Revised Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AC1-166

"Atlanta 69 kV IV" 49.9 MW Energy, 33.6 MW Capacity

October 2018
Revision 2

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.

Revised System Impact Study Report Changes:

The AC1-166 System Impact Study was revised in October 2018 to incorporate the following changes[1]:

1. Stuart Unit 1 deactivated on 9/30/2017 and their Capacity Interconnection Rights terminated as of 9/30/2018. With their rights terminated, a retool of the System Impact Study was required. Analysis results were updated and AC1-166 is now the first to cause the need for network upgrade n5933. AC1-166 will be charged full Security for this upgrade with the ISA. This upgrade is required for AC1-166 to be in-service.
2. Ownership of the Adkins-Beatty 345 kV line changed in June 2018 to be fully owned by American Electric Power (AEP). With this change, AEP will be completing network upgrade n5933. AC1-166 will have an ICSA with AEP for this upgrade.
3. Cost allocations for the Network Upgrades were changed based on the retooled analysis results. All costs will be updated in the Facilities Study.

[1] Stuart Unit 1 deactivated on 9/30/2017 and their Capacity Interconnection Rights terminated as of 9/30/2018. With their rights terminated, a retool of the System Impact Study was required.

The AC1-166 System Impact Study was revised in November 2017 to incorporate the following changes:

1. Load flow analysis was retooled considering the removal of the output from queue positions Z1-097 and Z2-029 (uprates to Adkins and Stuart units). The additional MW from Z1-097 and Z2-029 projects were already captured in the existing units in the case and thus were double modeled.
2. Load flow analysis was retooled considering separating the AC1-165 output from AC1-166. The original System Impact Study report from September 2017 combined the AC1-165 and AC1-166 output at the latter queue position for the analysis.
3. Results were updated considering a load flow software error which missed a "Basecase/N-0" overload on the Adkins-Beatty 345 kV line which requires an upgrade to the Dayton end normal rating of this line.

General

Buckeye Plains Solar Project, LLC, the Interconnection Customer (IC), has proposed a solar generating facility located along SR 207 in New Holland, Pickaway County, Ohio. The installed facilities will have a total capability of **49.9 MW** with **33.6 MW** of this output being recognized by PJM as capacity. The proposed in-service date for this project is **December 1, 2019**. **This study does not imply a Dayton Power & Light Company commitment to this in-service date.**

Point of Interconnection

AC1-166 "Atlanta 69 kV IV" will interconnect with the Dayton Power & Light Company transmission system at the Atlanta Substation 69 kV bus. Presently Atlanta Substation consists of two 345 kV line feeds, a 345/69 kV transformer, and a single 69 kV line. – Proposed interconnection queue projects, AC1-068, AC1-069, and AC1-165 will expand the 69 kV portion of the Atlanta Substation to a ring bus. The AC1-166 project would require further extension of that 69 kV ring bus to accommodate an additional 69 kV bay position with a 69 kV circuit breaker. The first dead-end structure outside the Atlanta Substation fence on the AC1-166 69 kV generator lead line will be designated as the Point of Interconnection (*see One Line in Attachment 1*).

Cost Summary

The **AC1-166 "Atlanta 69 kV IV"** project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$ 0
Direct Connection Network Upgrades	$ 0
Non Direct Connection Network Upgrades (Dayton)	$ 830,000
Allocation for New System Upgrades (AEP)	$ 400,000
Contribution for Previously Identified Upgrades (Dayton)	$ 13,729
Total Costs	**$ 1,243,729**

The costs given above exclude any applicable state or federal taxes. If at a future date Federal CIAC (contribution in aid of construction) taxes are deemed necessary by the IRS for this project, Dayton Power and Light Company shall be reimbursed by the Interconnection Customer for such taxes.

Attachment Facilities

The Interconnection Customer will construct the attachment line into the proposed Point of Interconnection as depicted on the one-line diagram in Attachment 1.

Direct Connection Cost Estimate

None.

Non-Direct Connection Cost Estimate

The scope of the non-direct connection work at Dayton's Atlanta Substation involves expanding the 69 kV ring bus to accommodate a new 69 kV breaker bay position with 69 kV circuit breaker (initial ring bus constructed for AC1-068/AC1-069/AC1-165 projects). Also install revenue class 69 kV metering, fiber line relaying, and a SCADA RTU upgrades to interconnect the AC1-166 generation. Dayton will install a single 69 kV line from the new 69 kV generator bay to a developer owned dead-end structure immediately outside of the Atlanta Substation fence (POI). The 69 kV generator lead line constructed by the developer will be terminated onto this POI deadened structure immediately outside of the Atlanta Substation fence. See one line diagram in Attachment 1.

The PJM Network Upgrade Number for this work is **n5895**.

The total preliminary cost estimate for the substation Non-Direct Connection work for the AC1-166 project is given in the table below.

Description	Total Cost
Atlanta Substation: 69 kV Ring Bus Expansion to accommodate additional Circuit Breaker Bay including metering, protection and control, and SCADA RTU upgrades.	$ 630,000
Metering, P&C, RTU Upgrades	$ 200,000
Total Non-Direct Connection Facility Costs	**$ 830,000**

The costs given above exclude any applicable state or federal taxes. If at a future date Federal CIAC (contribution in aid of construction) taxes are deemed necessary by the IRS for this project, Dayton Power and Light Company shall be reimbursed by the Interconnection Customer for such taxes.

Schedule

Overall elapsed time to complete both the required Network Upgrades (AEP and Dayton work) and Non-Direct Connection work (Dayton work only) is approximately **24 months**.

Based on the extent of the Dayton primary Non-Direct Connection upgrades required to support the AC1-166 generation project, it is expected to take a minimum of 24 months from the date of a fully executed Interconnection Construction Service Agreement to complete the installation subject to market conditions, vendor lead times, and any power siting requirements. This work can be done concurrently with the Network Upgrades required. This includes the requirement for the Interconnection Customer to make a preliminary payment to Dayton which funds construction of the Non-Direct Connection facilities and Network Upgrades. It assumes that there will be no environmental or permitting issues to implement the Non-Direct Connection and Network Upgrades for this project and that all system outages will be allowed when requested.

Interconnection Customer Requirements

Requirement from the PJM Open Access Transmission Tariff:

1. 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.

2. The Interconnection Customer may be required to install and/or pay for metering as necessary to properly track real time output of the facility as well as installing metering which shall be used for billing purposes. See Section 8 of Appendix 2 to the Interconnection Service Agreement as well as Section 4 of PJM Manual 14D for additional information.

Dayton Interconnection Requirements

The Dayton Power and Light Company (DP&L) has prepared this Facilities Connection Requirements document to ensure compliance with North American Electric Reliability Council (NERC) Reliability Standards and applicable Regional Reliability Organization, sub regional, Power Pool, and individual Transmission Owner planning criteria and facility connection requirements in compliance to NERC Standard FAC-001-2. These connection requirements apply to all generation facilities, transmission facilities, and end-users connecting to the DP&L transmission system. Detailed information outlining DP&L interconnection requirements can be reviewed utilizing the following link:

http://www.pjm.com/~/media/planning/plan-standards/private-dayton/dayton-facilities-connection-requirements.ashx

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.

Dayton Requirements

The Interconnection Customer will be required to comply with all Dayton Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the Dayton Power & Light Co. "Requirements for the Connection of Facilities to the Dayton Power & Light Co. Transmission System" document located at the following link:

http://www.pjm.com/~/media/planning/plan-standards/private-dayton/dayton-facilities-connection-requirements.ashx

The metering point for this interconnection will be located at the Stuart 345kV substation as shown in **Attachment 1**.

Network Impacts

The Queue Project AC1-166 was evaluated as a 49.9 MW (Capacity 33.6 MW) injection into the Atlanta 69 kV substation in the Dayton area. Project AC1-166 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-166 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Base Case Used

Summer Peak Analysis – 2020 Case

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
764_B2_TOR9237	CONTINGENCY '764_B2_TOR9237' OPEN BRANCH FROM BUS 242938 TO BUS 253038 CKT 1 / 242938 05MARQUI 345 253038 09KILLEN 345 1 END

Generator Deliverability

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

Overload	Contingency		Affected		Bus			Power	Loading %		Rating		MW	Flowgate
Number	Type	Name	Area	Facility Description	From	To	Circuit	Flow	Initial	Final	Type	MVA	Contribution	Appendix
1	Non	Non	AEP - AEP	09ADKINS-05BEATTY 345 kV line	253110	243453	1	AC	99.84	101.34	NR	1233	18.11	1

Note: Please see Attachment 3 for projects providing impacts to flowgate violations. The values in the Reference column correspond to the proper Appendix in the Attachment.

