Generation Interconnection Facilities Study Report

For

PJM Generation Interconnection Request Queue Position X2-052

Dumont-Olive (St. Joseph Energy Center) 345 kV

December 2014
Revised April 2015

X2-052 on Dumont – Olive 345 kV Facilities Study Report

A. Facilities Study Summary

1. Project Description

St. Joseph Energy Center, LLC proposes to install PJM Project #X2-052, a 675 MW (675 MW Capacity) Natural Gas facility connecting to American Electric Power's (AEP) Dumont - Olive 345 kV line (see Figure 2 on page 19). The proposed location of the X2-052 interconnection switching station is approximately 1 mile from the Olive 345 kV substation and approximately 14 miles from the Dumont 345 kV substation (see Figure 1 on page 18). This project was studied in the Feasibility Study as a 1,200 MW Natural Gas facility.

The requested in service date is June 1, 2018.

2. Amendments/Changes to the Impact Study Report

3. Interconnection Customer Schedule

PJM and AEP understand that St. Joseph Energy Center, LLC has established the following schedule dates:

Commercial Operation Date: **June 1, 2018**

4. AEP's Scope of Work to Facilitate Interconnection

- Construct a new 345 kV in-line switching station, Elderberry. This new station is to consist of three 345 kV circuit breakers physically configured in a breaker and half bus arrangement but initially operating as a ring-bus (see Figure 2). (n3711)
- Install 345 kV revenue metering, SCADA, and associated equipment will also be installed at the Elderberry station. (n3711.1)
- Loop the Dumont - Olive 345 kV line in to Elderberry station. (n3712)
- Perform remote end work at Olive and Dumont 345 kV stations. (n3713)

5. Description of Transmission Owner Facilities Included in the Facilities Study

Direct Connection Work

A new 345 kV in-line switching station, Elderberry, will be cut into the Dumont - Olive 345 kV line in Indiana. This new station is to consist of three 345 kV circuit breakers physically configured in a breaker and half bus arrangement but initially operating as a ring-bus (see Figure 2). Remote end work at Dumont and Olive 345 kV stations will also need to be performed.

Network Upgrade Work

None required.

6. <u>Total Cost of Transmission Owner Facilities Included in the Facilities Study:</u>

Direct Connection facilities	$10,635,900
Network Upgrade facilities	
Total Cost	$10,635,900

The estimates do not include the impact that delays in obtaining ROW, permits or other approvals may have.

7. <u>Summary of Schedule Milestones for Completion of Transmission Owner Work Included in Facilities Study:</u>

Schedule	
Engineering Start	June 1, 2015
Material Ordered	July 1, 2015
Construction Start	October 1, 2015
Outage (Cut-In & Testing)	September 15, 2017 to October 31, 2017
Ready for back feed	October 31, 2017
Commercial Operation Date	June 1, 2018

B. Transmission Owner Facilities Study Results

1. <u>Transmission Lines – New</u>

None required.

2. <u>Transmission Lines – Upgrades</u>

Loop the Dumont - Olive 345 kV line in to Elderberry station. (n3712)

3. <u>Substation Facilities – New</u>

Construct a new 345 kV in-line switching station, Elderberry. This new station is to consist of three 345 kV circuit breakers physically configured in a breaker and half bus arrangement but initially operating as a ring-bus. Install 345 kV revenue metering, SCADA, and associated equipment will also be installed at the Elderberry station. (n3711)

4. **<u>Substation Facilities – Upgrades</u>**

Dumont Station

Modify relaying and install ground switches (n3713)

Olive Station

Modify relaying and install ground switches (n3713)

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5. **<u>Metering & Communications</u>**

Standard 345 kV revenue metering will be installed at Elderberry station. A standard station communication scheme will be used. All metering equipment to be installed at the Elderberry station and shall meet the requirements as specified by AEP in the "AEP Metering and Telemetering Requirements for AEP Transmission Customers" document (SS-490011). Communication requirements are published in the "AEP SCADA RTU Requirements at Transmission Interconnection Facilities" (document SS-500000).

The Generation Interconnection Agreement does <u>not</u> in or by itself establish a requirement for American Electric Power to provide power for consumption at the developer's facilities. A separate agreement may be reached with the local utility that provides service in the area to ensure that infrastructure is in place to meet this demand and proper metering equipment is installed. The metering work above and cost indicated below do not include any potential work or cost to address metering requirements of the local service provider. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required. (n3711.1)

6. **<u>Environmental, Real Estate and Permitting Issues</u>**

St. Joseph Energy Center, LLC will obtain all necessary permits including those from the Indiana Power Siting Board.

7. Summary of Results of Study

Cost Estimates for AEP

	Engineering	Material	Construction	Misc.	Total
Elderberry 345kV Station Construction (n3711)	$286,000	$4,885,800	$2,212,500	$585,200	$7,969,500
345 kV Revenue Metering (n3711.1)	$37,700	$170,200	$29,700	$43,000	$280,600
Remote End Work Olive Station (n3713)	$114,600	$516,700	$294,400	$86,500	$1,012,200
Remote End Work Dumont Station (n3713)	$45,300	$460,800	$219,700	$66,900	$792,700
Transmission Line Cut-In Dumont – Olive 345 kV (n3712)	$31,700	$229,100	$224,200	$95,900	$580,900
Total	**$515,300**	**$6,262,600**	**$2,980,500**	**$877,500**	**$10,635,900**

Schedule

Funding Approved **May 1, 2015**
Outage requests made by January 30, 2015

In-Service Date **June 1, 2018**

Assumptions

- ISA signed **May 1, 2015**
- System conditions allow scheduled outages to occur.
- St. Joseph Energy Center, LLC will have their construction and required checkout completed prior to the start of the outage.

8. Information Required for Interconnection Service Agreement

Direct Interconnection Cost Breakdown

Direct Material -	$6,262,600
Direct Labor -	$3,495,800
Indirect Material -	$162,800
Indirect Labor -	$714,700
Total	$10,635,900

Network Upgrade Cost Breakdown

N/A

9. MISO and Duke Impacts

None

10. Stability Analysis

No Mitigations were required

Executive Summary

Generation Interconnection Request X2-052 is for a 695 MW 2x1 gas facility consisting of 2 x 230 MW gas combustion turbines and 1 x 235 MW steam turbine with a POI on the Dumont – Olive 345 kV circuit in the (American Electric Power) AEP network. X2-052 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of X2-052 as part of the overall system impact study.

The load flow scenario for the analysis was the RTEP 2015 summer light load case, with the addition of the X2-052 models at maximum power output and leading power factor. A total of 57 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) Single phase faults with single phase stuck breaker,
d) Single phase faults with delayed clearing at remote end due to primary relaying failure.

The fault simulations met the fault recovery criteria:

a) X2-052 was found to ride through the faults (except for faults where protective action tripped X2-052),
b) the system with X2-052 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,
e) with system stability being maintained.

No mitigations were found to be required.

1. Introduction

Generation Interconnection Request X2-052 is for a 695 MW 2x1 gas facility consisting of 2 x 230 MW gas combustion turbines and 1 x 235 MW steam turbine with a POI on the Dumont – Olive 345 kV circuit in the AEP network. As the Regional Transmission Operator, PJM Interconnection is responsible for planning the incorporation of generators into the grid. X2-052 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 X2-052 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of X2-052 will meet the dynamics requirements of the NERC and PJM reliability standards.

This report first describes the X2-052 project and how it is proposed to be connected to the grid, followed by a description of how the project is modeled in this study. The report then describes the fault cases that were analyzed, and discusses the results.

2. Description of the Project

The proposed X2-052 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 X2-052.

X2-052 is to be connected to the AEP system via the existing 12 mile, 345 kV circuit between Dumont 765 kV Substation and Olive 345 kV Substation, approximately 0.12 mile from Olive. The project includes the establishment of a new in-line switching station based on a 3-breaker ring bus arrangement.

Figures 1 shows how X2-052 has been modeled in this study. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the model in the stability study. Attachment 3 provides a diagram of the PSS/E model in the vicinity of X1-020; Attachment 4 gives the X2-052 PSS/E loadflow model.

The dynamic models for the X2-052 plant are based on standard PSS/E library models as well as user models provided by PJM.

