required beyond B2943 that AC2-157 may be responsible for.

   AC2-157 will need an interim study if coming into service prior to completion of baseline upgrade B2943.

4. To relieve the Dequine – Meadowlake 345 kV line #2 overload:

   The Dequine stuck breaker contingency causing the overload is no longer valid due to the completion of PJM netowrk upgrades N5817 and N5818 which added a 345 kV breaker at Dequine (breaker ‘D’). AC2-157 has no cost responsibility for this upgrade.

5. To relieve the Meadowlake – Reynolds 345 kV line #1 overload:

   PJM Baseline Upgrade B2449 – Rebuild the 7-mile 345 kV line between Meadowlake and Reynolds 345 kV stations. This upgrade is presently in-service.
   AC2-157 will have no cost responsibility for this upgrade.

   PJM Supplemental Project S1141 – Loop in the Meadowlake – Olive 345 kV circuit into Reynolds. This upgrade is presently in-service. AC2-157 will have no cost responsibility for this upgrade.

Schedule

It is anticipated that the time between receipt of executed agreements and Commercial Operation may range from 12 to 18 months if no line work is required. If line work is required, construction time would be between 24 to 36 months after signing an interconnection agreement.

Note: The time provided between anticipated normal completion of System Impact, Facilities Studies, subsequent execution of ISA and ICSA documents, and the proposed Backfeed Date is shorter than usual and may be difficult to achieve.

Conclusion

Based upon the results of this System Impact Study, the construction of the 200.0 MW (76.0 MW Capacity) solar generating facility of Invenergy (PJM Project #AC2-157) will require the following additional interconnection charges. This plan of service will interconnect the proposed solar generating facility in a manner that will provide operational reliability and flexibility to both the AEP system and the Invenergy generating facility.

Cost Breakdown for Point of Interconnection (Sullivan 345 kV Substation)			
Type of Network Upgrade	**Network Upgrade #**	**Description**	**Estimated Cost**
Attachment Cost	**n6049**	Expand the Sullivan 345 kV Substation	$3,500,000
Attachment Cost	**n6050**	345 kV Revenue Metering	$350,000
Non-Direct Connection Cost Estimate	**N5469**	Reconductor Trimble - Clifty 345 kV line **Update (July 2022): LG&E KU determined this upgrade is not required for AC2-157**	$17,400,000
	Total Estimated Cost for Project AC2-157		**$21,250,000**

Table 2

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: Point of Interconnection (Sullivan 345 kV Substation)