Multiple Facility Contingency

None.

Issues were not identified in the scope of this report but in real-time operations it is possible that multiple facility outages outside of the scope of this study could cause curtailments of generation in this region.

Short Circuit

(Summary of impacted circuit breakers)

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)

Dayton's Underlying System Analysis Results

Dayton's review of their underlying system showed a thermal overload on the New Holland-Robinson 69kV line for the loss of Adkins-Beatty 345kV line, which the AC1-166 project contributes towards. The Holland-Robinson 69kV line loads to 111% with AC1-166.

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Flowgate Appendix
2	N-1	Adkins-Beatty 345 kV Line	DAY - DAY	09NHOLLN-09ROBINS 69 kV line	253181	253201	1	AC	107	111	NR		7.9	

Steady-State Voltage Requirements

None

Stability and Reactive Power Requirement for Low Voltage Ride Through

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

No mitigations required. Find the finalized AC1-166 Stability study report in **Attachment 4.**

Real-time system operating conditions outside of the stability testing criteria included in this report could occur in this region causing curtailments to maintain stability of the BES system.

Affected System Analysis & Mitigation

LGEE Impacts:

None

MISO 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.

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.

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Flowgate Appendix
3	N-1	764_B2_TOR9237	AEP - AEP	09ADKINS-05BEATTY 345 kV line	253110	243453	1	AC	101.34	103.37	NR	1372	27.58	
4	Non	Non	AEP - AEP	09ADKINS-05BEATTY 345 kV line	253110	243453	1	AC	101.27	103.46	NR	1233	26.89	

Light Load Analysis

Not applicable.

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

Adkins – Beatty 345 kV line overload:

AEP:

- The SE rating is 1523 MVA and is sufficient for the single contingencies.
- The SN rating is 1233 MVA and is not sufficient for the non-contingency condition.

The AEP upgrade is to replace a full tension takeoff structure and upgrade the conductor leaving Adkins sub. The cost for this reinforcement is $400K and it will take approximately nine (9) months to complete. The new line rating will be 1339/1556 MVA SN/SE after this reinforcement. PJM Network Upgrade N5933.

AC1-166 is the first to cause the need for this reinforcement. Per PJM cost allocation rules, since the upgrade cost is less than $5M, the cost responsibility remains within the AC1 queue and the AC1-166 project will have cost allocation as it contributes to the loading on the Adkins-Beatty 345 kV line. See cost allocation below:

Violation #	Overloaded Facility	Upgrade Description	Network Upgrade Number	Total Upgrade Cost	AC1-068 Allocation	AC1-069 Allocation	AC1-085 Allocation	AC1-165 Allocation	AC1-166 Allocation
1	Adkins-Beatty 345 kV Line	(AEP): Replace a full takeoff structure and upgrade the conductor leaving Adkins substation. SN/SE ratings of Adkins-Beatty 345 kV line after reinforcement are 1339 MVA/1556 MVA, respectively. Estimated time to Complete: Nine (9) months	**N5933**	**$400,000**	**$83,945**	**$83,945**	**$66,055**	**$83,028**	**$83,028**
			Total New Network Upgrades		**$83,945**	**$83,945**	**$66,055**	**$83,028**	**$83,028***

**The AC1-166 project is the first to cause the need for this n5933 network upgrade. The AC1-166 project requires this reinforcement to be completed in order to be in-service and will be charged full Security initially in the ISA. As other projects move forward, this project will be reimbursed according to the PJM Cost Allocation rules.*

Contribution to Previously Identified System Reinforcements

New Holland-Robinson 69 kV Line Overload:

Dayton:

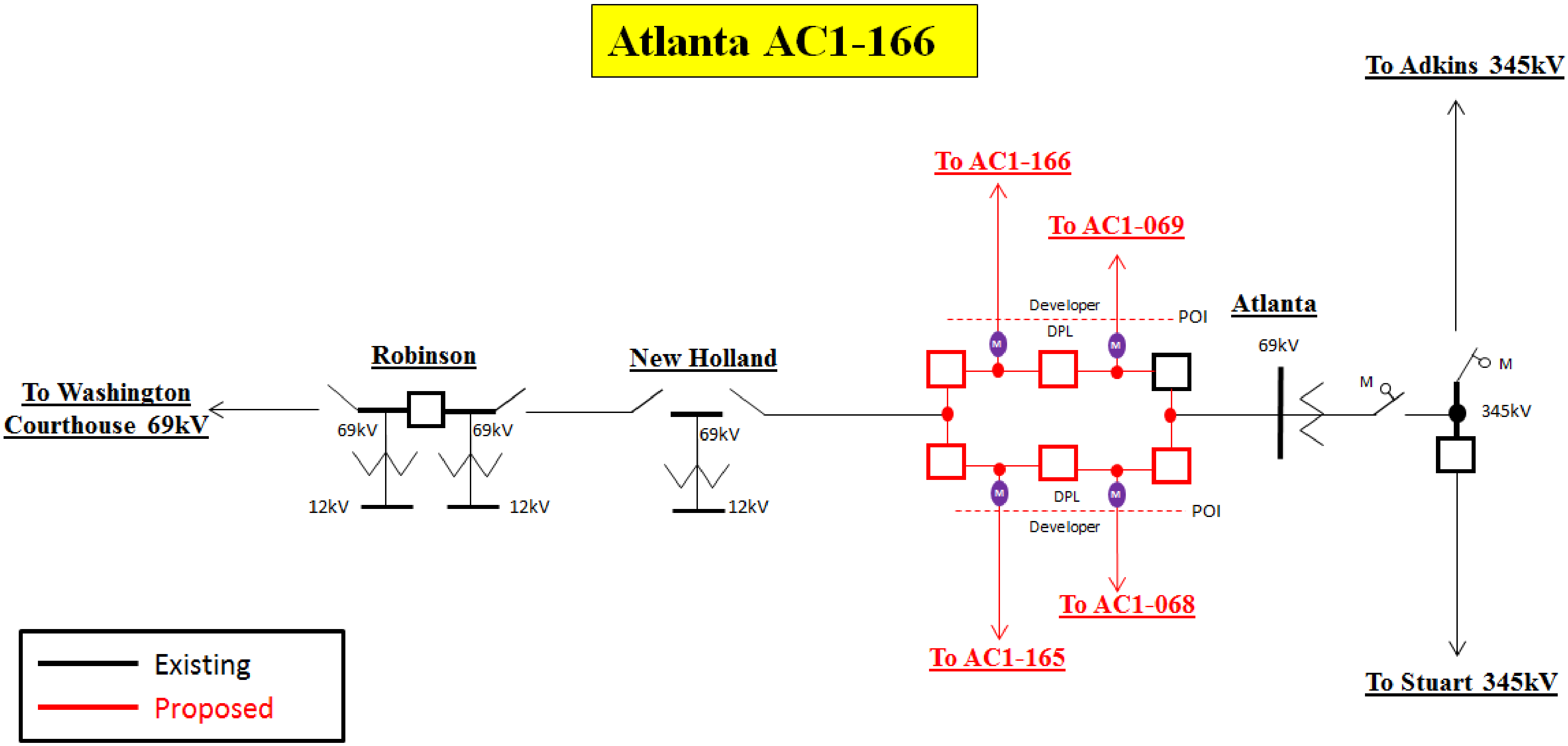
Dayton's review of their underlying system showed a thermal overload on the New Holland-Robinson 69kV line for the loss of Adkins-Beatty 345kV line as a result of the AC1 projects. This overload was identified in the feasibility study as well. The scope of work required to mitigate this overload entails replacing the 1200A wave trap on the New Holland 69 kV terminal at Robinson Substation with a new 2000A wave trap. It will take approximately 20 weeks to engineer, procure, and construct the upgrade. The cost of the upgrade is approximately $55,266. After the project is complete, the SN rating will be 221MVA and the SE rating will be 239MVA on the New Holland-Robinson 69kV line. PJM Network Upgrade N5456.