Figure 1. X2-052 Plant Model

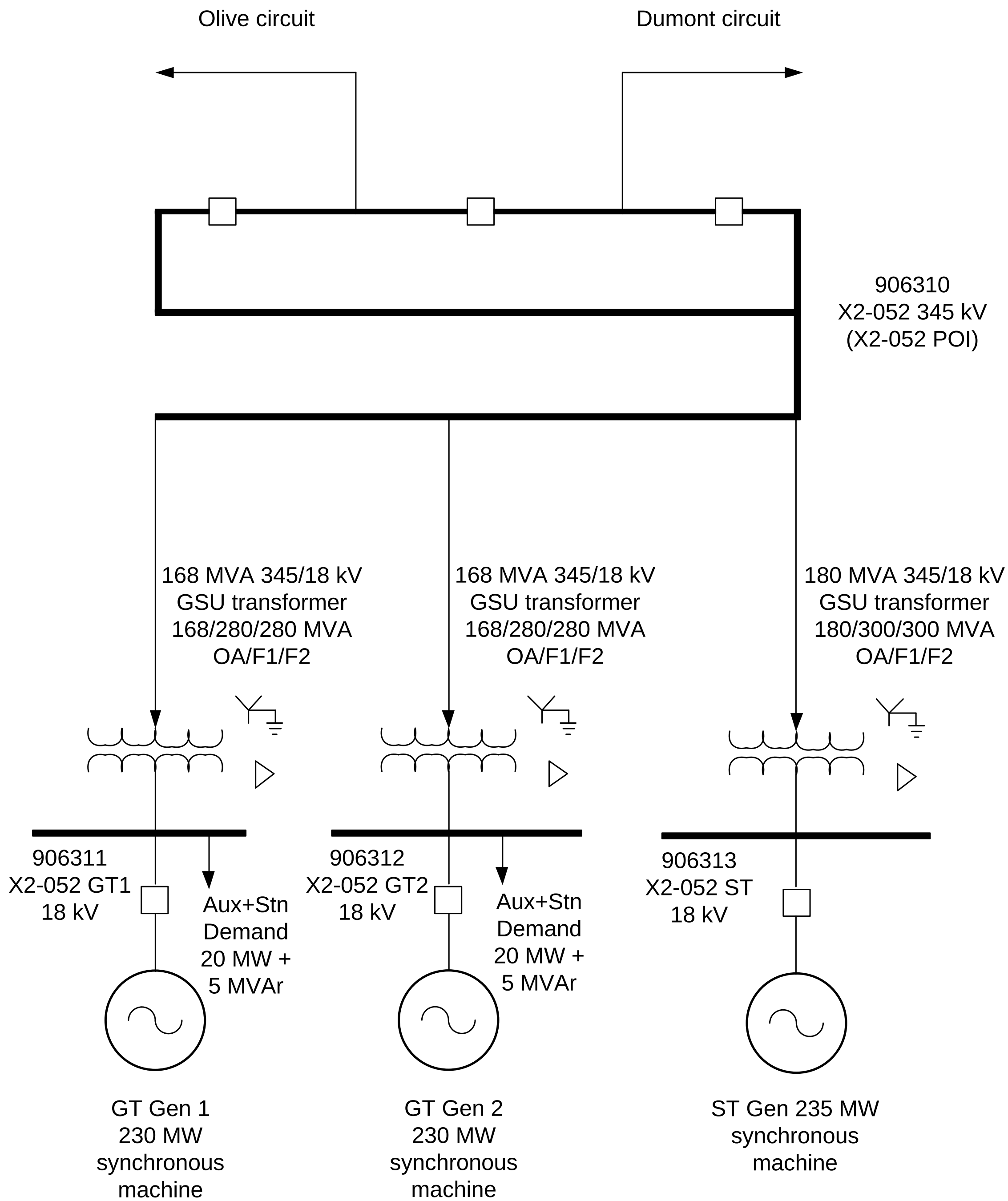

Table 1: X2-052 Plant Model

	Impact Study Data[1]	**Model**
Gas turbines		
Generator	2 x 230 MW CTs +130 / -90 MVAr / turbine. Vt = 18kV Per-turbine unsaturated reactances, pu @ 282.6 MVA: X''d(i) = 0.225 X''q(i) = 0.220	2 x 230 MW CTs MBASE 282.6 MVA PMAX 230 MW PMIN 0 MW CT1; 0 MW CT2 QMAX 130 MVAr QMIN -90 MVAr XSORCE 0.225 pu Dynamic data as included in Attachment 5
GSU transformer	2 x 168/280/280 MVA OA/F1/F2 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 168 MVA	2 x 168 MVA 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 168 MVA
Auxiliary demand	20 MW + 5 MVAr	20 MW + 5 MVAr
Steam turbine		
Generator	1 x 235 MW ST +170 / -130 MVAr. Vt = 18 kV Unsaturated reactance, pu @ 367 MVA: X''d(i) = 0.240 X''q(i) = 0.240	1 x 235 MW ST MBASE 367 MVA PMAX 235 MW PMIN 0 MW QMAX 170 MVAr QMIN -130 MVAr XSORCE 0.240 pu Dynamic data as included in Attachment 5
GSU transformer	1 x 180/300/300 MVA OA/F1/F2 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 180 MVA	1 x 180 MVA 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 180 MVA
Transmission line	N/A	Not modelled

[1] Winter ratings are used in the modeling.

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[2] and discussions with PJM.
The selected load flow scenario is the RTEP 2015 summer light load case, provided by PJM from the W3-088 study, with the following modifications:

a) Modeling of X2-052 on the 345 kV line between Dumont 345 kV Substation and Olive 345 kV Substation
b) Removal of withdrawn and subsequent queue projects in the vicinity of X2-052
c) Connection and disconnection of some distant generation units in the PJM system in order to maintain slack units within limits.

In the load flow, the X2-052 generators are set to maximum power output (230 MW combustion turbines and 235 MW for the steam turbine), 0.95 pu terminal voltage, and leading power factor.
Generation within the PJM500 system (area 225 in the PSS/E case) and within a 4 bus radius of X2-052 has been dispatched online at maximum output (P_{MAX}) – exceptions to this and the reason for them are listed in In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV line shunt reactors listed in Table 3 were switched out of service.

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

Table 2.
In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV line shunt reactors listed in Table 3 were switched out of service.

Table 2: Generation at reduced output within 4-bus radius of X2-052

Bus	Name	Unit	PGEN (MW)	PMAX (MW)	Reason
248000	06CLIFTY 345.00	6	73.26	366.3	Dynamic data, summer peak case and publicly available information suggest this machine is identical size to units 1-5
248000	06CLIFTY 345.00	A	110	124.715	Conflict with governor model, PMAX not achievable
248000	06CLIFTY 345.00	B	110	124.715	
248000	06CLIFTY 345.00	C	124.74	623.7001	Dynamic data, summer peak case and publicly available information suggest this machine is identical size to units 7-B
243225	05KEYSTN 345.00	1	50	59	Conflict with governor model, PMAX not achievable.
243225	05KEYSTN 345.00	2	50	60	
243225	05KEYSTN 345.00	3	50	60	
243225	05KEYSTN 345.00	4	50	59	
243187	05GVG2 26.000	2H	657.2	667	Conflict with governor model, PMAX not achievable
243187	05GVG2 26.000	2R	650	653	Conflict with governor model, PMAX not achieveable
243226	05LAWBG1 345.00	1A	151	195.667	Conflict with governor model, PMAX not achieveable
243226	05LAWBG1 345.00	1B	151	195.667	
243227	05LAWBG2 345.00	2A	151	195.667	
243227	05LAWBG2 345.00	2B	151	195.667	

Table 3: 765 kV Line shunt reactors switched out

From Bus Number	From Bus Name	To Bus Number	To Bus Name	Id	Line B From (pu on 100 MVA) Removed	Line B To (pu on 100 MVA) Removed
242510	05BAKER 765.00	242511	05BROADF 765.00	1	-3	-3
242509	05AXTON 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242515	05JOSHUA 765.00	1	-3	0
242511	05BROADF 765.00	242514	05J.FERR 765.00	1	-1.5	0
242513	05CULLOD 765.00	242517	05WYOMIN 765.00	1	0	-3

In addition, to the changes to P_{GEN} in the loadflow case, the following changes were made to the dynamics case to resolve initialization issues:

1. Switching off several distant generation units in the load flow case to avoid initialization problems in the dynamics simulation.