Single-Line Diagram

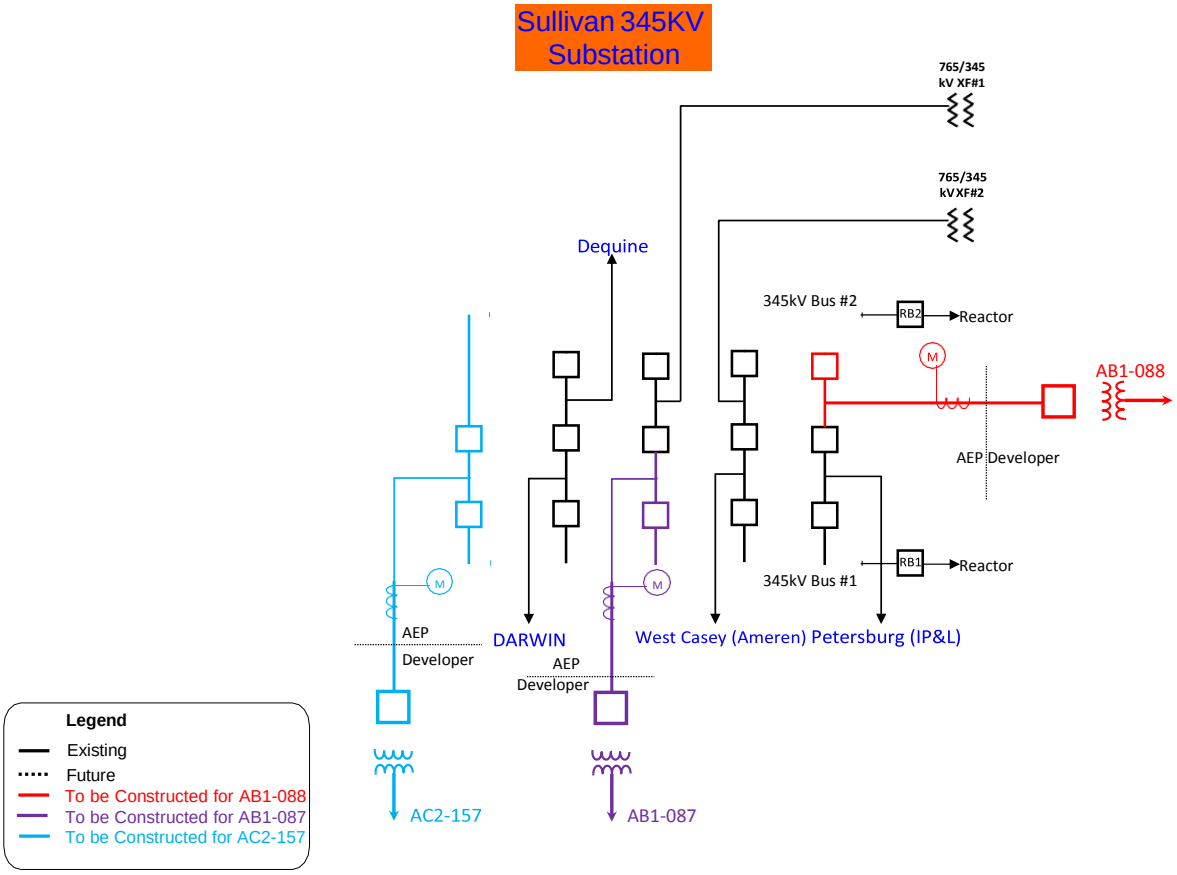
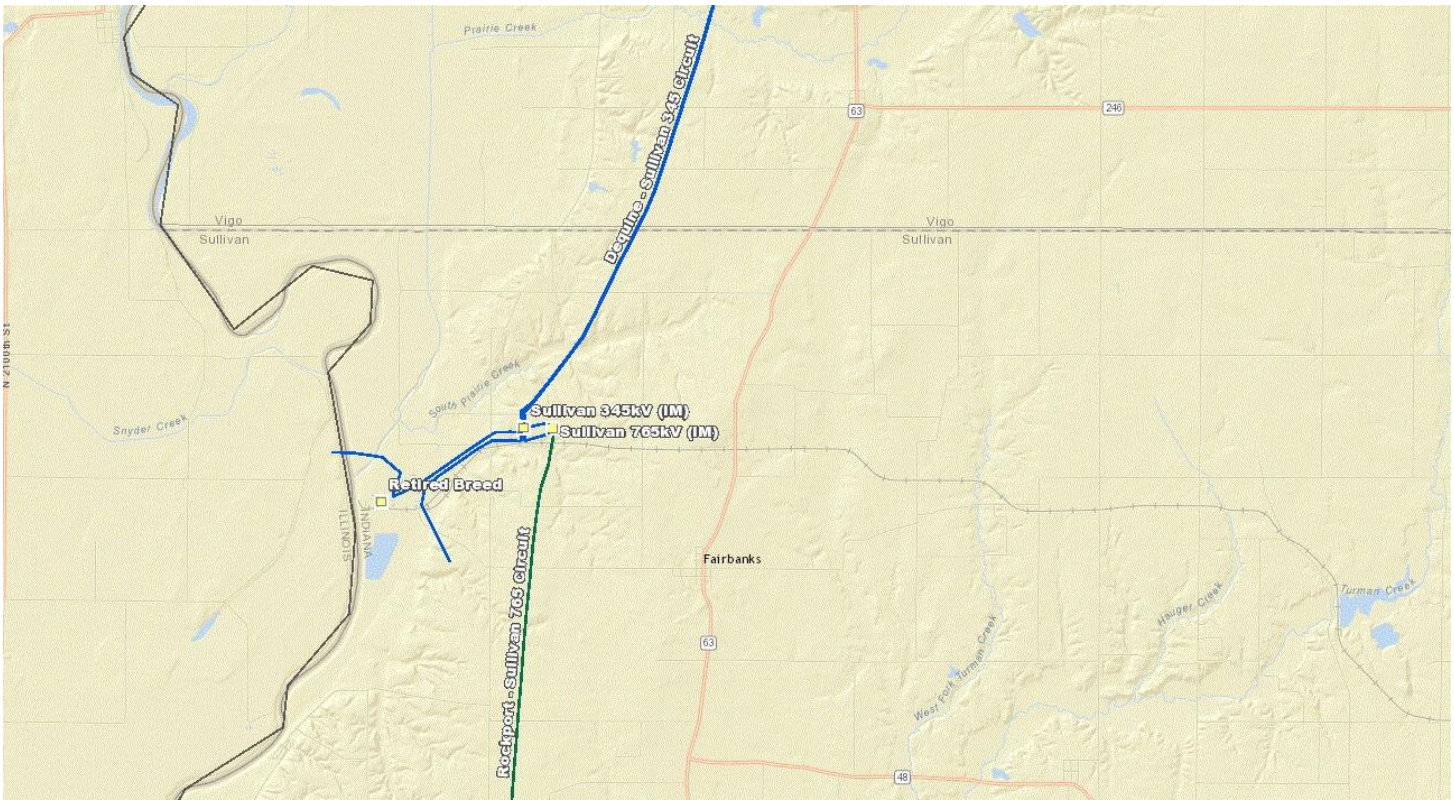