Per PJM cost allocation rules, since the upgrade cost is less than $5M, the cost responsibility remains within the AC1 queue and the AC1-166 project will have cost allocation as it contributes to the loading on the New Holland-Robinson 69 kV line. See cost allocation below:

Violation #	Overloaded Facility	Upgrade Description	Network Upgrade Number	Total Upgrade Cost	AC1-068 Allocation	AC1-069 Allocation	AC1-165 Allocation	AC1-166 Allocation
2	New Holland-Robinson 69 kV Line	(Dayton): Replace the 1200A wave trap on the New Holland 69 kV terminal at Robinson Substation with a new 2000A wave trap. SN/SE ratings of New Holland-Robinson 69 kV line after reinforcement are 221 MVA/239 MVA. Estimated time to Complete: 20 weeks	**N5456**	**$55,266**	**$13,904**	**$13,904**	**$13,729**	**$13,729**
				Total New Network Upgrades	**$13,904**	**$13,904**	**$13,729**	**$13,729***

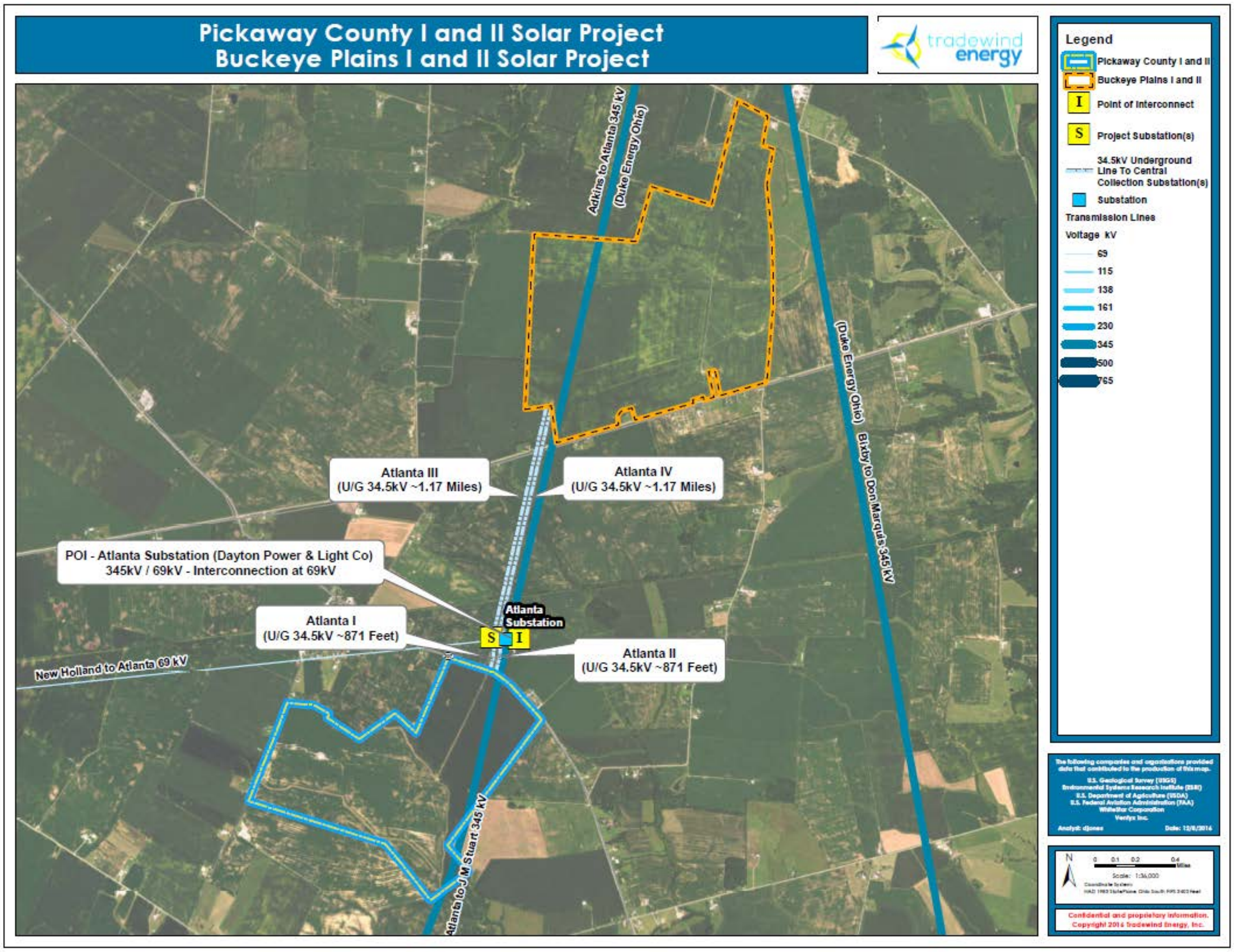
*This project contributes to an overload of the New Holland-Robins 69 kV line caused by the AC1-069 queue. Per PJM Cost Allocation Rules, this project will have cost allocation for the upgrade to alleviate the overload. That project is defined as Network Upgrade Number n5456 above.

Attachment 1- AC1-166 'Atlanta 69 kV IV': One Line Diagram



Attachment 2

Site Plan



Attachment 3

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. Although this information is not used "as is" for cost allocation purposes, it can be used to gage other generators impact.

It should be noted the generator contributions presented in the appendices sections are full contributions, whereas in the body of the report, those contributions take into consideration the commercial probability of each project.

Appendix 1 – Flowgate Details

Appendix 1

(DAY - AEP) The 09ADKINS-05BEATTY 345 kV line (from bus 253110 to bus 243453 ckt 1) loads from 99.84% to 101.34% (AC power flow) of its normal rating (1233 MVA) for non-contingency condition. This project contributes approximately 18.11 MW to the thermal violation.

Bus Number	*Bus Name*	*Full Contribution*
253110	*09ADKINS*	*67.78*
253077	*09STUART*	*55.28*
342957	*1SPURLK1G*	*4.97*
342960	*1SPURLK2G*	*9.25*
342963	*1SPURLK3G*	*4.86*
342966	*1SPURLK4G*	*4.86*
922612	*AB1-014 C*	*3.54*
923522	*AB1-169 C OP*	*135.3*
926671	*AC1-068 C*	*18.32*
926681	*AC1-069 C*	*18.32*
926841	*AC1-085 C OP*	*14.37*
927751	*AC1-165 C*	*18.11*
927761	*AC1-166 C*	*18.11*

Attachment 4

Stability Analysis Report

AC1-068/AC1-069/AC1-165/AC1-166

System Impact Study

Dynamic Simulation Analysis

TABLE OF CONTENTS

Executive Summary

Generator Interconnection Requests AC1-068, AC1-069, AC1-165 and AC1-166 are for a combined 199.92 MW Maximum Facility Output (MFO) solar generation plants. AC1-068, AC1-069, AC1-165 and AC1-166 each consists of 30 x Power Xpert Solar SMAXINV 1.67 MW inverters with a Point of Interconnection (POI) at the Atlanta 69kV substation, in the Dayton Power and Light (DPL) system, Pickaway County, Ohio.

This report describes a dynamic simulation analysis of AC1-068, AC1-069, AC1-165 and AC1-166 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 Summer peak case, modified to include applicable queue projects. AC1-068, AC1-069, AC1-165 and AC1-166 have been dispatched online at maximum power output.

AC1-068, AC1-069, AC1-165 and AC1-166 were tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 134 contingencies were studied, each with a 20 second simulation time period, with the exception of three phase faults with high speed reclosing (40 second). Studied faults included:

a) Steady state operation (20 second);
b) Three phase faults with normal clearing time on the intact network and during a scheduled outage of transmission or generation element;
c) Single phase faults with stuck breaker;
d) Single phase bus faults with normal clearing time;
e) Single phase faults with loss of multi-circuit tower line;
f) Three phase faults with speed reclosing (HSR).

Four high speed reclosing (HSR) contingencies (with less than 1 s reclosing time in the first attempt) were identified. Only unsuccessful high speed reclosing into a fault was considered.

There are no delayed (Zone 2) clearing faults since dual primary relays are employed in the DAY Transmission System.

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.

AB1-169 units trip due to rotor angle deviation for maintenance outage contingencies MA.3N.08, MA.3N.09, MB.3N.06, ME.3N.06, MG.3N.06 and ME.3N.09. AB1-169, Stuart and Killen units will be curtailed during these maintenance outage conditions.

Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units trip due to rotor angle deviation for maintenance outage contingencies MH.3N.01. Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units will be curtailed during these maintenance outage conditions.

1. Introduction

Generator Interconnection Requests AC1-068, AC1-069, AC1-165 and AC1-166 are for a combined 199.92 MW Maximum Facility Output (MFO) solar generation plants. AC1-068, AC1-069, AC1-165 and AC1-166 each consists of 30 x Power Xpert Solar SMAXINV 1.67 MW inverters with a Point of Interconnection (POI) at the Atlanta 69kV substation, in the Dayton Power and Light (DPL) system, Pickaway County, Ohio.