2. The following buses (outside the four bus radius from X2-052), have been netted to avoid DSTATE warnings on initialization of the dynamic case:
   - 349126 / Baldwin - ESAC8B K+2,K+3
   - 242802 / SMITHM - ESAC8B K+2
   - 349128 / Baldwin - ESAC8B K+3
   - 251893 / 08WABR6 - ESDC1A K+2
   - 242638 / GENSAL

   Two additional DSTATE error warnings – occurring at bus 243382, machines 1 and 2, EXCDC2 excitation system model (STATE(K+2)) – were ignored as the error was small (1.1%) and did not prevent the steady-state run from meeting criteria.
3. At bus 270000, units 1, 2 & 3 and bus 270001, units 1 & 2, the saturation factors S(1.0) and S(1.2) were much higher than expected; it was assumed they are % rather than per unit values. These values were thus divided by 100 to set more realistic values.
4. For bus 248000 units '6' and 'C', the governor model was switched off to avoid initializing out of limits (see also Table 2).

4. Fault Cases

This study is focused on the ability of the system, following the addition of X2-052, to maintain stability under contingencies of transmission elements.

Tables 2 – 5 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[3] (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) Single phase faults with single phase stuck breaker
d) Single phase to ground faults with delayed clearing at remote end due to primary relaying failure[4]

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 X2-052 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

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

[4] One of the delayed clearing contingencies (1D.03) was removed from the study, based on advice received from PJM of redundancy in communications channels.

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 X2-052 generator should maintain its pre-contingent power output following the fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Tables 2 – 5.

The fault simulations met the fault recovery criteria:

a) the system with X2-052 included was found to be transiently stable,

b) a new steady state was reached,

c) voltages at the POI and nearby buses returned to an acceptable range,

d) with X2-052 riding through the fault (except for faults where protective action tripped X2-052) and system stability being maintained.

Table 2. Steady State Operation

Fault ID	Duration	X2-052 No Mitigation
SS.01	Steady state 20 sec	Stable

Table 3.Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X2-052 No Mitigation
3N.01	Fault at X2-052 345 kV on X2-052 circuit. Trips X2-052 system.	3.5 / 3.5	Stable (with loss of X2-052)
3N.02	Fault at X2-052 345 kV on Olive circuit.	3.5 / 3.5	Stable
3N.03	Fault at X2-052 345 kV on Dumont circuit.	3.5 / 3.5	Stable
3N.04	Fault at Olive 345 kV on X2-052 circuit.	3.5 / 3.5	Stable
3N.05	Fault at Olive 345 kV on Green Acres circuit	3.5 / 3.5	Stable
3N.06	Fault at Olive 345 kV on Cook circuit	3.5 / 3.5	Stable
3N.07	Fault at Olive 345 kV Meadow Lake SW circuit	3.5 / 3.5	Stable
3N.08	Fault at Olive 345 kV University Park circuit	3.5 / 3.5	Stable
3N.09	Fault at Olive 345 kV Reynolds - Meadow Lake SW circuit	3.5 / 3.5	Stable
3N.10	Fault at Dumont 345 kV on 765/345 kV Transformer 2.	3.5 / 3.5	Stable
3N.11	Fault at Dumont 345 kV on X2-052 circuit.	3.5 / 3.5	Stable
3N.12	Fault at Dumont 345 kV on Twin Branch Circuit 1	3.5 / 3.5	Stable
3N.13	Fault at Dumont 345 kV on Stillwell circuit	3.5 / 3.5	Stable
3N.14	Fault at Dumont 345 kV on 765/345 kV Transformer 1	3.5 / 3.5	Stable
3N.15	Fault at Dumont 345 kV on Sorenson circuit	3.5 / 3.5	Stable

Table 4 Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal / Stuck Breaker (Cycles)	X2-052 No Mitigation
1B.01	Fault at X2-052 345 kV on X2-052 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit and X2-052 generation.	3.5 / 16	Stable (with loss of X2-052)
1B.02	Fault at X2-052 345 kV on Olive circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit and X2-052 generation.	3.5 / 16	Stable (with loss of X2-052)
1B.03	Fault at X2-052 345 kV on Dumont circuit. Breaker stuck to Olive circuit. Fault cleared with loss of Olive circuit and X2-052 generation.	3.5 / 16	Stable (with loss of X2-052)
1B.04	Fault at Olive 345 kV on X2-052 circuit. Breaker stuck to Reynolds - Meadow Lake SW circuit. Fault cleared with loss of Reynolds - Meadow Lake SW circuit and Reynolds 345 kV.	3.5 / 16	Stable
1B.05	Fault at Olive 345 kV on Green Acres circuit. Breaker stuck to Cook circuit. Fault cleared with loss of Cook circuit.	3.5 / 16	Stable
1B.06	Fault at Olive 345 kV on Cook circuit. Breaker stuck to Green acres circuit. Fault cleared with loss of Green Acres circuit.	3.5 / 16	Stable
1B.07	Fault at Olive 345 kV 345/138 kV on Transformer T-2. Breaker stuck to X2-052 circuit. Fault cleared with loss of X2-052 circuit.	3.5 / 16	Stable
1B.08	Fault at Olive 345 kV Meadow Lake SW circuit. Breaker stuck to University Park circuit. Fault cleared with loss of University Park circuit.	3.5 / 16	Stable
1B.09	Fault at Olive 345 kV University Park circuit. Breaker stuck to Meadow Lake SW Circuit 1. Fault cleared with loss of Meadow Lake SW Circuit 1.	3.5 / 16	Stable
1B.10	Fault at Olive 345 kV Reynolds - Meadow Lake SW circuit. Breaker stuck to X2-052. Fault cleared with loss of X2-052 circuit.	3.5 / 16	Stable
1B.11	Fault at Dumont 345 kV on 765/345 kV Transformer 2. Breaker stuck to X2-052 circuit. Fault cleared with loss of X2-052 circuit.	3.5 / 16	Stable
1B.12	Fault at Dumont 345 kV on X2-052 circuit. Stuck breaker. Fault cleared with loss of 765/345 kV Transformer 2.	3.5 / 16	Stable
1B.13	Fault at Dumont 345 kV on Twin Branch Circuit 1. Breaker stuck to Dumont 345 kV bus. Fault cleared with loss of X2-052 circuit and Dumont 765/345 kV Transformer 1.	3.5 / 16	Stable
1B.14	Fault at Dumont 345 kV on Twin Branch Circuit 2. Breaker E2 stuck to Dumont 765/345 kV Transformer 2. Fault cleared with loss of Dumont 765/345 kV Transformer 2 and X2-052 circuit.	3.5 / 16	Stable
1B.15	Fault at Dumont 345 kV on Stillwell circuit. Breaker stuck to Twin Branch Circuit 1. Fault cleared with loss of Twin Branch Circuit 1.	3.5 / 16	Stable
1B.16	Fault at Dumont 345 kV on 765/345 kV Transformer 1. Breaker stuck to Sorenson circuit. Fault cleared with loss of Sorenson circuit.	3.5 / 16	Stable
1B.17	Fault at Dumont 345 kV on 765/345 kV Transformer 1. Breaker stuck to Twin Branch circuit. Fault cleared with loss of Twin Branch circuit.	3.5 / 16	Stable
1B.18	Fault at Dumont 345 kV on Sorenson circuit. Breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with loss of Dumont 765/345 kV Transformer 1.	3.5 / 16	Stable