Figure 2: Point of Interconnection (Sullivan 345 kV Substation)



Appendices

The following appendices contain additional information about each flowgate presented in the body of the report. For each appendix, a description of the flowgate and its contingency was included for convenience. However, the intent of the appendix section is to provide more information on which projects/generators have contributions to the flowgate in question. All New Service Queue Requests, through the end of the Queue under study, that are contributors to a flowgate will be listed in the Appendices. Please note that there may be contributors that are subsequently queued after the queue under study that are not listed in the Appendices. Although this information is not used "as is" for cost allocation purposes, it can be used to gage the impact of other projects/generators.

It should be noted the project/generator MW contributions presented in the body of the report and appendices sections are full contributions, whereas the loading percentages reported in the body of the report, take into consideration the commercial probability of each project as well as the ramping impact of "Adder" contributions.

Appendix 1

(AEP - OVEC) The 05JEFRSO-06CLIFTY 345 kV line (from bus 242865 to bus 248000 ckt Z1) loads from 105.9% to 108.36% (AC power flow) of its emergency rating (2045 MVA) for the line fault with failed breaker contingency outage of '1760_C2_05JEFRSO 765-A'. This project contributes approximately 47.58 MW to the thermal violation.

CONTINGENCY '1760_C2_05JEFRSO 765-A'
OPEN BRANCH FROM BUS 243207 TO BUS 243208 CKT 1 / 243207 05GRNTWN 765 243208 05JEFRSO 765 1
OPEN BRANCH FROM BUS 242924 TO BUS 243208 CKT 1 / 242924 05HANG R 765 243208 05JEFRSO 765 1
END

Bus Number	*Bus Name*	*Full Contribution*
247900	*05FR-11G E*	*6.24*
247901	*05FR-12G E*	*6.14*
247902	*05FR-21G E*	*6.56*
247903	*05FR-22G E*	*6.28*
247904	*05FR-3G E*	*12.72*
247905	*05FR-4G E*	*9.57*
247906	*05MDL-1G E*	*10.8*
247907	*05MDL-2G E*	*5.36*
247912	*05MDL-3G E*	*5.6*
247913	*05MDL-4G E*	*5.34*
243442	*05RKG1*	*123.28*
243443	*05RKG2*	*121.41*
932601	*AC2-080 C O1*	*1.47*
932602	*AC2-080 E O1*	*9.83*
933391	*AC2-152 C*	*0.25*
933392	*AC2-152 E*	*0.41*
933441	*AC2-157 C*	*18.08*
933442	*AC2-157 E*	*29.5*
294401	*BSHIL;1U E*	*4.74*
294410	*BSHIL;2U E*	*4.74*
274890	*CAYUG;1U E*	*7.49*
274891	*CAYUG;2U E*	*7.49*
274849	*CRESCENT ;1U*	*3.23*
998111	*J468*	*1.87*
998112	*J468*	*10.58*
990901	*L-005 E*	*7.27*
293516	*O-009 E1*	*4.62*
293517	*O-009 E2*	*2.35*
293518	*O-009 E3*	*2.58*