This analysis is effectively a screening study to determine whether the addition of AC1-068, AC1-069, AC1-165, AC1-166 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the projects AC1-068, AC1-069, AC1-165 and AC1-166 projects and how they are proposed to be connected to the grid are first described, followed by a description of how the projects are modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of Project

Generator Interconnection Requests AC1-068, AC1-069, AC1-165 and AC1-166 are for a combined 199.92 MW Maximum Facility Output (MFO) solar generation plants. AC1-068, AC1-069, AC1-165 and AC1-166 each consists of 30 x Power Xpert Solar SMAXINV 1.67 MW inverters with a Point of Interconnection (POI) at the Atlanta 69kV substation, in the Dayton Power and Light (DPL) system, Pickaway County, Ohio.

Figure 1 shows the simplified one-line diagram of the AC1-068, AC1-069, AC1-165 and AC1-166 loadflow models. Tables 1, 2, 3 and 4 list the parameters given in the impact study data and the corresponding parameters of the AC1-068, AC1-069, AC1-165 and AC1-166 loadflow models respectively.

The dynamic models for the AC1-068, AC1-069, AC1-165 and AC1-166 plant are based on the Eaton Power Xpert Solar user defined models supplied by PJM, as indicated by the developer in the System Impact Study Datasheet.

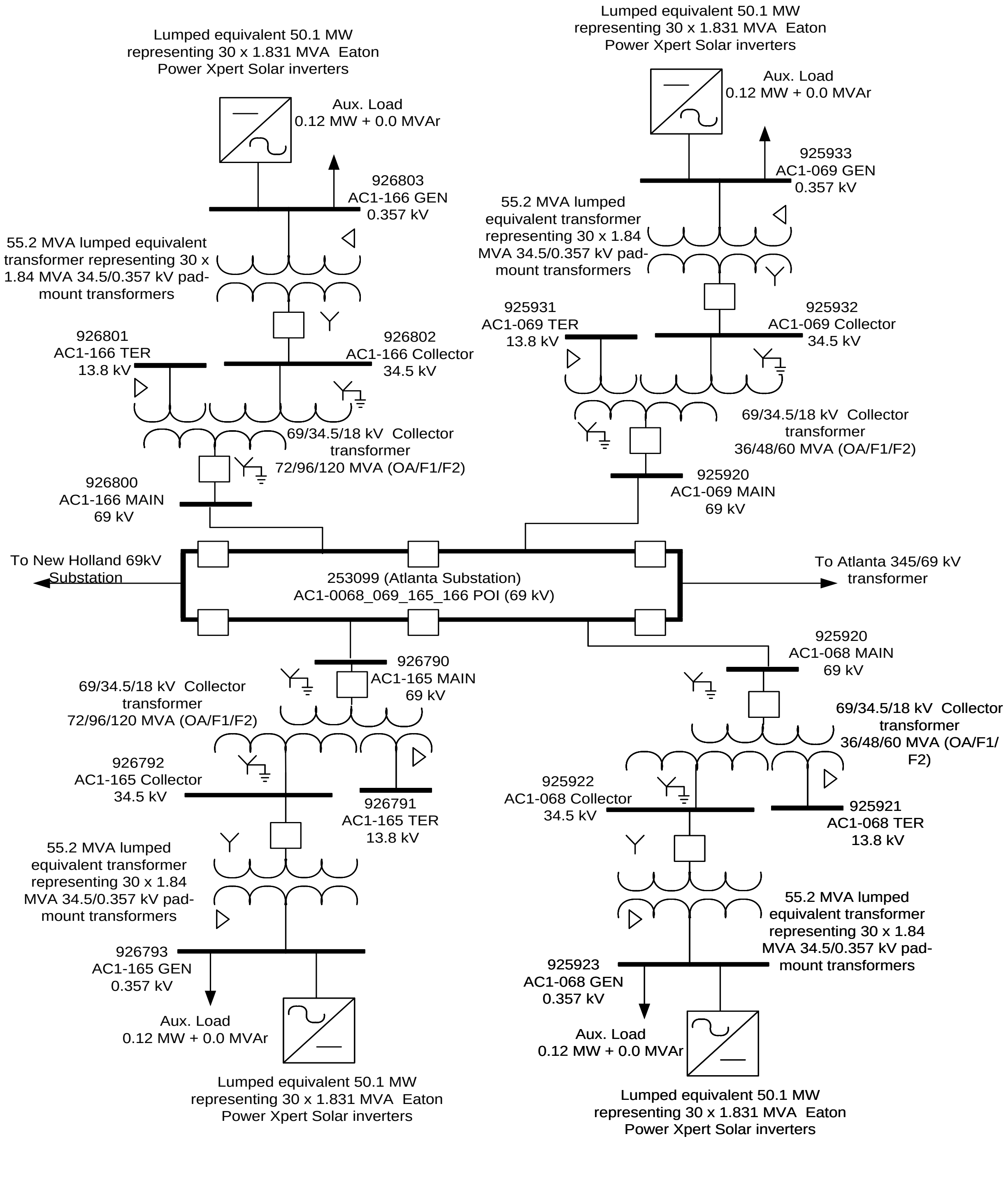


Figure 1: Plant Model

Table 1: AC1-068 Plant Model

	Impact Study Data	Model
Solar inverters	30 x 1.67 MW Power Electronics Solar inverters MVA base = 1.831 MVA Vt = 0.357 kV Unsaturated sub-transient reactance = N/A	Lumped equivalent representing 30 x 1.67 MW Power Electronics Solar inverters Pgen 50.1 MW Pmax 50.1 MW Pmin 0 MW Qgen 12.8607MVAr Qmax 22.77 MVAr Qmin -22.77 MVAr Mbase 54.93 MVA Zsource j999 pu @ Mbase
Solar inverter GSU transformers	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + J0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + J0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %

Collector step-up transformer	1 x 69/34.5/13.8 kV three winding transformer Rating = 36/48/60 MVA (OA/F1/F2) Transformer base = 36 MVA Impedances: High to low = 0.00293 + j0.07995 pu High to tertiary = 0.0028 + j0.0756 pu Low to tertiary = 0.014 + j0.0.0375 pu All impedances @ MVA base Number of taps = 5 Tap step size = NA	1 x 69/34.5/13.8 kV three winding transformer Rating = 36/48/60 MVA (OA/F1/F2) Transformer base = 36 MVA Impedances: High to low = 0.00293 + j0.07995 pu High to tertiary = 0.0028 + j0.0756 pu Low to tertiary = 0.014 + j0.0.0375 pu All impedances @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	0.0 MW + 0.0 MVAr	0.12 MW + 0.0 MVAr at low voltage side of GSU
Station load	0.0 MW + 0.0 MVAr	Not modeled
Transmission line	0.002167 MW + 0.007 MVAr charging Susceptance: j 0.0 all impedances @ 100 MVA base	0.002167 MW + 0.007 MVAr charging Susceptance: j 0.0 all impedances @ 100 MVA base

Table 2: AC1-069 Plant Model

	Impact Study Data	Model
Solar inverters	30 x 1.67 MW Power Electronics Solar inverters MVA base = 1.831 MVA Vt = 0.357 kV Unsaturated sub-transient reactance = N/A	Lumped equivalent representing 30 x 1.67 MW Power Electronics Solar inverters Pgen 50.1 MW Pmax 50.1 MW Pmin 0 MW Qgen 12.8607MVAr Qmax 22.77 MVAr Qmin -22.77 MVAr Mbase 54.93 MVA Zsource j999 pu @ Mbase
Solar inverter GSU transformers	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + J0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + J0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %

Collector step-up transformer	1 x 69/34.5/13.8 kV three winding transformer Rating = 36/48/60 MVA (OA/F1/F2) Transformer base = 36 MVA Impedances: High to low = 0.00293 + j0.07995 pu High to tertiary = 0.0028 + j0.0756 pu Low to tertiary = 0.014 + j0.0.0375 pu All impedances @ MVA base Number of taps = 5 Tap step size = NA	1 x 69/34.5/13.8 kV three winding transformer Rating = 36/48/60 MVA (OA/F1/F2) Transformer base = 36 MVA Impedances: High to low = 0.00293 + j0.07995 pu High to tertiary = 0.0028 + j0.0756 pu Low to tertiary = 0.014 + j0.0.0375 pu All impedances @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	0.0 MW + 0.0 MVAr	0.12 MW + 0.0 MVAr at low voltage side of GSU
Station load	0.0 MW + 0.0 MVAr	Not modeled
Transmission line	0.002167 MW + 0.007 MVAr charging Susceptance: j 0.0 all impedances @ 100 MVA base	0.002167 MW + 0.007 MVAr charging Susceptance: j 0.0 all impedances @ 100 MVA base

