Appendix D: PJM System Impact Study

Generation Interconnection
System Impact Study Report

For

PJM Generation Interconnection Request Queue
Position #Y2-050

Canton Central – Tidd 345 kV

October / 2013

Preface

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

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

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

General

Carroll County Energy LLC (CCE) proposes to install PJM Project #Y2-050, a 749 MW (710 MW capacity) natural gas fired 2x1 F class combined cycle plant. The proposed point of interconnection is located approximately 17 miles from the Canton Central station on the Canton Central-Tidd 345 kV line (see Figure 2). The location of the generating facility is in Carroll County Ohio approximately 2.5 miles from the proposed 345 kV switching station (see Figure 1).

The requested in-service date is August 31, 2017.

The objective of this Impact Study is to determine budgetary cost estimates and approximate construction timelines for identified transmission facilities required to connect the proposed generating facilities to the AEP transmission system. These reinforcements include the Attachment Facilities, Local Upgrades, and Network Upgrades required to maintain the reliability of the AEP transmission system.

Point of Interconnection

Y2-050 will interconnect with the AEP transmission system via a new three breaker ring bus switching station to be constructed between the existing AEP owned Canton Central and Tidd 345 kV Substations.

Attachment Facilities

A new in-line switching station will be located between AEP's Canton Central and Tidd 345 kV stations in Carroll County, Ohio. This new station is to consist of three (3) 345 kV circuit breakers physically configured in a breaker and one half bus arrangement initially operated as a ring-bus (see Figure 2). The interconnection station will be expandable to accommodate future projects in the area. The station will also include 345 kV metering, SCADA, and associated equipment. Protection relays in the surrounding area will need to be reset to accommodate the addition of the new station.

Carroll County Energy LLC is expected to obtain, at their cost, a station site for the AEP facilities. Carroll County Energy LLC shall obtain all necessary permits. Ownership of the in-line facilities shall be transferred from Carroll County Energy LLC to AEP upon successful completion of the work.

A 345 kV line extension is required to loop through the proposed station. For the cost estimate, the AEP switching station is assumed to be located immediately adjacent to the existing transmission lines. A supplemental line easement for the tap structures will be required. It is expected that Carroll County Energy LLC will obtain the supplemental easement when the station property is purchased.