293715	*O-029 E*	*4.93*
293716	*O-029 E*	*2.71*
293717	*O-029 E*	*2.49*
293771	*O-035 E*	*3.51*
247556	*T-127 C*	*1.37*
247943	*T-127 E*	*5.48*
274853	*TWINGROVE;U1*	*11.42*
274854	*TWINGROVE;U2*	*11.42*
276150	*W2-048 E*	*4.99*
905082	*W4-005 E*	*23.43*
909052	*X2-022 E*	*14.98*
913222	*Y1-054 E*	*-1.26*
247629	*Y3-038*	*3.36*
915662	*Y3-099 E*	*0.13*
915672	*Y3-100 E*	*0.13*
916182	*Z1-065 E*	*0.36*
920792	*Z2-087 C*	*1.72*
920793	*Z2-087 E*	*11.49*
LTF	*AA1-001*	*5.6*
LTF	*AA1-071*	*3.89*
921702	*AA2-039 C*	*1.16*
921703	*AA2-039 E*	*7.74*
922592	*AB1-006 C*	*1.76*
922593	*AB1-006 E*	*11.77*
922982	*AB1-087 C OP*	*130.85*
922992	*AB1-088 C OP*	*130.85*
924041	*AB2-047 C OP*	*2.17*
924042	*AB2-047 E OP*	*14.49*
924261	*AB2-070 C OP*	*2.05*
924262	*AB2-070 E OP*	*13.75*
925242	*AB2-178 E*	*1.33*
926321	*AC1-033 C*	*0.78*
926322	*AC1-033 E*	*5.2*
926521	*AC1-053 C*	*2.06*
926522	*AC1-053 E*	*13.79*
927781	*AC1-168 C OP*	*0.59*
927782	*AC1-168 E OP*	*3.97*
927811	*AC1-171 C OP*	*0.68*
927812	*AC1-171 E OP*	*4.52*
928251	*AC1-214 C OP*	*1.13*
928252	*AC1-214 E OP*	*3.58*

Appendix 2

(AEP - AEP) The 05DEQUIN-05MEADOW 345 kV line (from bus 243217 to bus 243878 ckt 2) loads from 126.35% to 128.32% (AC power flow) of its emergency rating (1304 MVA) for the line fault with failed breaker contingency outage of '4704_C2_05DEQUIN 345-B1'. This project contributes approximately 24.8 MW to the thermal violation.

CONTINGENCY '4704_C2_05DEQUIN 345-B1'
OPEN BRANCH FROM BUS 243217 TO BUS 243878 CKT 1 / 243217 05DEQUIN 345 243878 05MEADOW 345 1
OPEN BRANCH FROM BUS 243217 TO BUS 249525 CKT 1 / 243217 05DEQUIN 345 249525 08WESTWD 345 1
END

Bus Number	*Bus Name*	*Full Contribution*
243859	*05FR-11G C*	*2.05*
247900	*05FR-11G E*	*42.46*
243862	*05FR-12G C*	*2.02*
247901	*05FR-12G E*	*41.76*
243864	*05FR-21G C*	*2.15*
247902	*05FR-21G E*	*44.63*
243866	*05FR-22G C*	*2.06*
247903	*05FR-22G E*	*42.74*
243870	*05FR-3G C*	*4.17*
247904	*05FR-3G E*	*86.56*
243873	*05FR-4G C*	*3.23*
247905	*05FR-4G E*	*65.08*
933441	*AC2-157 C*	*9.42*
933442	*AC2-157 E*	*15.37*
998111	*J468*	*2.85*
998112	*J468*	*16.17*
998120	*J515*	*57.93*
971511	*J754*	*7.42*
971512	*J754*	*29.68*
701171	*Y4-018 C*	*1.02*
701172	*Y4-018 E*	*4.06*
LTF	*AA1-001*	*4.12*
922982	*AB1-087 C OP*	*68.19*
922992	*AB1-088 C OP*	*68.19*