Table 5 Single-phase Faults with Delayed Clearing at Remote End

Fault ID	Fault description	Clearing time Near / Remote end (cycles)	X2-052 No Mitigation
1D.01	Fault at X2-052 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.02	Fault at X2-052 345 kV on Dumont circuit. Delayed clearing at Dumont.	3.5 / 60	Stable
1D.03	Not used	N / A	N / A
1D.04	Fault at Olive 345 kV on Green Acres circuit. Delayed clearing at Green Acres.	3.5 / 60	Stable
1D.05	Fault at Olive 345 kV on Cook circuit. Delayed clearing at Cook.	3.5 / 60	Stable
1D.06	Fault at Olive 345 kV 345/138 kV on Transformer T-2. Delayed clearing at Olive 138 kV.	3.5 / 60	Stable
1D.07	Fault at Olive 345 kV Meadow Lake SW circuit. Delayed clearing at Meadow Lake SW.	3.5 / 60	Stable
1D.08	Fault at Olive 345 kV University Park circuit. Delayed clearing at Univeristy Park.	3.5 / 60	Stable
1D.09	Fault at Olive 345 kV Reynolds - Meadow Lake SW circuit. Delayed clearing at Meadow Lake SW.	3.5 / 60	Stable
1D.10	Fault at Green Acres 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.11	Fault at Cook 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.12	Fault at Olive 138 kV on Transformer T-2. Delayed clearing at Olive 345 kV.	4.5 / 60	Stable
1D.13	Fault at Meadow Lake SW 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.14	Fault at University Park 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.15	Fault at Meadow Lake SW 345 kV on Reynolds - Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.16	Fault at Dumont 345 kV on 765/345 kV Transformer 2. Delayed clearing at Dumont 765 kV.	3.5 / 60	Stable
1D.17	Fault at Dumont 345 kV on X2-052 circuit. Delayed clearing at X2-052.	3.5 / 60	Stable
1D.18	Fault at Dumont 345 kV on Twin Branch Circuit 1. Delayed clearing at Twin Branch.	3.5 / 60	Stable
1D.19	Fault at Dumont 345 kV on Stillwell circuit. Delayed clearing at Stillwell.	3.5 / 60	Stable
1D.20	Fault at Dumont 345 kV on 765/345 kV Transformer 1. Delayed clearing at Dumont 765 kV.	3.5 / 60	Stable
1D.21	Fault at Dumont 345 kV on Sorenson circuit. Delayed clearing at Sorenson.	3.5 / 60	Stable
1D.22	Fault at Twin Branch 345 kV on Dumont circuit 1. Delayed clearing at Dumont.	3.5 / 60	Stable
1D.23	Fault at Stillwell 345 kV on Dumont circuit. Delayed clearing at Dumont.	3.5 / 60	Stable
1D.24	Fault at Sorenson 345 kV on Dumont circuit. Delayed clearing at Dumont.	3.5 / 60	Stable