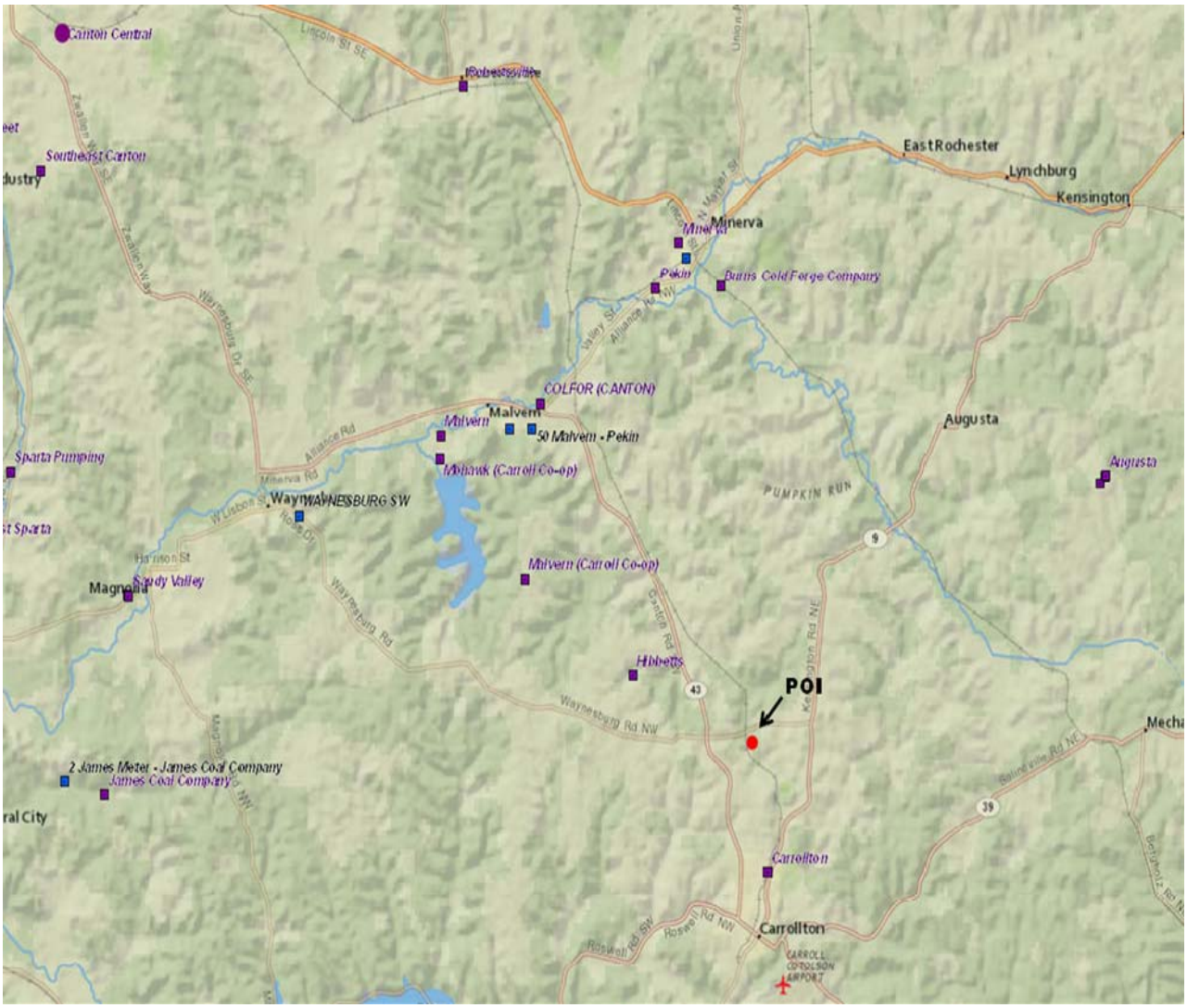

Figure 1: Y2-050 Point of Interconnection

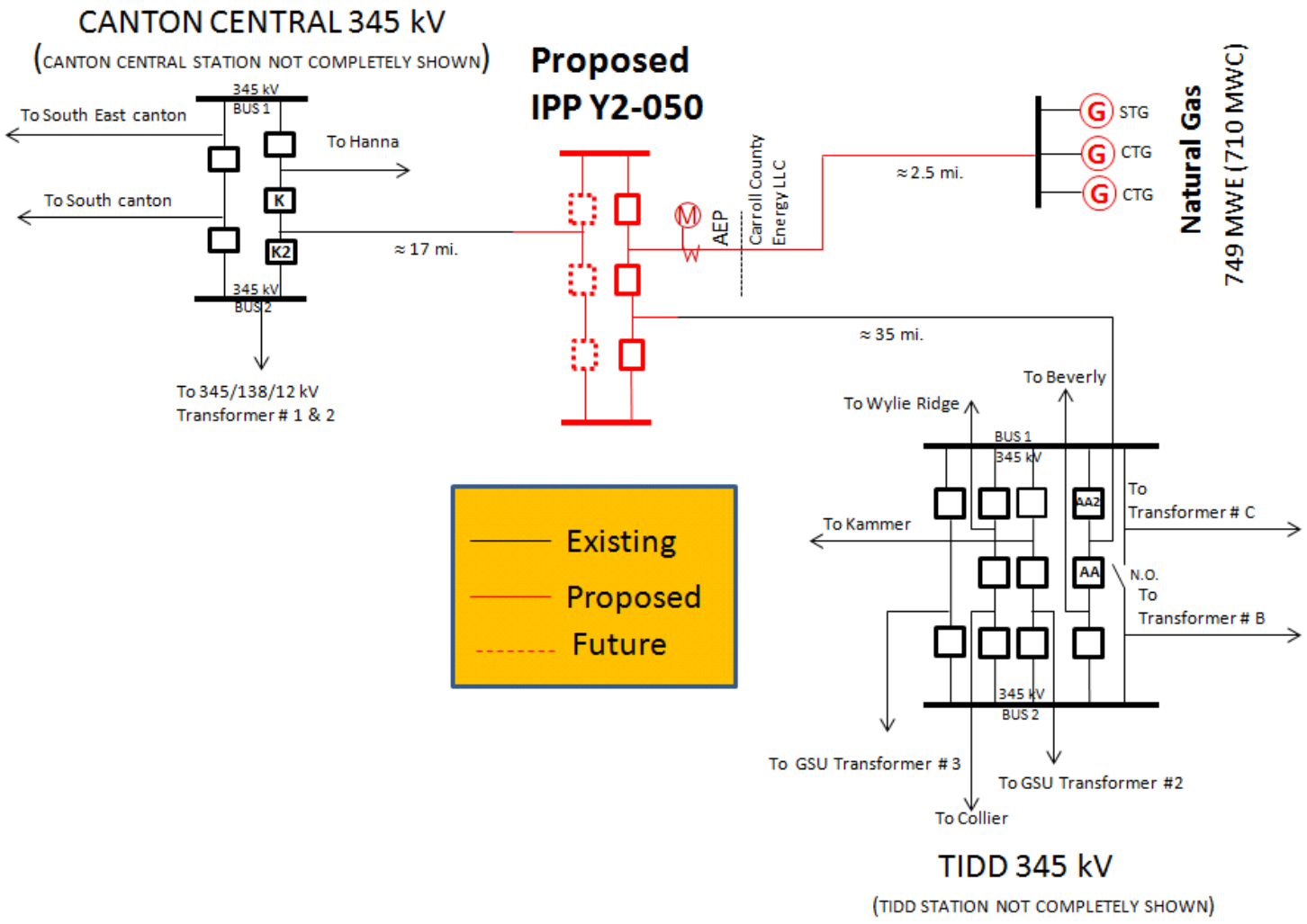

Figure 2: Point of Interconnection switching station

The following work is required to connect Project Y2-050 to the Canton Central – Tidd 345 kV line:

Station Cost:

- A new three (3) circuit breaker 345 kV switching station (see Figure 1) will need to be constructed to connect the proposed generation to AEP. SCADA, 345 kV revenue metering, and associated equipment will also need to be installed. Estimated project cost (2013 Dollars): $13,153,000. Network Upgrade Number (n3960).

Protection and Relaying Cost:

- Relays and controls for circuit breaker protection, bus differentials, and line protection will need to be installed at the new 345 kV switching station. Estimated Cost (2013 Dollars): $2,296,710. Network Upgrade Number (n3961).

- Line protection and controls at the Canton Central 345 kV Substation will need to be upgraded to coordinate with the new 345 kV switching station. Estimated Cost (2013 Dollars): $57,645. Network Upgrade Number (n3962).

- Line protection and controls at the Tidd 345 kV Substation will need to be upgraded to coordinate with the new 345 kV switching station. Estimated Cost (2013 Dollars): $57,645. Network Upgrade Number (n3963).

It is understood that Carroll County Energy LLC is responsible for all costs associated with this connection. The costs above are reimbursable to AEP. The cost of Carroll County Energy LLC's generating plant and the costs for the line connecting the generating plant to Carroll County Energy LLC's switching station are not included in this report; these are assumed to be Carroll County Energy LLC's responsibility.

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

AEP - Local and Network Impacts

The impact of the proposed generating facility on the AEP System was assessed for adherence with applicable reliability criteria. AEP planning criteria require that the transmission system meet performance parameters prescribed in the AEP FERC Form 715[1] and Connection Requirements for AEP Transmission System[2]. Therefore, these criteria were used to assess the impact of the proposed facility on the AEP System. Carroll County Energy LLC project Y2-050 was studied as a 672 MW (672 MW capacity) natural gas generating facility consistent with the interconnection application. Project #Y2-050 was evaluated for compliance with reliability criteria for summer peak conditions in 2016.

Potential network impacts were as follows:

Normal System (2016 Summer Conditions Capacity Output)

- No problems identified