Table 3: AC1-165 Plant Model

	Impact Study Data	**Model**
Solar inverters	30 x 1.67 MW Power Electronics Solar inverters MVA base = 1.831 MVA Vt = 0.357 kV Unsaturated sub-transient reactance = N/A	Lumped equivalent representing 30 x 1.67 MW Power Electronics Solar inverters Pgen 50.1 MW Pmax 50.1 MW Pmin 0 MW Qgen 12.8607MVAr Qmax 22.77 MVAr Qmin -22.77 MVAr Mbase 54.93 MVA Zsource j999 pu @ Mbase
Solar inverter GSU transformers	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + j0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + j0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %

Collector step-up transformer	1 x 69/34.5/13.8 kV three winding transformer Rating = 72/96/120 MVA (OA/F1/F2) Transformer base = 72 MVA Impedances: High to low = 0.00235 + j0.07997 pu High to tertiary = 0.00223 + j0.07607 pu Low to tertiary = 0.00171 + j0.05817 pu All impedances @ MVA base Number of taps = 5 Tap step size = NA	1 x 69/34.5/13.8 kV three winding transformer Rating = 72/96/120 MVA (OA/F1/F2) Transformer base = 72 MVA Impedances: High to low = 0.00235 + j0.07997 pu High to tertiary = 0.00223 + j0.07607 pu Low to tertiary = 0.00171 + j0.05817 pu All impedances @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	0.0 MW + 0.0 MVAr	0.12 MW + 0.0 MVAr at low voltage side of GSU
Station load	0.0 MW + 0.0 MVAr	Not modeled
Transmission line	0.003417 MW + 0.01858 MVAr charging Susceptance: 0.0 j all impedances @ 100 MVA base	0.003417 MW + 0.01858 MVAr charging Susceptance: 0.0 j all impedances @ 100 MVA base

Table 4: AC1-166 Plant Model

	Impact Study Data	Model
Solar inverters	30 x 1.67 MW Power Electronics Solar inverters MVA base = 1.831 MVA Vt = 0.357 kV Unsaturated sub-transient reactance = N/A	Lumped equivalent representing 30 x 1.67 MW Power Electronics Solar inverters Pgen 50.1 MW Pmax 50.1 MW Pmin 0 MW Qgen 12.8607MVAr Qmax 22.77 MVAr Qmin -22.77 MVAr Mbase 54.93 MVA Zsource j999 pu @ Mbase
Solar inverter GSU transformers	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + j0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %	30 x 34.5/0.357 kV two winding transformers Rating = 55.2 MVA Transformer base = 55.2 MVA Impedance = 0.00572 + j0.0572 pu @ MVA base Number of taps = 5 Tap step size = 2.5 %

Collector step-up transformer	1 x 69/34.5/13.8 kV three winding transformer Rating = 72/96/120 MVA (OA/F1/F2) Transformer base = 72 MVA Impedances: High to low = 0.00235 + j0.07997 pu High to tertiary = 0.00223 + j0.07607 pu Low to tertiary = 0.00171 + j0.05817 pu All impedances @ MVA base Number of taps = 5 Tap step size = NA	1 x 69/34.5/13.8 kV three winding transformer Rating = 72/96/120 MVA (OA/F1/F2) Transformer base = 72 MVA Impedances: High to low = 0.00235 + j0.07997 pu High to tertiary = 0.00223 + j0.07607 pu Low to tertiary = 0.00171 + j0.05817 pu All impedances @ MVA base Number of taps = 5 Tap step size = 2.5%
Auxiliary load	0.0 MW + 0.0 MVAr	0.12 MW + 0.0 MVAr at low voltage side of GSU
Station load	0.0 MW + 0.0 MVAr	Not modeled
Transmission line	0.003417 MW + 0.01858 MVAr charging Susceptance: 0.0 j all impedances @ 100 MVA base	0.003417 MW + 0.01858 MVAr charging Susceptance: 0.0 j all impedances @ 100 MVA base

3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.

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

The selected load flow scenario is the RTEP 2020 Summer Peak case with the following modifications:

a) Addition of all applicable queue projects prior to AC1-068, AC1-069, AC1-165 and AC1-166 projects
b) Addition of AC1-068, AC1-069, AC1-165 and AC1-166 queue projects
c) Removal of withdrawn and subsequent queue projects in the vicinity of AC1-068, AC1-069, AC1-165 and AC1-166 projects
d) Dispatch of units in the PJM system to maintain slack generators within limits.

The AC1-068, AC1-069, AC1-165 and AC1-166 initial conditions are listed in Table 2, indicating maximum power output.

Table 5: AC1-068, AC1-069, AC1-165 and AC1-166 machine initial conditions

Bus	Name	Unit	PGEN	QGEN	ETERM	POI Voltage
925923	AC1-068 GEN	1	50.1 MW	2.81 MVAr	1.0 pu	1.01 pu
925933	AC1-069 GEN	1	50.1 MW	2.81 MVAr	1.0 pu	1.01 pu
926793	AC1-165 GEN	1	50.1 MW	1.74 MVAr	1.0 pu	1.01 pu
926803	AC1-166 GEN	1	50.1 MW	1.74 MVAr	1.0 pu	1.01 pu

[2] Manual 14B: PJM Region Transmission Planning Process, Rev 33, May 5 2016, Attachment G : PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AC1-068, AC1-069, AC1-165 and AC1-166 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AC1-068, AC1-069, AC1-165 and AC1-166 is given in Attachment 5.

4. Fault Cases

Tables 5 to 15 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 20 second simulation time interval, with the exception of three phase faults with high speed reclosing (40 second).

The studied contingencies include:

a) Steady state operation (20 second);

b) Three phase faults with normal clearing time on the intact network and during a scheduled outage of transmission or generation element;

c) Single phase faults with stuck breaker;

d) Single phase bus faults with normal clearing time;

e) Single-phase faults with loss of multi-circuit tower line;

f) Three phase faults with speed reclosing (HSR).

Four high speed reclosing (HSR) contingencies (with less than 1 s reclosing time in the first attempt) were identified. Only unsuccessful high speed reclosing into a fault was considered.

There are no delayed (Zone 2) clearing faults since dual primary relays are employed in the DAY Transmission System.

The contingencies listed above were applied to:

- Stuart 345 kV
- Spurlock 345 kV
- Stuart 138 kV
- Killen 345 kV
- Clinton 345 kV
- Hillcrest 345 kV
- Atlanta 345 kV

The three phase faults with normal clearing time were performed under network intact conditions.

The three phase faults with normal clearing time were performed for the following maintenance outage scenarios:

1. N-1: Loss of Stuart-Spurlock 345kV followed by a Fault at:
    a. Stuart-Hillcrest 345kV circuit
    b. Stuart-AC1-085 345kV circuit
    c. Stuart-Atlanta 345kV circuit
    d. Stuart-Killen 345kV circuit
    e. Stuart 345/138kV transformer

2. N-1 Loss of Stuart-Hillcrest 345kV followed by a Fault at:
    a. Stuart-Spurlock 345kV circuit
    b. Stuart-Clinton 345kV circuit
    c. Stuart-Atlanta 345kV circuit
    d. Stuart-Killen 345kV circuit
    e. Stuart 345/138kV transformer
    f. Foster-Hillcrest 345kV circuit
    g. Hillcrest 345/138 kV transformer
3. N-1 Loss of Stuart-AC1-085 345kV followed by a Fault at:
    a. Stuart-Spurlock 345kV circuit
    b. Stuart-Hillcrest 345kV circuit
    c. Stuart-Atlanta 345kV circuit
    d. Stuart-Killen 345kV circuit
    e. Stuart 345/138kV transformer
4. N-1 Loss of Stuart-Atlanta 345kV followed by a Fault at:
    a. Stuart-Spurlock 345kV circuit
    b. Stuart-Hillcrest 345kV circuit
    c. Stuart-AC1-085 345kV circuit
    d. Stuart-Killen 345kV circuit
    e. Stuart 345/138kV transformer
5. N-1 Loss of Stuart-Killen 345kV followed by a Fault at:
    a. Stuart-Spurlock 345kV circuit
    b. Stuart-Hillcrest 345kV circuit

c. Stuart-AC1-085 345kV circuit
d. Stuart-Atlanta 345kV circuit
e. Stuart 345/138kV transformer

6. N-1 Loss of Stuart 345/138kV followed by a Fault at:
    a. Stuart-Spurlock 345kV circuit
    b. Stuart-Hillcrest 345kV circuit
    c. Stuart-AC1-085 345kV circuit
    d. Stuart-Atlanta 345kV circuit
    e. Stuart –Killen 345kV circuit

7. N-1 Loss of Killen-Marquis 345kV followed by a Fault at:
    a. Stuart-Spurlock 345kV circuit
    b. Stuart-Hillcrest 345kV circuit
    c. Stuart-AC1-085 345kV circuit
    d. Stuart-Atlanta 345kV circuit
    e. Stuart 345/138kV transformer

Clearing times listed in Tables 4 to 15 are as per Revision 18 of "*2016 Revised Clearing times for each PJM company*" spreadsheet.