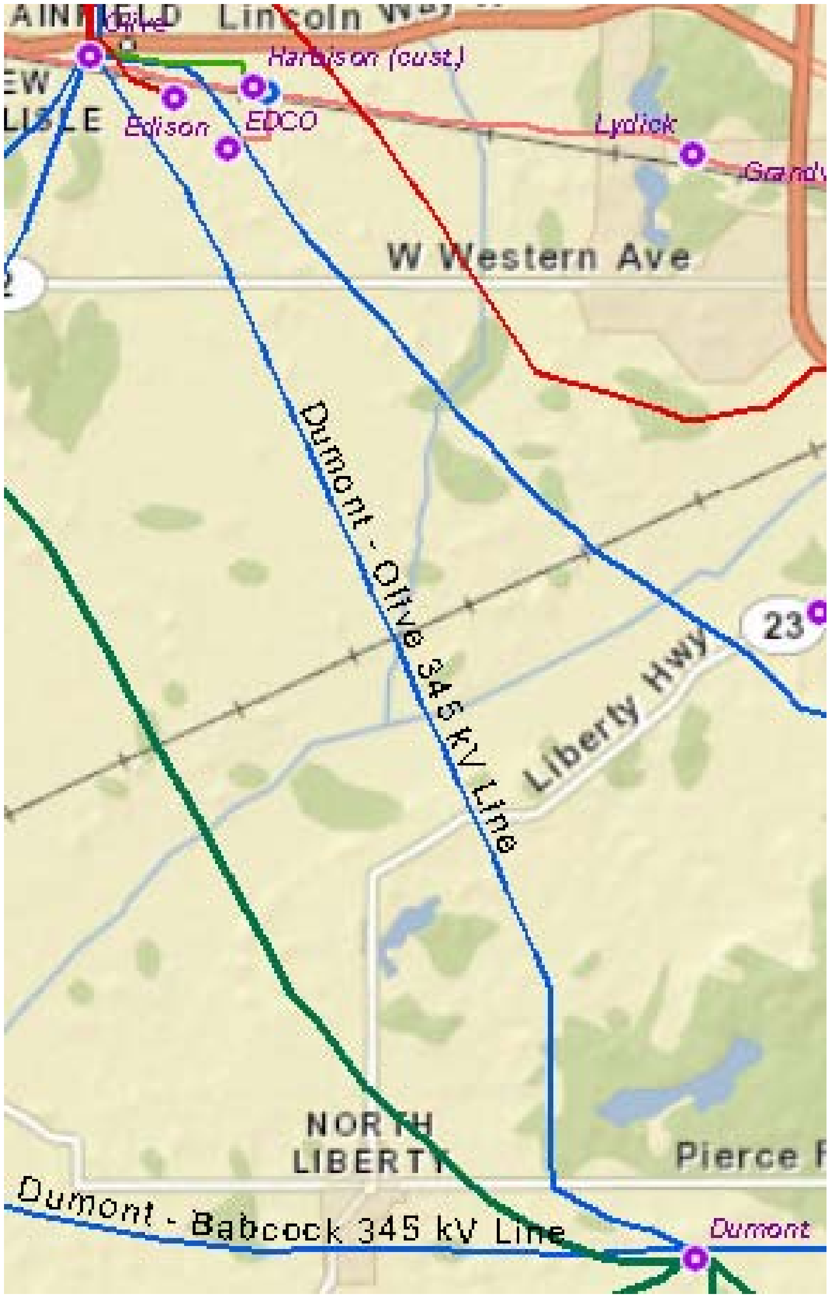

Figure 1: Approximate interconnection location of the proposed facilities

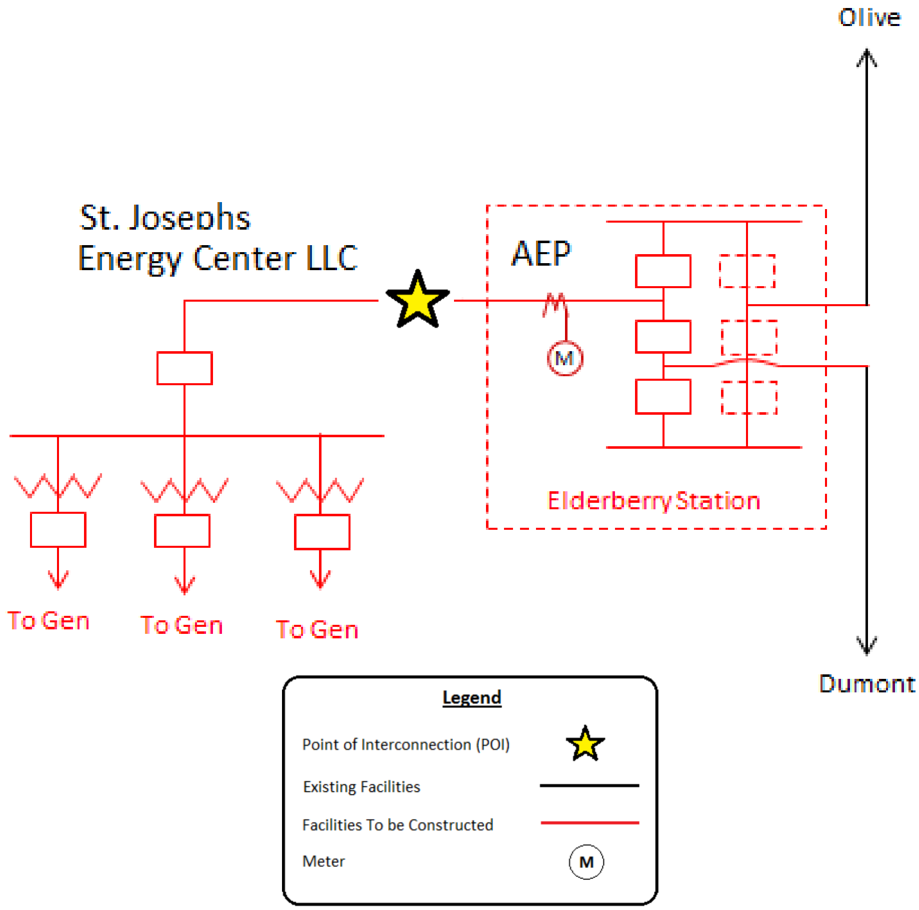

Figure 2: Simplified diagram of proposed interconnection

Generation Interconnection
Facilities Study Report

For

PJM Generation Interconnection Request
Queue Position X2-052

Dumont-Olive (St. Joseph Energy Center) 345 kV

December 2014

X2-052 on Dumont – Olive 345 kV Facilities Study Report

A. Facilities Study Summary

1. Project Description

St. Joseph Energy Center, LLC proposes to install PJM Project #X2-052, a 675 MW (675 MW Capacity) Natural Gas facility connecting to American Electric Power's (AEP) Dumont - Olive 345 kV line (see Figure 2 on page 19). The proposed location of the X2-052 interconnection switching station is approximately 1 mile from the Olive 345 kV substation and approximately 14 miles from the Dumont 345 kV substation (see Figure 1 on page 18). This project was studied in the Feasibility Study as a 1,200 MW Natural Gas facility.

The requested in service date is June 1, 2016.

2. Amendments/Changes to the Impact Study Report

3. Interconnection Customer Schedule

PJM and AEP understand that St. Joseph Energy Center, LLC has established the following schedule dates:

Commercial Operation Date: **October 15, 2016**

4. AEP's Scope of Work to Facilitate Interconnection

- A sag check will be required for the 14 mile "Rail" Conductor Section of the Dumont to Olive 345 kV Line to determine if the line section can be operated above its emergency rating of 1409 MVA. The results could prove that no additional upgrades are necessary, that some upgrades on the circuit are necessary, or that the entire 14 mile section of line would need to be rebuilt. Estimated Cost for the Sag Study: $56,000.

  If the sag study results determine that a complete line rebuild is required to increase the Maximum Operating Temperature (MOT), AEP proposes looping in the Dumont – Sorenson 345 kV into the X2-052 interconnection station instead of going forward with a rebuild. Preliminary cost $5,000,000. Dumont – Sorenson is on the other side of the Dumont – Olive 345 kV which is being terminated at the interconnection station for this project.

- Construct a new 345 kV in-line switching station, Elderberry. This new station is to consist of three 345 kV circuit breakers physically configured in a breaker and half bus arrangement but initially operating as a ring-bus (see Figure 2).

- Install 345 kV revenue metering, SCADA, and associated equipment will also be installed at the Elderberry station.
- Loop the Dumont - Olive 345 kV line in to Elderberry station.
- Perform remote end work at Olive and Dumont 345 kV stations.

5. Description of Transmission Owner Facilities Included in the Facilities Study

Direct Connection Work

A new 345 kV in-line switching station, Elderberry, will be cut into the Dumont - Olive 345 kV line in Indiana. This new station is to consist of three 345 kV circuit breakers physically configured in a breaker and half bus arrangement but initially operating as a ring-bus (see Figure 2). Remote end work at Dumont and Olive 345 kV stations will also need to be performed.

Network Upgrade Work

None required.

6. Total Cost of Transmission Owner Facilities Included in the Facilities Study:

Direct Connection facilities	$10,635,900
Network Upgrade facilities	$5,000,000
Total Cost	$15,635,900

The estimates do not include the impact that delays in obtaining ROW, permits or other approvals may have.

7. Summary of Schedule Milestones for Completion of Transmission Owner Work Included in Facilities Study:

Engineering Start January 2, 2015
Material Ordered February 1, 2015
Construction Start April 1, 2015
Outage (Cut-In & Testing) September 1, 2016 To October 15, 2016
Ready for back feed October 15, 2016

B. Transmission Owner Facilities Study Results

1. Transmission Lines – New

None required.

2. **Transmission Lines – Upgrades**
   Loop the Dumont - Olive 345 kV line in to Elderberry station. (n3712)
   Loop the Dumont - Sorenson 345 kV line in to Elderberry station. (n4323)

3. **Substation Facilities – New**
   Construct a new 345 kV in-line switching station, Elderberry. This new station is to consist of three 345 kV circuit breakers physically configured in a breaker and half bus arrangement but initially operating as a ring-bus. Install 345 kV revenue metering, SCADA, and associated equipment will also be installed at the Elderberry station. (n3711)

4. **<u>Substation Facilities – Upgrades</u>**

Dumont Station

Modify relaying and install ground switches (n3713)

Olive Station

Modify relaying and install ground switches (n3713)

.

5. **<u>Metering & Communications</u>**

Standard 345 kV revenue metering will be installed at Elderberry station. A standard station communication scheme will be used. All metering equipment to be installed at the Elderberry station and shall meet the requirements as specified by AEP in the "AEP Metering and Telemetering Requirements for AEP Transmission Customers" document (SS-490011). Communication requirements are published in the "AEP SCADA RTU Requirements at Transmission Interconnection Facilities" (document SS-500000).

The Generation Interconnection Agreement does <u>not</u> in or by itself establish a requirement for American Electric Power to provide power for consumption at the developer's facilities. A separate agreement may be reached with the local utility that provides service in the area to ensure that infrastructure is in place to meet this demand and proper metering equipment is installed. The metering work above and cost indicated below do not include any potential work or cost to address metering requirements of the local service provider. It is the responsibility of the developer to contact the local service provider to determine if a local service agreement is required. (n3711.1)

6. **<u>Environmental, Real Estate and Permitting Issues</u>**

St. Joseph Energy Center, LLC will obtain all necessary permits including those from the Indiana Power Siting Board.

7. Summary of Results of Study

Cost Estimates for AEP

	Engineering	Material	Construction	Misc.	Total
Elderberry 345kV Station Construction	$286,000	$4,885,800	$2,212,500	$585,200	$7,969,500
345 kV Revenue Metering	$37,700	$170,200	$29,700	$43,000	$280,600
Remote End Work Olive Station	$114,600	$516,700	$294,400	$86,500	$1,012,200
Remote End Work Dumont Station	$45,300	$460,800	$219,700	$66,900	$792,700
Transmission Line Cut-In Dumont – Olive 345 kV	$31,700	$229,100	$224,200	$95,900	$580,900
Transmission Line Cut-In Dumont – Sorenson 345 kV	$395,177	$2,705,784	$1,337,424	$561,614	$5,000,000
Total	**$910,477**	**$8,968,384**	**$4,317,924**	**$1,439,114**	**$15,635,900**

Schedule

Funding Approved **March 1, 2015**
Outage requests made by January 30, 2015

In-Service Date **October 15, 2016**

Assumptions

- ISA signed **December 1, 2014**
- System conditions allow scheduled outages to occur.
- St. Joseph Energy Center, LLC will have their construction and required checkout completed prior to the start of the outage.

8. Information Required for Interconnection Service Agreement

Direct Interconnection Cost Breakdown

Direct Material -	$9,206,686
Direct Labor -	$5,139,196
Indirect Material -	$239,333
Indirect Labor -	$1,050,685
Total	$15,635,900

Network Upgrade Cost Breakdown

N/A

9. <u>MISO and Duke Impacts</u>

None

10. <u>Stability Analysis</u>

No Mitigations were required

Executive Summary

Generation Interconnection Request X2-052 is for a 695 MW 2x1 gas facility consisting of 2 x 230 MW gas combustion turbines and 1 x 235 MW steam turbine with a POI on the Dumont – Olive 345 kV circuit in the (American Electric Power) AEP network. X2-052 is now at the system impact study phase of PJM's Generation and Transmission Interconnection Process. This report describes a dynamic simulation analysis of X2-052 as part of the overall system impact study.

The load flow scenario for the analysis was the RTEP 2015 summer light load case, with the addition of the X2-052 models at maximum power output and leading power factor. A total of 57 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) Single phase faults with single phase stuck breaker,
d) Single phase faults with delayed clearing at remote end due to primary relaying failure.

The fault simulations met the fault recovery criteria:

a) X2-052 was found to ride through the faults (except for faults where protective action tripped X2-052),
b) the system with X2-052 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,
e) with system stability being maintained.