Appendix 3

(AEP - MISO NIPS) The 05MEADOW-17REYNOLDS 345 kV line (from bus 243878 to bus 255205 ckt 1) loads from 101.23% to 102.77% (AC power flow) of its emergency rating (2627 MVA) for the line fault with failed breaker contingency outage of '8648_C2_05JEFRSO 765-B1'. This project contributes approximately 35.37 MW to the thermal violation.

CONTINGENCY '8648_C2_05JEFRSO 765-B1'
OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1 / 243208 05JEFRSO 765 243209 05ROCKPT 765 1
OPEN BRANCH FROM BUS 243208 TO BUS 242865 CKT 2 / 243208 05JEFRSO 765 242865 05JEFRSO 345 2
OPEN BRANCH FROM BUS 242865 TO BUS 248000 CKT Z1 / 242865 05JEFRSO 345 248000 06CLIFTY 345 Z1
END

Bus Number	*Bus Name*	*Full Contribution*
243859	*05FR-11G C*	*1.95*
247900	*05FR-11G E*	*40.36*
243862	*05FR-12G C*	*1.92*
247901	*05FR-12G E*	*39.69*
243864	*05FR-21G C*	*2.05*
247902	*05FR-21G E*	*42.42*
243866	*05FR-22G C*	*1.96*
247903	*05FR-22G E*	*40.62*
243870	*05FR-3G C*	*3.97*
247904	*05FR-3G E*	*82.27*
243873	*05FR-4G C*	*3.07*
247905	*05FR-4G E*	*61.85*
246909	*05MDL-1G C*	*4.69*
247906	*05MDL-1G E*	*97.1*
246910	*05MDL-2G C*	*2.34*
247907	*05MDL-2G E*	*48.15*
246976	*05MDL-3G C*	*2.34*
247912	*05MDL-3G E*	*50.34*
246979	*05MDL-4G C*	*4.69*
247913	*05MDL-4G E*	*48.03*
243442	*05RKG1*	*45.01*
243443	*05RKG2*	*44.33*
933441	*AC2-157 C*	*13.44*
933442	*AC2-157 E*	*21.93*
998120	*J515*	*57.08*
971511	*J754*	*7.24*
971512	*J754*	*28.97*

247556	*T-127 C*	*12.32*
247943	*T-127 E*	*49.27*
247629	*Y3-038*	*1.23*
LTF	*AA1-001*	*5.62*
922592	*AB1-006 C*	*15.81*
922593	*AB1-006 E*	*105.79*
922982	*AB1-087 C OP*	*97.28*
922992	*AB1-088 C OP*	*97.28*

Appendix 4

(OVEC - OVEC) The 06CLIFTY-06DEARB1 345 kV line (from bus 248000 to bus 248001 ckt 1) loads from 118.54% to 119.63% (AC power flow) of its emergency rating (956 MVA) for the line fault with failed breaker contingency outage of '1760_C2_05JEFRSO 765-A'. This project contributes approximately 12.19 MW to the thermal violation.

CONTINGENCY '1760_C2_05JEFRSO 765-A'
OPEN BRANCH FROM BUS 243207 TO BUS 243208 CKT 1 / 243207 05GRNTWN 765 243208 05JEFRSO 765 1
OPEN BRANCH FROM BUS 242924 TO BUS 243208 CKT 1 / 242924 05HANGR 765 243208 05JEFRSO 765 1
END

Bus Number	*Bus Name*	*Full Contribution*
243442	*05RKG1*	*28.86*
243443	*05RKG2*	*28.42*
933441	*AC2-157 C*	*4.63*
933442	*AC2-157 E*	*7.56*
247629	*Y3-038*	*0.79*
922982	*AB1-087 C OP*	*33.53*
922992	*AB1-088 C OP*	*33.53*

Appendix 5

(LGEE - OVEC) The 7TRIMBLE-06CLIFTY 345 kV line (from bus 324114 to bus 248000 ckt 1) loads from 162.05% to 163.24% (AC power flow) of its emergency rating (1370 MVA) for the line fault with failed breaker contingency outage of 'ADD615'. This project contributes approximately 19.28 MW to the thermal violation.