Single Contingency (2016 Summer Conditions Capacity Output)

- No problems identified

Multiple Contingency (2016 Summer Conditions Capacity Output)

- No problems identified

Contribution to Previously Identified Overloads (2016 Summer Conditions Capacity Output)

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

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

- No Problems identified.

Normal System (2016 Summer Conditions Full Output)

- No problems identified

Single Contingency (2016 Summer Conditions Full Output)

- No problems identified.

Multiple Contingency (2016 Summer Conditions Full Output)

- No problems identified

Contribution to Previously Identified Overloads (2016 Summer Conditions Full Output)

- No problems identified

Short Circuit Analysis

- No problems identified.

Stability Analysis

- No problems identified.

Voltage Variations

- No problems identified.

Additional Limitations of Concern

- No known additional limitations of concern.

Local/Network Upgrades

- No problems identified.

Conclusion

Based upon the results of this Impact Study, the construction of the Carroll County Energy LLC (PJM Project #Y2-050) natural gas generation project will require additional interconnection charges.

- **Estimated Interconnection Cost (2013 Dollars): $13,153,000**
- **Estimated Protection and Relaying Cost (2013 Dollars): $2,412,000**

Total Estimated Cost for Project Y2-050 (2013 Dollars): $ 15,565,000

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.

PJM - Network Impacts

The Queue Project #Y2-050 was studied as a(n) 672.0 MW(Capacity 672.0 MW) injection into **Tidd-Canton Central 345 kV line** in the AEP area. Project #Y2-050 was evaluated for compliance with reliability criteria for summer peak conditions in 2016. Potential network impacts were as follows:

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

None

Light Load Analysis

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

No Problems Identified

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

None

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

No Problems Identified

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

None

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

To be determined

Stability and Reactive Power Requirement
(Results of the dynamic studies should be inserted here)

No Problems Identified (See Appendix 1)

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

None

Contribution to Previously Identified System Reinforcements

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

None

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.