Attachment 2 contains the one-line diagrams of the DAY and East Kentucky Power Cooperative networks in the vicinity of AC1-068, AC1-069, AC1-165 and AC1-166, showing where faults were applied.

The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case, modified to ensure that connected generators in the vicinity of AC1-068, AC1-069, AC1-165 and AC1-166 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

All baseline and supplemental upgrades in DAY were included except capacitor banks.

5. Evaluation Criteria

This study is focused on AC1-068, AC1-069, AC1-165 and AC1-166 along with the rest of the PJM system, maintaining synchronism and having all states return to an acceptable new condition following the disturbance. The recovery criteria applicable to this study are as per PJM's Regional Transmission Planning Process and Transmission Owner criteria:

a) AC1-068, AC1-069, AC1-165 and AC1-166 are able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AC1-068, AC1-069, AC1-165 and AC1-166 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 3%.

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.

AB1-169 units trip due to rotor angle deviation for maintenance outage contingencies MA.3N.08, MA.3N.09, MB.3N.06, ME.3N.06, MG.3N.06 and ME.3N.09. AB1-169, Stuart and Killen units will be curtailed during these maintenance outage conditions.

Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units trip due to rotor angle deviation for maintenance outage contingencies MH.3N.01. Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units will be curtailed during these maintenance outage conditions.

6. Summary of Results

AB1-169 units trip due to rotor angle deviation for maintenance outage contingencies MA.3N.08, MA.3N.09, MB.3N.06, ME.3N.06, MG.3N.06 and ME.3N.09. AB1-169, Stuart and Killen units will be curtailed during these maintenance outage conditions.

Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units trip due to rotor angle deviation for maintenance outage contingencies MH.3N.01. Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units will be curtailed during these maintenance outage conditions.

Real-time system operating conditions outside of the stability testing criteria included in this report could occur in this region causing curtailments to maintain stability of the BES system.

7. Mitigations

No Mitigations required.

Table 3: Steady State Operation

Fault ID	Duration	Result No Mitigation
SS.01	Steady state 20 sec	Stable

Table 4: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
3N.01	Fault at Atlanta (AC1-068 POI) - AC1-068 69 kV line (Trips AC1-068)	8	Stable
3N.02	Fault at Atlanta (AC1-069 POI) - AC1-069 69 kV line (Trips AC1-069)	8	Stable
3N.03	Fault at Atlanta (AC1-165 POI) - AC1-165 69 kV line (Trips AC1-165)	8	Stable
3N.04	Fault at Atlanta (AC1-166 POI) - AC1-166 69 kV line (Trips AC1-166)	8	Stable
3N.05	Fault at Atlanta – New Holland – Robinson 69 kV line	8	Stable
3N.06	Fault at Robinson – Washington 69 kV line	8	Stable
3N.07	Fault at Washington – Sabina – Airpark 69 kV line	6	Stable
3N.08	Fault at Washington – Texas Tap 69 kV line	6	Stable
3N.09	Fault at Washington – Greenfield 69 kV line	6	Stable
3N.10	Fault at Atlanta 345/69 kV transformer (trips Atlanta – Adkins 345 kV circuit 34551)	6	Stable
3N.11	Fault at Atlanta - Stuart 345 kV circuit 34552.	6	Stable
3N.12	Fault at Atlanta - Adkins circuit 345 kV 34551 (Trips Atlanta 345/69 kV Transformer).	6	Stable
3N.13	Fault at Stuart - AB1-169 345 kV circuit (Trips AB1-169).	6	Stable
3N.14	Fault at Stuart - Stuart Unit 4 345 kV circuit (Trips Stuart Unit 4).	6	Stable
3N.15	Fault at Stuart - Stuart Unit 1 345 kV circuit (Trips Stuart Unit 1).	6	Stable
3N.16	Fault at Stuart - Stuart Unit 2 345 kV circuit (Trips Stuart Unit 2).	6	Stable
3N.17	Fault at Stuart - Stuart Unit 3 345 kV circuit (Trips Stuart Unit 3).	6	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
3N.18	Fault at Stuart - Spurlock circuit 345 kV 34553.	5**	Stable
3N.19	Fault at Stuart - Stuart 345/138 kV Transformer 7.	6	Stable
3N.20	Fault at Stuart - Killen circuit 345 kV 34510.	5**	Stable
3N.21	Fault at Stuart – AC1-085 circuit 345 kV 34509.	6	Stable
3N.22	Fault at Stuart - Hillcrest circuit 345 kV 34511.	5**	Stable
3N.23	Fault at Stuart - Atlanta circuit 345 kV 34552.	5**	Stable
3N.24	Fault at Adkins – Beatty 345 kV line 34542	6	Stable
3N.25	Fault at Adkins – Adkins POI (Trips Adkins units)	6	Stable
3N.26	Fault at AC1-085 – Clinton circuit 345 kV 34509.	6	Stable
3N.27	Fault at Clinton – Greene 345 kV line 34522	6	Stable
3N.28	Fault at Greene – South Charleston 345 kV line 34506	6	Stable
3N.29	Fault at South Charleston – Beatty 345 kV line 34506	6	Stable
3N.30	Fault at Adkins – Adkins Unit 1 345 kV circuit (Trips Adkins Unit 1).	6	Stable
3N.31	Fault at Adkins – Adkins Unit 2 345 kV circuit (Trips Adkins Unit 2).	6	Stable
3N.32	Fault at Adkins – Adkins Unit 3 345 kV circuit (Trips Adkins Unit 3).	6	Stable
3N.33	Fault at Adkins – Adkins Unit 4 345 kV circuit (Trips Adkins Unit 4).	6	Stable
3N.34	Fault at Adkins – Adkins Unit 5 345 kV circuit (Trips Adkins Unit 5).	6	Stable
3N.35	Fault at Adkins – Adkins Unit 6 345 kV circuit (Trips Adkins Unit 6).	6	Stable
3N.36	Fault at Killen – Don Morquis 345 kV circuit	6	Stable