CONTINGENCY 'ADD615'
OPEN BRANCH FROM BUS 243208 TO BUS 243209 CKT 1
OPEN BRANCH FROM BUS 243208 TO BUS 243207 CKT 1
END

Bus Number	*Bus Name*	*Full Contribution*
247900	*05FR-11G E*	*4.66*
247901	*05FR-12G E*	*4.58*
247902	*05FR-21G E*	*4.9*
247903	*05FR-22G E*	*4.69*
247904	*05FR-3G E*	*9.5*
247905	*05FR-4G E*	*7.14*
247906	*05MDL-1G E*	*8.57*
247907	*05MDL-2G E*	*4.25*
247912	*05MDL-3G E*	*4.44*
247913	*05MDL-4G E*	*4.24*
342900	*1COOPER1 G*	*2.98*
342903	*1COOPER2 G*	*5.78*
342918	*1JKCT 1G*	*2.27*
342921	*1JKCT 2G*	*2.27*
342924	*1JKCT 3G*	*2.27*
342933	*1JKCT 6G*	*1.51*
342936	*1JKCT 7G*	*1.51*
342945	*1LAUREL 1G*	*1.67*
932551	*AC2-075 C*	*0.99*
932552	*AC2-075 E*	*0.5*
932881	*AC2-115 1*	*1.08*
932891	*AC2-115 2*	*1.08*
932921	*AC2-116*	*0.38*
933341	*AC2-147 C*	*0.42*
933342	*AC2-147 E*	*0.69*
933351	*AC2-148 C*	*0.43*
933352	*AC2-148 E*	*0.7*
933371	*AC2-150 C*	*0.43*
933372	*AC2-150 E*	*0.7*
933391	*AC2-152 C*	*0.23*
933392	*AC2-152 E*	*0.38*

933401	*AC2-153 C*	*0.2*
933402	*AC2-153 E*	*0.33*
933431	*AC2-156 C O1*	*0.39*
933432	*AC2-156 E O1*	*0.64*
933441	*AC2-157 C*	*7.33*
933442	*AC2-157 E*	*11.96*
294401	*BSHIL;1U E*	*4.73*
294410	*BSHIL;2U E*	*4.73*
274890	*CAYUG;1U E*	*6.94*
274891	*CAYUG;2U E*	*6.94*
274849	*CRESCENT ;1U*	*3.2*
274859	*EASYR;U1 E*	*5.37*
274860	*EASYR;U2 E*	*5.37*
290051	*GSG-6; E*	*4.74*
971521	*J759*	*9.64*
971531	*J762*	*29.93*
971571	*J783*	*9.69*
990901	*L-005 E*	*7.21*
290108	*LEEDK;1U E*	*10.64*
274850	*MENDOTA H;RU*	*2.73*
293061	*N-015 E*	*6.03*
293516	*O-009 E1*	*4.73*
293517	*O-009 E2*	*2.4*
293518	*O-009 E3*	*2.64*
293715	*O-029 E*	*5.05*
293716	*O-029 E*	*2.77*
293717	*O-029 E*	*2.55*
293771	*O-035 E*	*3.48*
293644	*O22 E1*	*4.26*
293645	*O22 E2*	*8.27*
290021	*O50 E*	*8.62*
294392	*P-010 E*	*7.66*
294763	*P-046 E*	*4.39*
274830	*PWR VTREC;1U*	*2.69*
274831	*PWR VTREC;2U*	*2.69*
274722	*S-055 E*	*4.68*
295111	*SUBLETTE E*	*1.23*
247556	*T-127 C*	*1.09*
247943	*T-127 E*	*4.35*
274853	*TWINGROVE;U1*	*10.32*
274854	*TWINGROVE;U2*	*10.32*
276150	*W2-048 E*	*4.44*
905082	*W4-005 E*	*20.94*