No Problems Identified

Appendix 1 – Stability Analysis

Executive Summary

Generation Interconnection Request Y2-050 is for a 753 MW (winter rating) 2x1 combined cycle facility with a with a Point of Interconnection (POI) on the 345 kV circuit between Canton Central 345 kV Substation and Tidd 345 kV Substation in the American Electric Power (AEP) network, in Carroll County, Ohio.

Y2-050 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of Y2-050 as part of the overall system impact study.

The load flow scenario for the analysis was the RTEP 2015 summer peak load case, with the addition of the Y2-050 models at maximum power output and leading power factor.

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

a) Steady state operation
b) Three phase faults with normal clearing time
c) Three phase faults with loss of multiple-circuit tower line
d) Single phase fault at substation buses with normal clearing time
e) Single phase faults with single phase stuck breaker
f) Single phase faults with delayed clearing at remote end due to primary relaying failure

Contingencies were tested against the fault recovery criteria:

a) Y2-050 is required to ride through the faults (except for faults where protective action trips Y2-050),
b) the system with Y2-050 included is to be transiently stable,
c) a new steady state is to be reached,
d) voltages at the POI and nearby buses are to return to an acceptable range, with system stability being maintained.

No mitigations were found to be required.

1. Introduction

Generation Interconnection Request Y2-050 is for a 753 MW (winter rating) 2x1 combined cycle facility with a Point of Interconnection (POI) on the 345 kV circuit between Canton Central 345 kV Substation and Tidd 345 kV Substation in the American Electric Power (AEP) network, in Carroll County, Ohio.

As the Regional Transmission Operator, PJM Interconnection is responsible for planning the incorporation of generators into the grid. Y2-050 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process.

PJM contracted Power Systems Consultants (PSC) to carry out this dynamic simulation analysis of Y2-050 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of Y2-050 will meet the dynamics requirements of the NERC and PJM reliability standards.

In this report the Y2-050 project and how it is proposed to be connected to the grid is first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of Project

The proposed Y2-050 project is specified in the Impact Study data provided in Attachment 1. Attachment 2 shows the one line diagram of the AEP network in the vicinity of Y2-050.

The Y2-050 generation plant will consist of two combustion turbine (CT) units, each rated at 223.6 MW (winter rating), and one steam turbine (ST) unit, rated at 305.6 MW (winter rating). Each CT unit is connected to the 345 kV station bus via a 160/213/267 MVA OA/FA1/FA2 18/345 kV generator step up (GSU) transformer. The ST unit is connected to the 345 kV station bus via a 216/288/360 MVA OA/FA1/FA2 18/345 kV GSU transformer. A 0.75 mile transmission line connects the 345 kV station bus to the POI. The POI is situated 18 miles from Canton Central 345 kV substation on the Canton Central – Tidd 345 kV transmission line.

Figure 1 shows how Y2-050 has been modeled in this study. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the Y2-050 loadflow model. Attachment 3 provides a diagram of the PSS/E model in the vicinity of Y2-050; Attachment 4 gives the Y2-050 PSS/E loadflow model.

The dynamic model for the Y2-050 plant are based on standard PSS/E models, with parameters supplied by PJM. The dynamic model of the Y2-050 plant is given in Attachment 5.