** Actual clearing time provided by the TO

Table 5: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
1B.01	Fault at Atlanta – AC1-068 69 kV (Trips AC1-068). Breaker stuck at Atlanta 69 kV (POI) bus, Fault cleared with loss of AC1-165 unit (Trips AC1-165)	6 /15	Stable
1B.02	Fault at Atlanta – AC1-068 69 kV (Trips AC1-068). Breaker stuck at Atlanta 69 kV (POI) bus, Fault cleared with loss of Atlanta 345/69 kV transformer and Atlanta – Adkins 345 kV circuit 34551	6 /15	Stable
1B.03	Fault at Atlanta – AC1-166 69 kV (Trips AC1-166). Breaker stuck at Atlanta 69 kV (POI) bus, Fault cleared with loss of Atlanta – New Holland – Robinson 69 kV line	6 /15	Stable
1B.04	Fault at Atlanta – AC1-166 69 kV (Trips AC1-166). Breaker stuck at Atlanta 69 kV (POI) bus, Fault cleared with loss of AC1-069 unit (Trips AC1-069)	6 /15	Stable
1B.05	Fault at Atlanta – New Holland – Robinson 69 kV line. Breaker stuck at Robinson 69 kV bus, Fault cleared with loss of Robinson – Washington 69 kV line	6 /15	Stable
1B.06	Fault at Atlanta - Adkins circuit 345 kV 34551 (Trips Atlanta 345/69 kV Transformer). Breaker BB stuck. Fault cleared with loss of Stuart circuit 34552.	6 /18	Stable
1B.07	Fault at Atlanta - Adkins circuit 345 kV 34551 (Trips Atlanta 345/69 kV Transformer). Breaker FF at Adkins. Fault cleared with loss of Adkins – Beatty 345 kV circuit 34542.	6 /18	Stable
1B.08	Fault at Atlanta - Adkins circuit 345 kV 34551 (Trips Atlanta 345/69 kV Transformer). Breaker DD at Adkins. Fault cleared with loss of Adkins Unit (units 1 to 6).	6/18	Stable
1B.09	Fault at Atlanta 345 kV on Stuart circuit 34552. Breaker BB stuck. Fault cleared with loss of Atlanta 345/69 kV Transformer and Atlanta – Adkins circuit 34551	6/18	Stable
1B.10	Fault at Stuart 345 kV on AB1-169 circuit (Trips AB1-169). Breaker stuck to Stuart 345 kV bus 1. Fault cleared with loss of Stuart 345/138 kV Transformer 7.	6 / 18	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
1B.11	Fault at Stuart 345 kV on Stuart unit 4 circuit (Trips Stuart unit 4). Breaker GG stuck. Fault cleared with loss of Spurlock circuit 34553.	5 / 12**	Stable
1B.12	Fault at Stuart 345 kV on Stuart unit 1 circuit (Trips Stuart unit 1). Breaker VV stuck. Fault cleared with loss of Killen circuit 34510.	6 / 18	Stable
1B.13	Fault at Stuart 345 kV on Stuart unit 2 circuit (Trips Stuart unit 2). Breaker SS stuck. Fault cleared with loss of Atlanta circuit 34552.	6 / 18	Stable
1B.14	Fault at Stuart 345 kV on Stuart unit 3 circuit (Trips Stuart unit 3). Breaker JJ stuck. Fault cleared with loss of Hillcrest circuit 34511.	6 / 18	Stable
1B.15	Fault at Stuart 345 kV on Spurlock circuit 34553. Breaker HH stuck. Fault cleared with loss of Stuart 345/138 kV Transformer 7.	5 / 12**	Stable
1B.16	Fault at Stuart 345 kV on Spurlock circuit 34553. Breaker GG stuck. Fault cleared with loss of Z2-029.	5 / 12**	Stable
1B.17	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7. Breaker stuck to AB1-169 circuit. Fault cleared with loss of AB1-169.	6 / 18	Stable
1B.18	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7. Breaker HH stuck. Fault cleared with loss of Spurlock circuit 34553.	5 / 12**	Stable
1B.19	Fault at Stuart 345 kV on Killen circuit 34510. Breaker VV stuck. Fault cleared with loss of Stuart Unit 1.	5 / 12**	Stable
1B.20	Fault at Stuart 345 kV on Killen circuit 34510. Breaker WW stuck. Fault cleared with loss of Stuart 345/138 kV Transformer 7.	5 / 12**	Stable
1B.21	Fault at Stuart 345 kV on Atlanta circuit 34552. Breaker SS stuck. Fault cleared with loss of Stuart Unit 2.	5 / 12**	Stable
1B.22	Fault at Stuart 345 kV on Atlanta circuit 34552. Breaker TT stuck. Fault cleared with loss of Stuart 345/138 kV Transformer 7.	5 / 12**	Stable
1B.23	Fault at Stuart 345 kV on AC1-085 circuit 34509. Breaker at NN stuck. Fault cleared with loss of Stuart 345/138 kV Transformer 7.	5 / 12**	Stable
1B.24	Fault at Stuart 345 kV on Hillcrest circuit 34511. Breaker JJ stuck. Fault cleared with loss of Stuart Unit 3.	5 / 12**	Stable

Fault ID	Fault description	Clearing Time Normal & Delayed (Cycles)	Result No Mitigation
1B.25	Fault at Stuart 345 kV on Hillcrest circuit 34511. Breaker KK stuck. Fault cleared with loss of Stuart 345/138 kV Transformer 7.	5 / 12**	Stable

** Actual clearing time provided by the TO

Table 6: Single-phase Bus Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Normal and Delayed (Cycles)	Result No Mitigation
1S.01	Fault at Brown 138 kV Bus. Fault cleared with loss of: • Brown 138/69/34.5 kV Three Winding Transformer • Brown – Eastwood circuit 5884. • Brown – Stuart circuit 13817. • Trips AA2-100 units 1-4. CONTINGENCY ‘C1 BROWN'	4	Stable

Table 7: Single-phase Faults with Loss of Multiple-Circuit Tower Line

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
1T.01	Fault at Stuart 345 kV on Hillcrest circuit 34511 resulting in tower failure. Fault cleared with loss of: • Stuart – Hillcrest circuit 34511 • Stuart – AC1-085 circuit 34509. CONTINGENCY '4511HILLCRESTSTUARTCLINTONSTUARTDPL'	6	Stable
1T.02	Fault at Stuart 345 kV on Spurlock circuit 34553 resulting in tower failure. Fault cleared with loss of: • Stuart – Spurlock circuit 34553 • Meldahl Dam IC – Zimmer circuit 34576. CONTINGENCY 'C5 4541ZIMMERSPRLCKSTUARTSPURLOCKDPLEK'	6	Stable
1T.03	Fault at Stuart 345 kV on Spurlock circuit 34553 resulting in tower failure. Fault cleared with loss of: • Stuart – Spurlock circuit 34553 • Spurlock – Meldhal Dam IC circuit 34541. CONTINGENCY 'C5 4541MELDAHLSPRLCKSTUARTSPURLOCKDPLEK'	6	Stable
1T.04	Fault at Hillcrest 345 kV on Foster circuit 34569 resulting in tower failure. Fault cleared with loss of: • Hillcrest – Foster circuit 34569 • Foster – Bath circuit 34598. CONTINGENCY 'C5 34569FOSTERHILLCREST34598FOSTERBATH'	3	Stable
1T.05	Fault at Hillcrest 345 kV on Foster circuit 34569 resulting in tower failure. Fault cleared with loss of: • Hillcrest – Foster circuit 34569 • Foster – Sugarcreek circuit 34524. CONTINGENCY 'C5 34569FOSTERHILLCREST4524FOSTRSUGRCRK'	3	Stable
1T.06	Fault at Spurlock 345 kV on North Clark circuit resulting in tower failure. Fault cleared with loss of: • Spurlock – North Clark circuit 1438 • Spurlock – Flemingsburg – Goddard 138 kV circuit 954. CONTINGENCY 'TOWER_2'	5	Stable
1T.07	Fault at Clinton 345 kV on Greene circuit 34522 resulting in tower failure. Fault cleared with loss of: • Foster – Bath circuit 34598 • Clinton – Greene circuit 34522 • Clinton 345/69 kV Transformers. CONTINGENCY '495'	6	Stable

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Result No Mitigation
1T.08	Fault at Greene 345 kV on Sugarcreek circuit 34503 resulting in tower failure. Fault cleared with loss of: • Greene – Sugarcreek circuit 34503 • Sugarcreek – Foster circuit 34524 CONTINGENCY '497'	6	Stable
1T.09	Fault at Hillcrest 345 kV on Foster circuit 34569 resulting in tower failure. Fault cleared with loss of: • Hillcrest – Foster circuit 34569 • Foster – Bath circuit 34598. • Foster – Sugarcreek circuit 34524	3	Stable
1T.10	Fault at Adkins 345 kV on Beatty circuit 34542 resulting in tower failure. Fault cleared with loss of: • Adkins – Beatty circuit 34542 • Beatty – New South Charleston circuit 34506 • Beatty 345/138 kV Transformer #3. CONTINGENCY '8123'	6	Stable
1T.11	Fault at Greene 345 kV on Bath circuit 34526 resulting in tower failure. Fault cleared with loss of: • Greene – Bath circuit 34526 • Bath – Foster circuit 34598 CONTINGENCY '494'	6	Stable
1T.12	Fault at Foster 345 kV on Bath circuit 34598 resulting in tower failure. Fault cleared with loss of: • Foster – Bath circuit 34598 • Greene – Sugarcreek circuit 34503. CONTINGENCY '493'	3	Stable
1T.13	Fault at Foster 345 kV on Bath circuit 34598 resulting in tower failure. Fault cleared with loss of: • Foster – Bath circuit 34598 • Foster – Sugarcreek circuit 34524. CONTINGENCY 'C5 4524FOSTRSUGRCRK34598FOSTERBATH'	3	Stable