No mitigations were found to be required.

1. Introduction

Generation Interconnection Request X2-052 is for a 695 MW 2x1 gas facility consisting of 2 x 230 MW gas combustion turbines and 1 x 235 MW steam turbine with a POI on the Dumont – Olive 345 kV circuit in the AEP network. As the Regional Transmission Operator, PJM Interconnection is responsible for planning the incorporation of generators into the grid. X2-052 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 X2-052 as part of the overall system impact study. This analysis is effectively a screening study to determine whether the addition of X2-052 will meet the dynamics requirements of the NERC and PJM reliability standards.

This report first describes the X2-052 project and how it is proposed to be connected to the grid, followed by a description of how the project is modeled in this study. The report then describes the fault cases that were analyzed, and discusses the results.

2. Description of the Project

The proposed X2-052 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 X2-052.

X2-052 is to be connected to the AEP system via the existing 12 mile, 345 kV circuit between Dumont 765 kV Substation and Olive 345 kV Substation, approximately 0.12 mile from Olive. The project includes the establishment of a new in-line switching station based on a 3-breaker ring bus arrangement.

Figures 1 shows how X2-052 has been modeled in this study. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the model in the stability study. Attachment 3 provides a diagram of the PSS/E model in the vicinity of X1-020; Attachment 4 gives the X2-052 PSS/E loadflow model.

The dynamic models for the X2-052 plant are based on standard PSS/E library models as well as user models provided by PJM.

Figure 1. X2-052 Plant Model

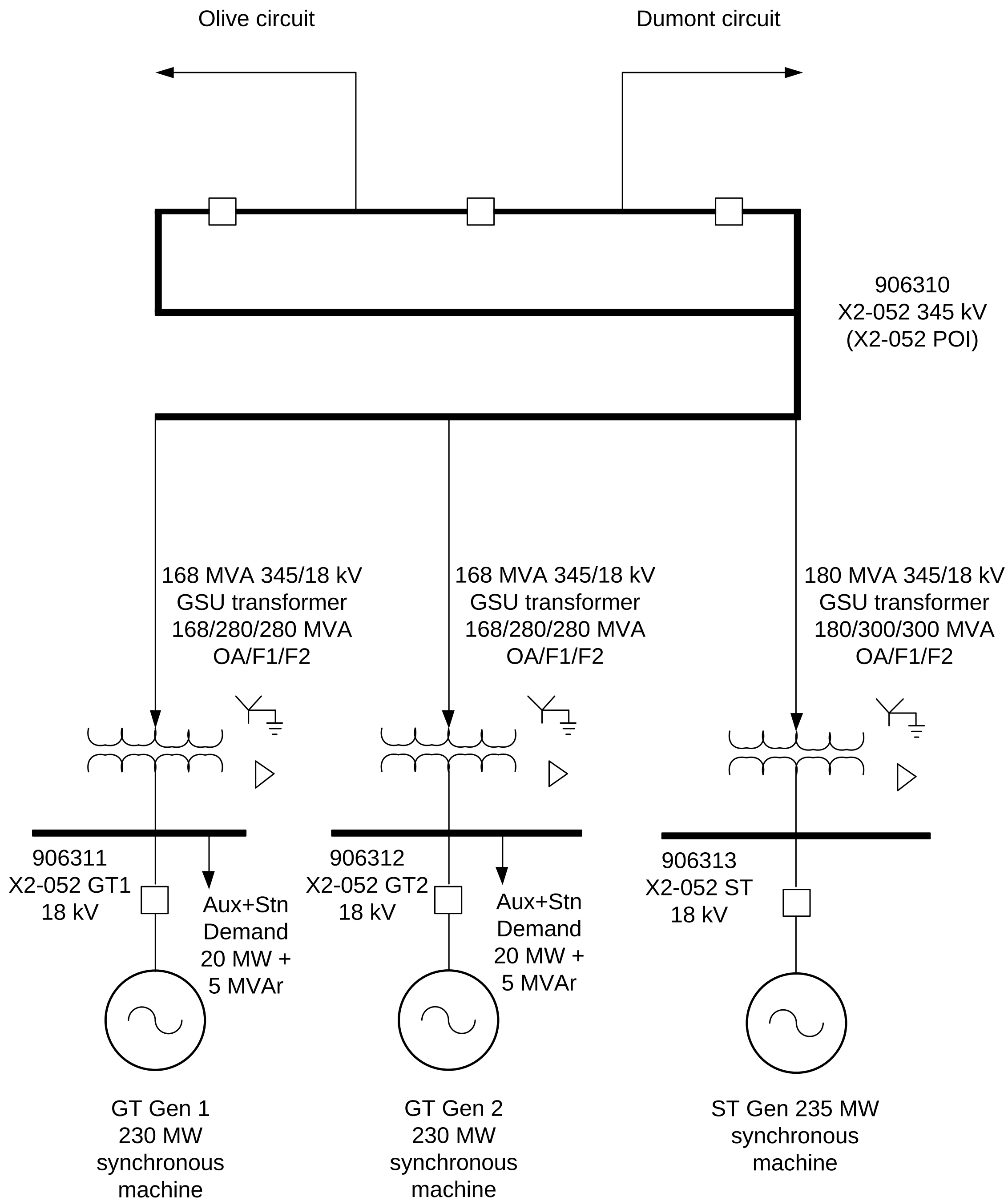

Table 1: X2-052 Plant Model

	Impact Study Data[1]	Model
Gas turbines		
Generator	2 x 230 MW CTs +130 / -90 MVAr / turbine. Vt = 18kV Per-turbine unsaturated reactances, pu @ 282.6 MVA: X''d(i) = 0.225 X''q(i) = 0.220	2 x 230 MW CTs MBASE 282.6 MVA PMAX 230 MW PMIN 0 MW CT1; 0 MW CT2 QMAX 130 MVAr QMIN -90 MVAr XSORCE 0.225 pu Dynamic data as included in Attachment 5
GSU transformer	2 x 168/280/280 MVA OA/F1/F2 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 168 MVA	2 x 168 MVA 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 168 MVA
Auxiliary demand	20 MW + 5 MVAr	20 MW + 5 MVAr
Steam turbine		
Generator	1 x 235 MW ST +170 / -130 MVAr. Vt = 18 kV Unsaturated reactance, pu @ 367 MVA: X''d(i) = 0.240 X''q(i) = 0.240	1 x 235 MW ST MBASE 367 MVA PMAX 235 MW PMIN 0 MW QMAX 170 MVAr QMIN -130 MVAr XSORCE 0.240 pu Dynamic data as included in Attachment 5
GSU transformer	1 x 180/300/300 MVA OA/F1/F2 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 180 MVA	1 x 180 MVA 345 / 18 kV Ynd 0.22 % + j 11.00 % @ 180 MVA
Transmission line	N/A	Not modelled

[1] Winter ratings are used in the modeling.

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[2] and discussions with PJM.
The selected load flow scenario is the RTEP 2015 summer light load case, provided by PJM from the W3-088 study, with the following modifications:

a) Modeling of X2-052 on the 345 kV line between Dumont 345 kV Substation and Olive 345 kV Substation
b) Removal of withdrawn and subsequent queue projects in the vicinity of X2-052
c) Connection and disconnection of some distant generation units in the PJM system in order to maintain slack units within limits.

In the load flow, the X2-052 generators are set to maximum power output (230 MW combustion turbines and 235 MW for the steam turbine), 0.95 pu terminal voltage, and leading power factor.
Generation within the PJM500 system (area 225 in the PSS/E case) and within a 4 bus radius of X2-052 has been dispatched online at maximum output (P_{MAX}) – exceptions to this and the reason for them are listed in In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV line shunt reactors listed in Table 3 were switched out of service.

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

Table 2.
In order to achieve an acceptable voltage profile across the 765 kV network, the 765 kV line shunt reactors listed in Table 3 were switched out of service.