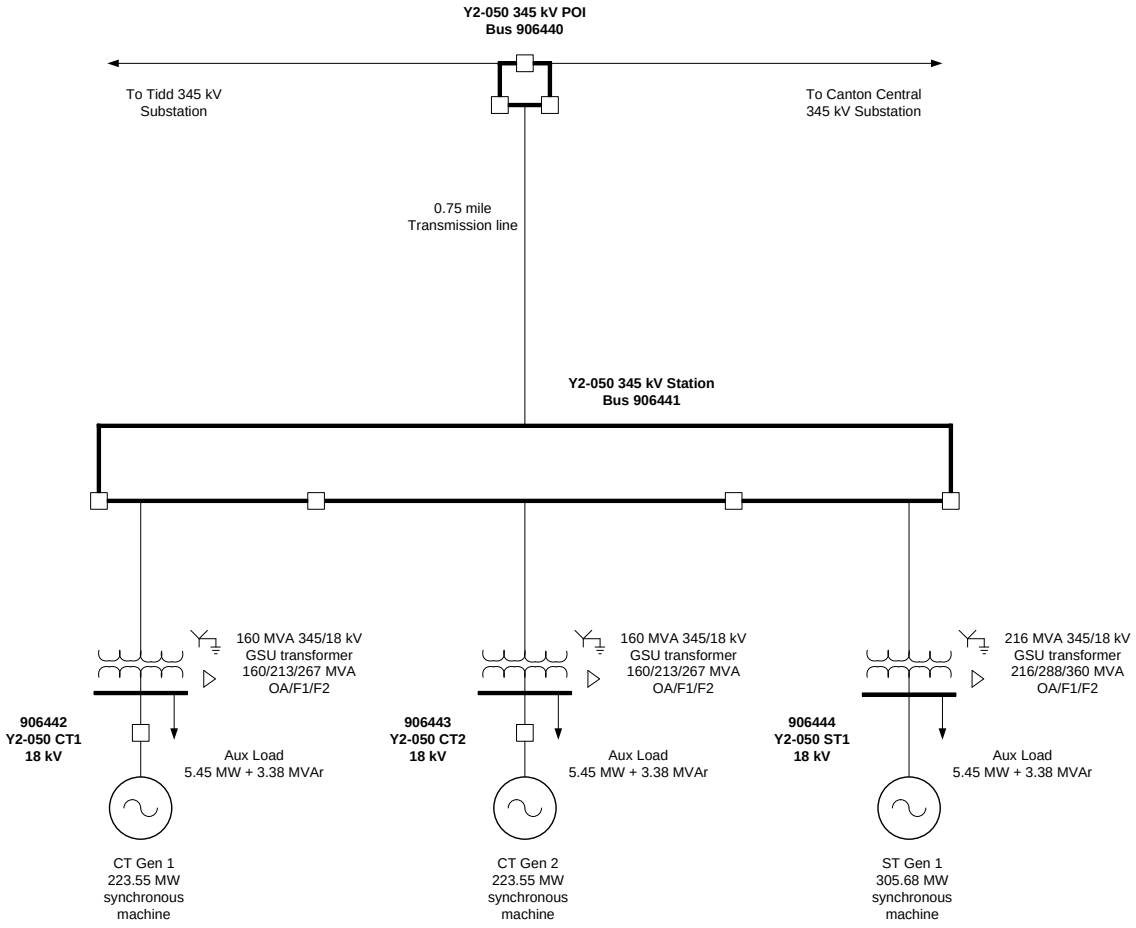

Figure 1. Connection of Y2-050 on Tidd – Canton Central 345 kV circuit

Table 1: Y2-050 Plant Model

	Impact Study Data[3]	**Model**
Gas turbines		
Generator	2 x 223.55 MW CT +146 / -86 MVAr Vt = 18 kV Per-turbine unsaturated reactances, pu @ 277 MVA: X''d(i) = 0.22 X''q(i) = 0.22	2 x 223.55 MW CT MBASE 277 MVA PMAX 223.55 MW PMIN 71.57 MW QMAX 146 MVAr QMIN -86 MVAr XSORCE 0.22 pu Dynamic data as included in Attachment 5
GSU transformers	345 / 18 kV Ynd 160/213/267 MVA (OA/FA1/FA2) 0.137 % + j 9.000 % @ 160 MVA 5 taps @ 2.5 %	345 / 18 kV Ynd 160/213/267 MVA (OA/FA1/FA2) 0.00137 + j 0.09000 pu @ 160 MVA 5 taps @ 2.5 %
Auxiliary demand	5.45 MW + 3.38 MVAr at low voltage side of GSU transformer	5.45 MW + 3.38 MVAr at 18 kV bus
Steam turbine		
Generator	1 x 305.68 MW ST +198 / -118 MVAr Vt = 18 kV Unsaturated reactance, pu @ 425 MVA: X''d(i) = 0.285	1 x 305.68 MW ST MBASE 425 MVA PMAX 305.68 MW PMIN 58.43 MW QMAX 198 MVAr QMIN -118 MVAr

[3] As was noted in Section 2, winter ratings are employed in the modeling.

	X’’q(i) = 0.280	XSORCE 0.285 pu Dynamic data as included in Attachment 5
GSU transformer	345 / 18 kV Ynd 216/288/360 MVA (OA/FA1/FA2) 0.131 + j 9.000 % @ 216 MVA 5 taps @ 2.5 %	345 / 18 kV Ynd 216/288/360 MVA (OA/FA1/FA2) 0.00131 + j 0.090 pu @ 216 MVA 5 taps @ 2.5 %
Auxiliary demand	5.45 MW + 3.38 MVAr at low voltage side of GSU transformer	5.45 MW + 3.38 MVAr at 18 kV bus
Station		
Transmission Line	0.75 mile ACSR 0.037 + j 0.573 % per mile @ 100 MVA Charging admittance 0.290 % @ 100 MVA per mile	345 kV Parameters @ 100 MVA: • R1 = 0.00028 pu • X1 = 0.00430 pu • B1 = 0.0022 pu

3. Loadflow and Dynamics Case Setup

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

The load flow scenario and fault cases for this study are based on PJM's Region Transmission Planning Process[4] and discussions with PJM.