Table 8: Three-phase Faults with Unsuccessful High Speed Reclosing

Fault ID	Fault description	Clearing/HSR/ Reclosing Times (Cycles)	Result No Mitigation
3R.01	Fault at Greene 345 kV on Sugarcreek circuit 34503. • Fault cleared after 6 cycles with loss of Greene – Sugarcreek circuit 34503 • High speed reclosers AA and BB close after 1.5 cycles (7.5 cycles total) • Reclose unsuccessful, fault cleared after 6 cycles (13.5 cycles total) by opening reclosers AA and BB • Reclosers AA and BB close after 300 cycles (313.5 cycles total) • Reclose unsuccessful, fault cleared after 6 cycles (319.5 cycles total) by opening reclosers AA and BB	6/1.5/300	Stable
3R.02	Fault at Greene 345 kV on New South Charleston circuit 34506. • Fault cleared after 6 cycles with loss of Greene - New South Charleston circuit 34506 • High speed reclosers DD and EE close after 1.5 cycles (7.5 cycles total) • Reclose unsuccessful, fault cleared after 6 cycles (13.5 cycles total) by opening reclosers DD and EE • Reclosers DD and EE close after 300 cycles (313.5 cycles total) • Reclose unsuccessful, fault cleared after 6 cycles (319.5 cycles total) by opening reclosers DD, EE	6/1.5/300	Stable
3R.03	Fault at Greene 345 kV on Bath circuit 34526. • Fault cleared after 6 cycles with loss of Greene - Bath circuit 34526 • High speed reclosers EE and FF close after 1.5 cycles (7.5 cycles total) • Reclose unsuccessful, fault cleared after 6 cycles (13.5 cycles total) by opening reclosers EE and FF • Reclosers EE and FF close after 300 cycles (313.5 cycles total) • Reclose unsuccessful, fault cleared after 6 cycles (319.5 cycles total) by opening reclosers EE and FF	6/1.5/300	Stable
3R.04	Fault at Atlanta 69 kV Bus on New Holland – Valero Renewable Fuels - Robinson circuit 6638. • Fault cleared after 8 cycles with loss of Atlanta – New Holland – Valero Renewable Fuels - Robinson circuit 6638. • High speed recloser 1 closes after 1.5 cycles (9.5 cycles total)	8/1.5/600,1200	Stable

Fault ID	Fault description	Clearing/HSR/ Reclosing Times (Cycles)	Result No Mitigation
	• Reclose unsuccessful, fault cleared after 8 cycles (17.5 cycles total) by opening recloser 1 • Recloser 1 closes after 600 cycles (617.5 cycles total) • Reclose unsuccessful, fault cleared after 8 cycles (625.5 cycles total) by opening recloser 1 • Recloser closes after 1200 cycles (1817.5 cycles total) • Reclose unsuccessful, fault cleared after 8 cycles (1825.5 cycles total) by opening recloser 1		

Table 9: Three-phase Faults with Normal Clearing – Prior outage of Stuart - Spurlock 345 kV circuit 34553

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MA.3N.07	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7.	6	Stable
MA.3N.08	Fault at Stuart 345 kV on Killen circuit 34510.	5**	Trips AB1-169 units due to rotor angle deviation
MA.3N.09	Fault at Stuart 345 kV on AC1-085 circuit 34509.	6	Trips AB1-169 units due to rotor angle deviation
MA.3N.10	Fault at Stuart 345 kV on Hillcrest circuit 34511.	5**	Stable
MA.3N.11	Fault at Stuart 345 kV on Atlanta circuit 34552.	5**	Stable
MA.3N.12	Fault at Atlanta 345kV bus and trip Atlanta – Atkins 345 kV	6	Stable

** Actual clearing time provided by the TO

Table 10: Three-phase Faults with Normal Clearing – Prior outage of Stuart - Hillcrest 345 kV circuit 34511

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MB.3N.06	Fault at Stuart 345 kV on Spurlock circuit 34553.	5**	Trips AB1-169 units due to rotor angle deviation
MB.3N.07	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7.	6	Stable
MB.3N.08	Fault at Stuart 345 kV on Killen circuit 34510.	5**	Stable
MB.3N.09	Fault at Stuart 345 kV on AC1-085 circuit 34509.	6	Stable
MB.3N.11	Fault at Stuart 345 kV on Atlanta circuit 34552.	5**	Stable
MB.3N.31	Fault at Hillcrest 345 kV on Hillcrest 345/138 kV Transformer.	3	Stable
MB.3N.34	Fault at Foster 345 kV on Hillcrest circuit 34569.	3	Stable
MB.3N.12	fault at Atlanta 345kV bus and trip Atlanta – Atkins 345 kV	6	Stable

** Actual clearing time provided by the TO

Table 11: Three-phase Faults with Normal Clearing – Prior outage of Stuart - AC1-085 345 kV circuit 34509

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MC.3N.06	Fault at Stuart 345 kV on Spurlock circuit 34553.	5**	Stable
MC.3N.07	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7.	6	Stable
MC.3N.08	Fault at Stuart 345 kV on Killen circuit 34510.	5**	Stable
MC.3N.10	Fault at Stuart 345 kV on Hillcrest circuit 34511.	5**	Stable
MC.3N.11	Fault at Stuart 345 kV on Atlanta circuit 34552.	5**	Stable
MC.3N.12	Fault at Atlanta 345kV bus and trip Atlanta – Atkins 345 kV	6	Stable

** Actual clearing time provided by the TO

Table 12: Three-phase Faults with Normal Clearing – Prior outage of Stuart - Atlanta 345 kV circuit 34552

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MD.3N.06	Fault at Stuart 345 kV on Spurlock circuit 34553.	5**	Stable
MD.3N.07	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7.	6	Stable
MD.3N.08	Fault at Stuart 345 kV on Killen circuit 34510.	5**	Stable
MD.3N.09	Fault at Stuart 345 kV on AC1-085 circuit 34509.	6	Stable
MD.3N.10	Fault at Stuart 345 kV on Hillcrest circuit 34511.	5**	Stable

** Actual clearing time provided by the TO

Table 13: Three-phase Faults with Normal Clearing – Prior outage of Stuart - Killen 345 kV circuit 34510

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
ME.3N.06	Fault at Stuart 345 kV on Spurlock circuit 34553.	5**	Trips AB1-169 units due to rotor angle deviation
ME.3N.07	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7.	6	Stable
ME.3N.09	Fault at Stuart 345 kV on AC1-085 circuit 34509.	6	Stable
ME.3N.10	Fault at Stuart 345 kV on Hillcrest circuit 34511.	5**	Stable
ME.3N.11	Fault at Stuart 345 kV on Atlanta circuit 34552.	5**	Stable
ME.3N.12	Fault at Atlanta 345kV bus and trip Atlanta – Atkins 345 kV	6	Stable

** Actual clearing time provided by the TO

Table 14: Three-phase Faults with Normal Clearing – Prior outage of Stuart 345/138 kV Transformer 7

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MF.3N.06	Fault at Stuart 345 kV on Spurlock circuit 34553.	5**	Stable
MF.3N.08	Fault at Stuart 345 kV on Killen circuit 34510.	5**	Stable
MF.3N.09	Fault at Stuart 345 kV on AC1-085 circuit 34509.	6	Stable
MF.3N.10	Fault at Stuart 345 kV on Hillcrest circuit 34511.	5**	Stable
MF.3N.11	Fault at Stuart 345 kV on Atlanta circuit 34552.	5**	Stable
MF.3N.12	fault at Atlanta 345kV bus and trip Atlanta – Atkins 345 kV	6	Stable

** Actual clearing time provided by the TO

Table 15: Three-phase Faults with Normal Clearing – Prior outage of Killen - Don Marquis 345 kV circuit 34549

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MG.3N.06	Fault at Stuart 345 kV on Spurlock circuit 34553.	5**	Trips Stuart, Killen and AB1-169 units due to rotor angle deviation
MG.3N.07	Fault at Stuart 345 kV on Stuart 345/138 kV Transformer 7.	6	Stable
MG.3N.09	Fault at Stuart 345 kV on AC1-085 circuit 34509.	6	Trips AB1-169 units due to rotor angle deviation

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MG.3N.10	Fault at Stuart 345 kV on Hillcrest circuit 34511.	5**	Stable
MG.3N.11	Fault at Stuart 345 kV on Atlanta circuit 34552.	5**	Stable

** Actual clearing time provided by the TO

Table 16: Three-phase Faults with Normal Clearing – Prior outage of Adkins – Beatty 345 kV circuit

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MH.3N.01	Fault at Atlanta 345kV bus and trip Atlanta – Stuart 345 kV	6	Trips Adkins, AC1-068, AC1-069, AC1-165 and AC1-166 units due to rotor angle deviation
MH.3N.02	Fault at Stuart 345kV bus and trip Stuart - AC1-085 345kV	6	Stable
MH.3N.03	Fault at Stuart 345kV bus and trip Stuart - Hillcrest 345kV	5**	Stable
MH.3N.04	Fault at Stuart 345kV bus and trip Stuart - Spurlock 345kV	5**	Stable
MH.3N.05	Fault at Stuart 345kV bus and trip Stuart - Killen 345kV	5**	Stable
MH.3N.06	Fault at AC1-085 POI and trip AC1-085-Clinton	8	Stable

** Actual clearing time provided by the TO

Table 17: Three-phase Faults with Normal Clearing – Prior outage of AC1-085 - Clinton 345 kV circuit

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
MI.3N.01	fault at Atlanta 345kV bus and trip Atlanta – Atkins 345 kV	6	Stable