Table 2: Generation at reduced output within 4-bus radius of X2-052

Bus	Name	Unit	PGEN (MW)	PMAX (MW)	Reason
248000	06CLIFTY 345.00	6	73.26	366.3	Dynamic data, summer peak case and publicly available information suggest this machine is identical size to units 1-5
248000	06CLIFTY 345.00	A	110	124.715	Conflict with governor model, PMAX not achieveable
248000	06CLIFTY 345.00	B	110	124.715	
248000	06CLIFTY 345.00	C	124.74	623.7001	Dynamic data, summer peak case and publicly available information suggest this machine is identical size to units 7-B
243225	05KEYSTN 345.00	1	50	59	Conflict with governor model, PMAX not achieveable.
243225	05KEYSTN 345.00	2	50	60	
243225	05KEYSTN 345.00	3	50	60	
243225	05KEYSTN 345.00	4	50	59	
243187	05GVG2 26.000	2H	657.2	667	Conflict with governor model, PMAX not achieveable
243187	05GVG2 26.000	2R	650	653	Conflict with governor model, PMAX not achieveable
243226	05LAWBG1 345.00	1A	151	195.667	Conflict with governor model, PMAX not achieveable
243226	05LAWBG1 345.00	1B	151	195.667	
243227	05LAWBG2 345.00	2A	151	195.667	
243227	05LAWBG2 345.00	2B	151	195.667	

Table 3: 765 kV Line shunt reactors switched out

From Bus Number	From Bus Name	To Bus Number	To Bus Name	Id	Line B From (pu on 100 MVA) Removed	Line B To (pu on 100 MVA) Removed
242510	05BAKER 765.00	242511	05BROADF 765.00	1	-3	-3
242509	05AXTON 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242514	05J.FERR 765.00	1	-3	0
242512	05CLOVRD 765.00	242515	05JOSHUA 765.00	1	-3	0
242511	05BROADF 765.00	242514	05J.FERR 765.00	1	-1.5	0
242513	05CULLOD 765.00	242517	05WYOMIN 765.00	1	0	-3

In addition, to the changes to P_{GEN} in the loadflow case, the following changes were made to the dynamics case to resolve initialization issues:

1. Switching off several distant generation units in the load flow case to avoid initialization problems in the dynamics simulation.

2. The following buses (outside the four bus radius from X2-052), have been netted to avoid DSTATE warnings on initialization of the dynamic case:
   - 349126 / Baldwin - ESAC8B K+2,K+3
   - 242802 / SMITHM - ESAC8B K+2
   - 349128 / Baldwin - ESAC8B K+3
   - 251893 / 08WABR6 - ESDC1A K+2
   - 242638 / GENSAL

   Two additional DSTATE error warnings – occurring at bus 243382, machines 1 and 2, EXCDC2 excitation system model (STATE(K+2)) – were ignored as as the error was small (1.1%) and did not prevent the steady-state run from meeting criteria.
3. At bus 270000, units 1, 2 & 3 and bus 270001, units 1 & 2, the saturation factors S(1.0) and S(1.2) were much higher than expected; it was assumed they are % rather than per unit values. These values were thus divided by 100 to set more realistic values.
4. For bus 248000 units '6' and 'C', the governor model was switched off to avoid initializing out of limits (see also Table 2).

4. Fault Cases

This study is focused on the ability of the system, following the addition of X2-052, to maintain stability under contingencies of transmission elements.
Tables 2 – 5 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[3] (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) Single phase faults with single phase stuck breaker
d) Single phase to ground faults with delayed clearing at remote end due to primary relaying failure[4]

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 X2-052 have not withdrawn from the PJM queue, and are not greater than the queue position under study.

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[3] One bus removed from the POI refers to buses with transmission circuit breakers, not tee-offs or buses with only supply circuit breakers.
[4] One of the delayed clearing contingencies (1D.03) was removed from the study, based on advice received from PJM of redundancy in communications channels.

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 X2-052 generator should maintain its pre-contingent power output following the fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6, with results summarized in Tables 2 – 5.

The fault simulations met the fault recovery criteria:

a) the system with X2-052 included was found to be transiently stable,
b) a new steady state was reached,
c) voltages at the POI and nearby buses returned to an acceptable range,
d) with X2-052 riding through the fault (except for faults where protective action tripped X2-052) and system stability being maintained.

Table 2. Steady State Operation

Fault ID	Duration	X2-052 No Mitigation
SS.01	Steady state 20 sec	Stable

Table 3.Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time Near & Remote (Cycles)	X2-052 No Mitigation
3N.01	Fault at X2-052 345 kV on X2-052 circuit. Trips X2-052 system.	3.5 / 3.5	Stable (with loss of X2-052)
3N.02	Fault at X2-052 345 kV on Olive circuit.	3.5 / 3.5	Stable
3N.03	Fault at X2-052 345 kV on Dumont circuit.	3.5 / 3.5	Stable
3N.04	Fault at Olive 345 kV on X2-052 circuit.	3.5 / 3.5	Stable
3N.05	Fault at Olive 345 kV on Green Acres circuit	3.5 / 3.5	Stable
3N.06	Fault at Olive 345 kV on Cook circuit	3.5 / 3.5	Stable
3N.07	Fault at Olive 345 kV Meadow Lake SW circuit	3.5 / 3.5	Stable
3N.08	Fault at Olive 345 kV University Park circuit	3.5 / 3.5	Stable
3N.09	Fault at Olive 345 kV Reynolds - Meadow Lake SW circuit	3.5 / 3.5	Stable
3N.10	Fault at Dumont 345 kV on 765/345 kV Transformer 2.	3.5 / 3.5	Stable
3N.11	Fault at Dumont 345 kV on X2-052 circuit.	3.5 / 3.5	Stable
3N.12	Fault at Dumont 345 kV on Twin Branch Circuit 1	3.5 / 3.5	Stable
3N.13	Fault at Dumont 345 kV on Stillwell circuit	3.5 / 3.5	Stable
3N.14	Fault at Dumont 345 kV on 765/345 kV Transformer 1	3.5 / 3.5	Stable
3N.15	Fault at Dumont 345 kV on Sorenson circuit	3.5 / 3.5	Stable

Table 4 Single-phase Faults with Stuck Breaker

Fault ID	Fault description	Clearing Time Normal / Stuck Breaker (Cycles)	X2-052 No Mitigation
1B.01	Fault at X2-052 345 kV on X2-052 circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit and X2-052 generation.	3.5 / 16	Stable (with loss of X2-052)
1B.02	Fault at X2-052 345 kV on Olive circuit. Breaker stuck to Dumont circuit. Fault cleared with loss of Dumont circuit and X2-052 generation.	3.5 / 16	Stable (with loss of X2-052)
1B.03	Fault at X2-052 345 kV on Dumont circuit. Breaker stuck to Olive circuit. Fault cleared with loss of Olive circuit and X2-052 generation.	3.5 / 16	Stable (with loss of X2-052)
1B.04	Fault at Olive 345 kV on X2-052 circuit. Breaker stuck to Reynolds - Meadow Lake SW circuit. Fault cleared with loss of Reynolds - Meadow Lake SW circuit and Reynolds 345 kV.	3.5 / 16	Stable
1B.05	Fault at Olive 345 kV on Green Acres circuit. Breaker stuck to Cook circuit. Fault cleared with loss of Cook circuit.	3.5 / 16	Stable
1B.06	Fault at Olive 345 kV on Cook circuit. Breaker stuck to Green acres circuit. Fault cleared with loss of Green Acres circuit.	3.5 / 16	Stable
1B.07	Fault at Olive 345 kV 345/138 kV on Transformer T-2. Breaker stuck to X2-052 circuit. Fault cleared with loss of X2-052 circuit.	3.5 / 16	Stable
1B.08	Fault at Olive 345 kV Meadow Lake SW circuit. Breaker stuck to University Park circuit. Fault cleared with loss of University Park circuit.	3.5 / 16	Stable
1B.09	Fault at Olive 345 kV University Park circuit. Breaker stuck to Meadow Lake SW Circuit 1. Fault cleared with loss of Meadow Lake SW Circuit 1.	3.5 / 16	Stable
1B.10	Fault at Olive 345 kV Reynolds - Meadow Lake SW circuit. Breaker stuck to X2-052. Fault cleared with loss of X2-052 circuit.	3.5 / 16	Stable
1B.11	Fault at Dumont 345 kV on 765/345 kV Transformer 2. Breaker stuck to X2-052 circuit. Fault cleared with loss of X2-052 circuit.	3.5 / 16	Stable
1B.12	Fault at Dumont 345 kV on X2-052 circuit. Stuck breaker. Fault cleared with loss of 765/345 kV Transformer 2.	3.5 / 16	Stable
1B.13	Fault at Dumont 345 kV on Twin Branch Circuit 1. Breaker stuck to Dumont 345 kV bus. Fault cleared with loss of X2-052 circuit and Dumont 765/345 kV Transformer 1.	3.5 / 16	Stable
1B.14	Fault at Dumont 345 kV on Twin Branch Circuit 2. Breaker E2 stuck to Dumont 765/345 kV Transformer 2. Fault cleared with loss of Dumont 765/345 kV Transformer 2 and X2-052 circuit.	3.5 / 16	Stable
1B.15	Fault at Dumont 345 kV on Stillwell circuit. Breaker stuck to Twin Branch Circuit 1. Fault cleared with loss of Twin Branch Circuit 1.	3.5 / 16	Stable
1B.16	Fault at Dumont 345 kV on 765/345 kV Transformer 1. Breaker stuck to Sorenson circuit. Fault cleared with loss of Sorenson circuit.	3.5 / 16	Stable
1B.17	Fault at Dumont 345 kV on 765/345 kV Transformer 1. Breaker stuck to Twin Branch circuit. Fault cleared with loss of Twin Branch circuit.	3.5 / 16	Stable
1B.18	Fault at Dumont 345 kV on Sorenson circuit. Breaker stuck to Dumont 765/345 kV Transformer 1. Fault cleared with loss of Dumont 765/345 kV Transformer 1.	3.5 / 16	Stable