The selected load flow scenario is the RTEP 2015 peak load case[5], provided by PJM, with the following modifications:

a) Modeling of Y2-050 with a POI 18 miles from Canton Central 345 kV substation on the Canton Central – Tidd 345 kV transmission line
b) Removal of withdrawn and subsequent queue projects in the vicinity of Y2-050
c) Connection and disconnection of some distant generation units in the PJM system in order to maintain slack units within limits
d) Removal of several distant generation units from the dynamic simulation to avoid initialization problems

In the load flow the Y2-050 generators are set to maximum power output, 0.95 pu terminal voltage, and leading power factor.

Generation within the PJM500 system (area 225 in the PSS/E case) and within a 5-bus radius of Y2-050 has been dispatched online at maximum output (PMAX) – exceptions and the reasons for them are listed in Table 2.

Table 2: Generation at reduced output within 5-bus radius of Y2-050

Bus	Name	Unit	PGEN (MW)	PMAX (MW)	Reason
242807	05SPORNA 138.00	5	35	42	Conflict with governor model, PMAX not achieveable
242807	05SPORNA 138.00	6	35	42	

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

[5] Y2-050 was intended to be evaluated on on the 2015 light load case. It was found that, although the system was transiently stable under the 2015 light load case, in most cases the post fault voltage damping was insufficient to satisfy the PJM damping criterion. Subsequent tests on two onerous contingencies with Y2-050 offline similarly did not meet the damping criterion. Evaluation of Y2-050 was therefore completed using the 2015 summer peak case instead.

242807	05SPORNA 138.00	7	35	42	
242807	05SPORNA 138.00	8	35	42	
242931	05BEVERL 345.00	1A	176	216.667	Conflict with governor model, PMAX not achieveable
242931	05BEVERL 345.00	1B	176	216.667	
242940	05MUSKNG 345.00	5	589	600	Conflict with governor model, PMAX not achieveable
242947	05WATERF 345.00	1A	185	227.5	Conflict with governor model, PMAX not achieveable
242947	05WATERF 345.00	1B	185	227.5	
242947	05WATERF 345.00	1C	151	227.5	

4. Fault Cases

This study is focused on the ability of the plant to ride through the fault. Table 3 to Table 8 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 10 second simulation time interval. Faults were applied to transmission circuits and transformers connected to the Point of Interconnection or one bus removed[6] (up to two buses removed for delayed (Zone 2) clearing faults).

The studied faults included :

a) Steady state operation
b) Three phase faults with normal clearing time
c) Three phase faults with loss of multiple-circuit tower line
d) Single phase fault at substation buses with normal clearing time
e) Single phase faults with single phase stuck breaker
f) Single phase faults with delayed clearing at remote end due to primary relaying failure

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

The positive sequence fault impedances for single line to ground faults were derived from a separate short circuit case provided by PJM, modified by PSC to ensure that connected generators in the vicinity of Y2-050 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

5. Fault Recovery Criteria

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

a) Post-contingency voltages should remain within +/- 0.05 pu of the pre-contingency voltages at transmission level buses.
b) Post-contingency oscillations should be positively damped with a damping margin of at least 3%.
c) The Y2-050 generators should maintain their pre-contingent power output following the fault.

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

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Table 3 to Table 8.

The results indicate that the fault simulations met the fault recovery criteria for the 2015 summer peak case:

a) Y2-050 was able to ride through the faults (except for faults where protective action tripped Y2-050),
b) the system with Y2-050 included was found to be transiently stable,
c) a new steady state was reached,
d) voltages at the POI and nearby buses returned to an acceptable range,

with system stability being maintained.

No mitigations were found to be required.

Table 3: Steady State Operation

Fault ID	Duration	Y2-050 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)	Y2-050 No Mitigation
3N.01	Fault at Y2-050 345 kV POI on Y2-050 circuit.	3.5 / 3.5	Stable (Trips Y2-050 system)
3N.02	Fault at Y2-050 345 kV POI on Canton Central circuit.	3.5 / 3.5	Stable
3N.03	Fault at Y2-050 345 kV POI on Tidd circuit.	3.5 / 3.5	Stable
3N.04	Fault at Canton Central 345 kV on South East Canton circuit.	3.5 / 3.5	Stable
3N.05	Fault at Canton Central 345 kV on Hanna circuit.	3.5 / 3.5	Stable
3N.06	Fault at Canton Central 345 kV on South Canton circuit.	3.5 / 3.5	Stable
3N.07	Fault at Canton Central 345 kV on Y2-050 circuit.	3.5 / 3.5	Stable
3N.08	Fault at Canton Central 345 kV on Canton Central 345/138 kV Transformers 1 and 2.	3.5 / 3.5	Stable
3N.09	Fault at Tidd 345 kV on Tidd Unit 3.	3.5 / 3.5	Stable (Trips Tidd unit 3)
3N.10	Fault at Tidd 345 kV on Tidd Unit 2.	3.5 / 3.5	Stable (Trips Tidd unit 2)
3N.11	Fault at Tidd 345 kV on Wylie Ridge circuit.	3.5 / 3.5	Stable
3N.12	Fault at Tidd 345 kV on West Bellaire - Kammer circuit.	3.5 / 3.5	Stable
3N.13	Fault at Tidd 345 kV on Tidd 345/138 kV Transformer C.	3.5 / 3.5	Stable
3N.14	Fault at Tidd 345 kV on Collier circuit.	3.5 / 3.5	Stable
3N.15	Fault at Tidd 345 kV on Y2-050 circuit.	3.5 / 3.5	Stable