295109	*WESTBROOK E*	*2.54*
909052	*X2-022 E*	*13.33*
920462	*Y2-103*	*18.72*
920472	*Y3-013 1*	*1.56*
920482	*Y3-013 2*	*1.56*
920492	*Y3-013 3*	*1.56*
915662	*Y3-099 E*	*0.11*
915672	*Y3-100 E*	*0.11*
701842	*Y4-085 E*	*1.59*
916502	*Z1-106 E1*	*0.51*
916504	*Z1-106 E2*	*0.51*
916522	*Z1-108 E*	*1.04*
920782	*Z2-081*	*0.71*
920792	*Z2-087 C*	*1.58*
920793	*Z2-087 E*	*10.55*
LTF	*AA1-001*	*6.87*
920932	*AA1-018 C*	*1.02*
920933	*AA1-018 E*	*6.83*
LTF	*AA1-071*	*4.69*
921632	*AA1-146*	*8.95*
921682	*AA2-030*	*8.95*
921702	*AA2-039 C*	*1.15*
921703	*AA2-039 E*	*7.72*
922183	*AA2-123 E*	*1.06*
922592	*AB1-006 C*	*1.39*
922593	*AB1-006 E*	*9.34*
922982	*AB1-087 C OP*	*53.03*
922992	*AB1-088 C OP*	*53.03*
923002	*AB1-089 C*	*29.68*
930761	*AB1-122 1*	*29.27*
930762	*AB1-122 2*	*29.89*
924041	*AB2-047 C OP*	*1.98*
924042	*AB2-047 E OP*	*13.28*
924261	*AB2-070 C OP*	*1.83*
924262	*AB2-070 E OP*	*12.22*
924471	*AB2-096*	*18.69*
925161	*AB2-173 C*	*1.6*
925242	*AB2-178 E*	*1.07*
925301	*AB2-191 C*	*0.45*
925302	*AB2-191 E*	*0.63*
926321	*AC1-033 C*	*0.78*
926322	*AC1-033 E*	*5.19*
926521	*AC1-053 C*	*1.83*

926522	*AC1-053 E*	*12.27*
926731	*AC1-074 C OP*	*4.16*
926732	*AC1-074 E OP*	*1.78*
927081	*AC1-109*	*1.52*
927101	*AC1-110*	*1.53*
927121	*AC1-111*	*1.83*
927191	*AC1-113*	*1.08*
927211	*AC1-114*	*1.08*
927781	*AC1-168 C OP*	*0.58*
927782	*AC1-168 E OP*	*3.9*
927811	*AC1-171 C OP*	*0.65*
927812	*AC1-171 E OP*	*4.37*
927951	*AC1-185*	*2.69*
928141	*AC1-204*	*28.16*
928142	*AC1-204*	*28.16*
928251	*AC1-214 C OP*	*1.12*
928252	*AC1-214 E OP*	*3.55*

Attachment 1

Dynamic Simulation Analysis

Executive Summary

Generator Interconnection Request AC2-157 is for a 200 MW Maximum Facility Output (MFO) Solar PV Inverter plant. AC2-157 consists of 70 x Power Electronics FS3000 CU15, 3.5 MVA Solar PV Inverters with the total capacity of 201.6 MW. AC2-157 has a Point of Interconnection (POI) at the Sullivan (AB1-087_088 POI) 345 kV substation, in the AEP transmission system, Sullivan County, Indiana.

This report describes the dynamic simulation analysis of AC2-157 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 peak load case, modified to include applicable queue projects. AC2-157 has been dispatched online at maximum power output, with 1.0 p.u. voltage at the generator bus.

AC2-157 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. Steady-state condition and 84 contingencies were studied, each with a 20 second simulation time period. Studied faults included:

a) Steady-state operation (20 second);

b) Three-phase faults with normal clearing;

c) Single-phase bus faults with normal clearing time;

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

e) Three-phase faults with loss of multiple-circuit tower line.

No relevant Zone 2 delayed clearing or High Speed Reclosing (HSR) contingencies were identified.

The three-phase fault contingencies with normal clearing were performed under network intact conditions and a subset were performed with prior outage of:

- Sullivan– Rockport 765 kV circuit
- Sullivan – Petersburg 765 kV circuit
- Sullivan – J1180 POI 345 kV circuit
- Sullivan – Darwin 345 kV circuit
- Rockport – Jefferson 765 kV circuit

AC2-157 queue project was re-studied using 2020 peak load case with the following system adjustments:

- X3-028, X1-020 and S57/S58 are not dispatched,
- Sullivan – Reynolds 765 kV circuit upgrade is not included,
- Rockport – Coleman – Duff 345 kV circuit upgrade is not included.

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 fault contingencies tested on the 2020 peal load case:

a) AC2-157 was able to ride through all contingencies.

b) Post-contingency oscillations were positively damped with a damping margin of at least 3% for local and inter-area modes.

c) Following fault clearing, all bus voltages recovered to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus[1]).

d) Rockport units G1 and G2 units tripped because of angle deviation in contingency P6.ME.02 involving the prior outage of Rockport – Jefferson 765 kV circuit. Other than that, no other transmission element tripped, except for those either directly connected or designed to trip as a consequence of that fault.

Contingencies P1.15, P4.24, and P6.ME.01 ~ P6.ME.04 (prior outage of Rockport – Jefferson 765 kV circuit) showed tripping issue for Rockport G1 and G2 units. Contingency P6.ME.02 showed tripping issue for AB1-087 and AB1-088. These contingencies were tested after activation of the fast-valving special protection scheme (SPS) at Rockport units. The fast-valving SPS resolved the tripping issue of Rockport G1 and G2 units in the contingencies P1.15, P4.24, P6.ME.01, P6.ME.03 and P6.ME.04. The tripping issue of AB1-087 and AB1-088 units in contingency P6.ME.02 was also resolved by the fast-valving SPS. However, in the contingency P6.ME.02, with the fast-valving SPS, the Rockport G1 and G2 units still tripped due to angle deviation. For these contingencies, a user-defined model has been used for the Rockport units in order to enable the testing of the fast-valving SPS.

During the AB1-087_088 study, the contingencies P6.ME.01 – P6.ME.02 (prior outage of Rockport – Jefferson 765 kV circuit) exhibited the tripping issue of Rockport units G1 and G2 even with the active fast-valving SPS. Therefore, the tripping issue of Rockport units G1 and G2 in these contingencies is a pre-existing issue and it is not attributable to addition of AC2-157 units. Furthermore, the prior outage cases have been tested for informational purposes and no mitigation is required.

Contingencies P1.05, P1.15, P4.06, P4.24, P6.MB.01, P6.MC.01, P6.ME.01 and P6.ME.03 yield a post-contingency terminal voltage for AC2-157 was between 1.05 and 1.075 V p.u. Contingencies P1.11, P1.14, P4.16, P4.17, P4.18, P4.22 and P4.23 yield a post-contingency terminal voltage for AC2-157 between 0.925 and 0.918 V p.u. After performing several tests, it was concluded that this difference is due to the updated dynamic model for AC2-157 and is not attributable to any modification in the loadflow model. Since these voltage values are related to the AC2-157 plant and did not cause any system instability no mitigations were performed.

AC2-157 exhibited a slow reactive power output (Qelec) recovery for several contingencies. This issue did not cause instability in the system and the model can be tuned to achieve a faster reactive power output settlement upon request.

No mitigations were found to be required due to instability; however, it was observed that the AC2-157 plant is deficient in lagging power factor requirement at the high-voltage side of the main transformer by 5.46 MVAr. This may need to be addressed through reactive compensation.

[1] Except for P6.ME.02 where Rockport Units G1 and G2 were tripped due to angle deviations at 4.9625 seconds. For this contingency all bus voltages recover to a minimum of 0.7 per unit after 5.0 seconds.