Table 5: Three-phase Faults with Loss of Multiple-circuit Tower Line

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Y2-050 No Mitigation
3T.01	Fault at Tidd 345 kV on Collier circuit resulting in tower failure. Fault cleared with loss of Tidd – Collier circuit and Tidd – Wylie Ridge circuit.	3.5/3.5	Stable
3T.02	Fault at Kammer 345 kV on Muskingum River circuit resulting in tower failure. Fault cleared with loss of Kammer – Muskingum River circuit and Muskingum River circuit – Beverly circuit.	3.5/3.5	Stable
3T.03	Fault at Tidd 345 kV on West Bellaire circuit resulting in tower failure. Fault cleared with loss of Tidd – West Bellaire Circuit, Tidd – Beverly circuit, Kammer - West Bellaire circuit and West Bellaire 345/138 kV Transformer.	3.5/3.5	Stable
3T.04	Fault at Tidd 345 kV on Beverly circuit resulting in tower failure. Fault cleared with loss of Kammer - Muskingum River Circuit and Tidd – Beverly circuit.	3.5/3.5	Stable
3T.05	Fault at Canton Central 345 kV on South Canton circuit resulting in tower failure. Fault cleared with loss of Canton Central - South Canton Circuit and South Canton – South East Canton circuit.	3.5/3.5	Stable
3T.06	Fault at Canton Central 345 kV on South Canton circuit resulting in tower failure. Fault cleared with loss of Canton Central - South Canton Circuit and Canton Central – South East Canton circuit.	3.5/3.5	Stable
3T.07	Fault at Canton Central 345 kV on South Canton circuit resulting in tower failure. Fault cleared with loss of Canton Central - South Canton Circuit, Canton Central – South East Canton circuit and South East Canton 345/138 kV Transformer.	3.5/3.5	Stable

Table 6: Single-phase Bus Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	Y2-050 No Mitigation
1S.01	Fault at Kammer 345 kV on Bus. Fault cleared with loss of Kammer 345/138 kV Transformer 3.	3.5/3.5	Stable
1S.02	Fault at South Canton 345 kV on Bus. Fault cleared with loss of South Canton 345/138 kV Transformer 1.	3.5/3.5	Stable
1S.03	Fault at Tidd 345 kV on Bus. Fault cleared with loss of Tidd 345/138 kV Transformer B.	3.5/3.5	Stable
1S.04	Fault at Beverly 345 kV on Bus. Fault cleared with loss of Beverly Units 1A, 1B and 1S.	3.5/3.5	Stable
1S.05	Fault at Canton Central 345 kV Bus 1-L. Fault cleared with loss of Canton Central-SouthEast Canton circuit and South-east Canton 345/138 kV transformer.	3.5/3.5	Stable
1S.06	Fault at Canton Central 345 kV Bus 1-L. Fault cleared with loss of Canton Central-SouthEast Canton circuit.	3.5/3.5	Stable
1S.07	Fault at Canton Central 345 kV Bus 2. Fault cleared with loss of Canton Central 345/138 kV transformer 12.	3.5/3.5	Stable
1S.08	Fault at Kammer 345 kV on Bus. Fault cleared with loss of Kammer 345/138 kV Transformer 1B.	3.5/3.5	Stable
1S.09	Fault at Tidd 345 kV on Bus. Fault cleared with loss of Tidd 345/138 kV Transformer C	3.5/3.5	Stable

Table 7: Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal / Stuck Breaker (Cycles)	Y2-050 No Mitigation
1B.01	Fault at Y2-050 345 kV POI on Y2-050 circuit. Breaker stuck. Fault cleared with loss of Canton Central - Y2-050 - Tidd circuit. (Trips Y2-050 system)	3.5 / 16	Stable (Trips Y2-050 system)
1B.02	Fault at Y2-050 345 kV POI on Canton Central circuit. Breaker stuck. Fault cleared with loss of Canton Central - Y2-050 - Tidd circuit. (Trips Y2-050 system)	3.5 / 16	Stable (Trips Y2-050 system)
1B.03	Fault at Y2-050 345 kV POI on Tidd circuit. Breaker stuck. Fault cleared with loss of Canton Central - Y2-050 - Tidd circuit. (Trips Y2-050 system)	3.5 / 16	Stable (Trips Y2-050 system)
1B.04	Fault at Canton Central 345 kV on South East Canton circuit. Breaker L stuck. Breaker Fault cleared with loss of South Canton circuit.	3.5 / 16	Stable
1B.05	Fault at Canton Central 345 kV on Hanna circuit. Breaker K Stuck. Fault cleared with loss of Y2-050 circuit.	3.5 / 16	Stable
1B.06	Fault at Canton Central 345 kV on South Canton circuit. Breaker L Stuck. Fault cleared with loss of South East Canton circuit.	3.5 / 16	Stable
1B.07	Fault at Canton Central 345 kV on Y2-050 circuit. Breaker K stuck. Fault cleared with loss of Hanna circuit.	3.5 / 16	Stable
1B.08	Fault at Canton Central 345 kV on Canton Central 345/138 kV Transformers 1 and 2. Breaker K2 stuck. Fault cleared with loss of Y2-050 circuit.	3.5 / 16	Stable
1B.09	Fault at Tidd 345 kV on Tidd Unit 3. Breaker FF1 stuck. Fault cleared with loss of Tidd 345/138 kV Transformer B.	3.5 / 16	Stable (Trips Tidd unit 3)
1B.10	Fault at Tidd 345 kV on Tidd Unit 2. Breaker BB stuck. Fault cleared with loss of West Bellaire - Kammer circuit.	3.5 / 16	Stable (Trips Tidd unit 2)
1B.11	Fault at Tidd 345 kV on Wylie Ridge circuit. Breaker CC stuck. Fault cleared with loss of Collier circuit.	3.5 / 16	Stable
1B.12	Fault at Tidd 345 kV on West Bellaire - Kammer circuit. Breaker BB stuck. Fault cleared with loss of Tidd Unit 2.	3.5 / 16	Stable (Trips Tidd unit 2)
1B.13	Fault at Tidd 345 kV on Tidd 345/138 kV Transformer B. Breaker AA1 stuck. Fault cleared with loss of Y2-050 circuit.	3.5 / 16	Stable
1B.14	Fault at Tidd 345 kV on Collier circuit. Breaker CC stuck. Fault cleared with loss of Wylie Ridge circuit.	3.5 / 16	Stable
1B.15	Fault at Tidd 345 kV on Y2-050 circuit. Breaker AA stuck. Fault cleared with loss of Beverly circuit.	3.5 / 16	Stable

Table 8: Single-phase Faults with Delayed Clearing at Remote End

Fault ID	Fault description	Clearing time Near / Remote end (cycles)	Y2-050 No Mitigation
1D.01	Fault at Y2-050 345 kV POI on Y2-050 circuit. Delayed clearing at Y2-050.	3.5 / 60	Stable (Trips Y2-050 system)
1D.02	Fault at Y2-050 345 kV POI on Canton Central circuit. Delayed clearing at Canton Central.	3.5 / 60	Stable
1D.03	Fault at Y2-050 345 kV POI on Tidd circuit. Delayed clearing at Tidd.	3.5 / 60	Stable
1D.04	Fault at South East Canton 345 kV on Canton Central circuit. Delayed clearing at Canton Central.	3.5 / 60	Stable
1D.05	Fault at Hanna 345 kV on Canton Central circuit. Delayed clearing at Canton Central.	3.5 / 60	Stable
1D.06	Fault at South Canton 345 kV on Canton Central circuit. Delayed clearing at Canton Central.	3.5 / 60	Stable
1D.07	Fault at Canton Central 345 kV on Y2-050 circuit. Delayed clearing at Y2-050.	3.5 / 60	Stable
1D.08	Fault at Wylie Ridge 345 kV on Tidd circuit. Delayed clearing atTidd.	3.5 / 60	Stable
1D.09	Fault at Kammer 345 kV on West Bellaire - Tidd circuit. Delayed clearing at Tidd.	3.5 / 60	Stable
1D.10	Fault at Collier 345 kV on Tidd circuit. Delayed clearing at Tidd.	3.5 / 60	Stable
1D.11	Fault at Tidd 345 kV on Y2-050 circuit. Delayed clearing at Y2-050.	3.5 / 60	Stable

Summary: Application Appendix D: PJM System Impact Study electronically filed by Ms. Miranda R Leppla on behalf of Carroll County Energy LLC