Table 5 Single-phase Faults with Delayed Clearing at Remote End

Fault ID	Fault description	Clearing time Near / Remote end (cycles)	X2-052 No Mitigation
1D.01	Fault at X2-052 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.02	Fault at X2-052 345 kV on Dumont circuit. Delayed clearing at Dumont.	3.5 / 60	Stable
1D.03	Not used	N / A	N / A
1D.04	Fault at Olive 345 kV on Green Acres circuit. Delayed clearing at Green Acres.	3.5 / 60	Stable
1D.05	Fault at Olive 345 kV on Cook circuit. Delayed clearing at Cook.	3.5 / 60	Stable
1D.06	Fault at Olive 345 kV 345/138 kV on Transformer T-2. Delayed clearing at Olive 138 kV.	3.5 / 60	Stable
1D.07	Fault at Olive 345 kV Meadow Lake SW circuit. Delayed clearing at Meadow Lake SW.	3.5 / 60	Stable
1D.08	Fault at Olive 345 kV University Park circuit. Delayed clearing at Univeristy Park.	3.5 / 60	Stable
1D.09	Fault at Olive 345 kV Reynolds - Meadow Lake SW circuit. Delayed clearing at Meadow Lake SW.	3.5 / 60	Stable
1D.10	Fault at Green Acres 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.11	Fault at Cook 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.12	Fault at Olive 138 kV on Transformer T-2. Delayed clearing at Olive 345 kV.	4.5 / 60	Stable
1D.13	Fault at Meadow Lake SW 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.14	Fault at University Park 345 kV on Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.15	Fault at Meadow Lake SW 345 kV on Reynolds - Olive circuit. Delayed clearing at Olive.	3.5 / 60	Stable
1D.16	Fault at Dumont 345 kV on 765/345 kV Transformer 2. Delayed clearing at Dumont 765 kV.	3.5 / 60	Stable
1D.17	Fault at Dumont 345 kV on X2-052 circuit. Delayed clearing at X2-052.	3.5 / 60	Stable
1D.18	Fault at Dumont 345 kV on Twin Branch Circuit 1. Delayed clearing at Twin Branch.	3.5 / 60	Stable
1D.19	Fault at Dumont 345 kV on Stillwell circuit. Delayed clearing at Stillwell.	3.5 / 60	Stable
1D.20	Fault at Dumont 345 kV on 765/345 kV Transformer 1. Delayed clearing at Dumont 765 kV.	3.5 / 60	Stable
1D.21	Fault at Dumont 345 kV on Sorenson circuit. Delayed clearing at Sorenson.	3.5 / 60	Stable
1D.22	Fault at Twin Branch 345 kV on Dumont circuit 1. Delayed clearing at Dumont.	3.5 / 60	Stable
1D.23	Fault at Stillwell 345 kV on Dumont circuit. Delayed clearing at Dumont.	3.5 / 60	Stable
1D.24	Fault at Sorenson 345 kV on Dumont circuit. Delayed clearing at Dumont.	3.5 / 60	Stable

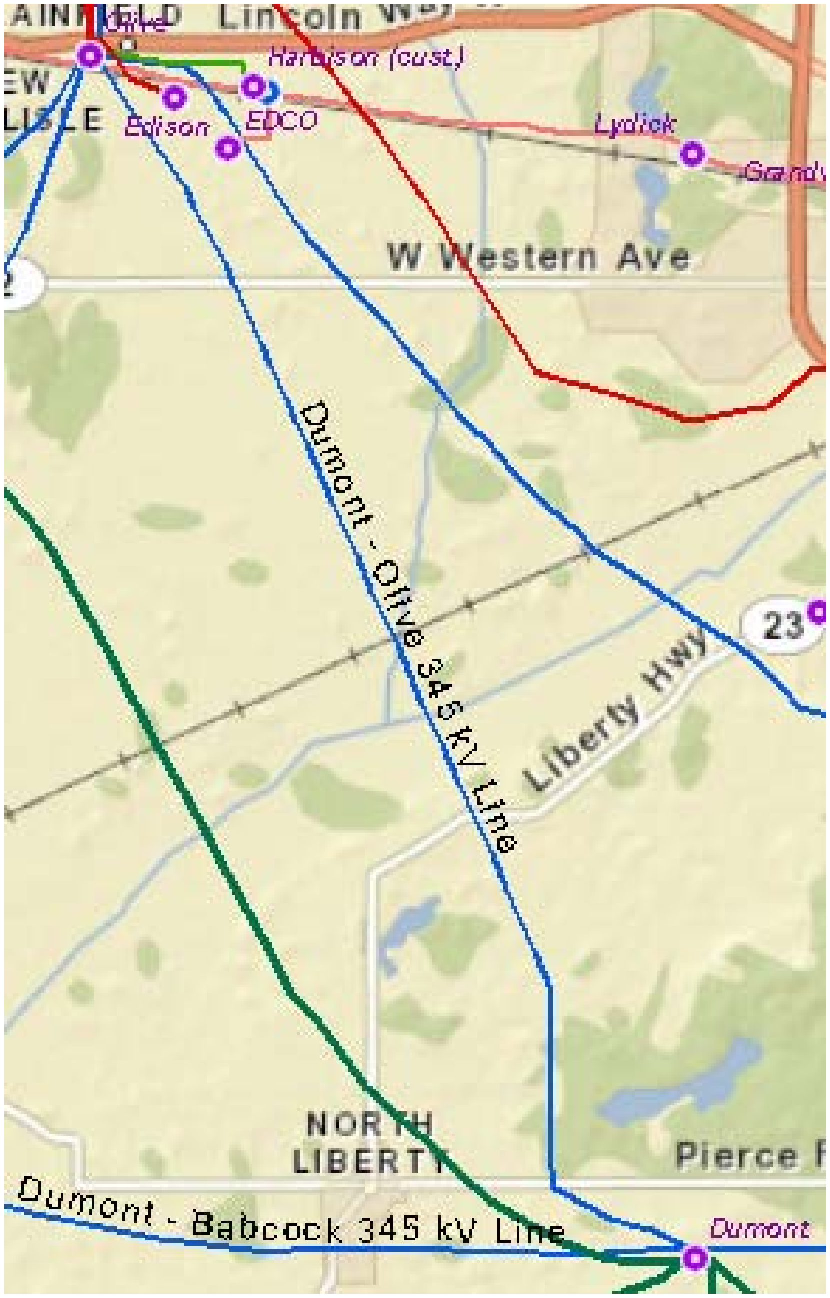

Figure 1: Approximate interconnection location of the proposed facilities

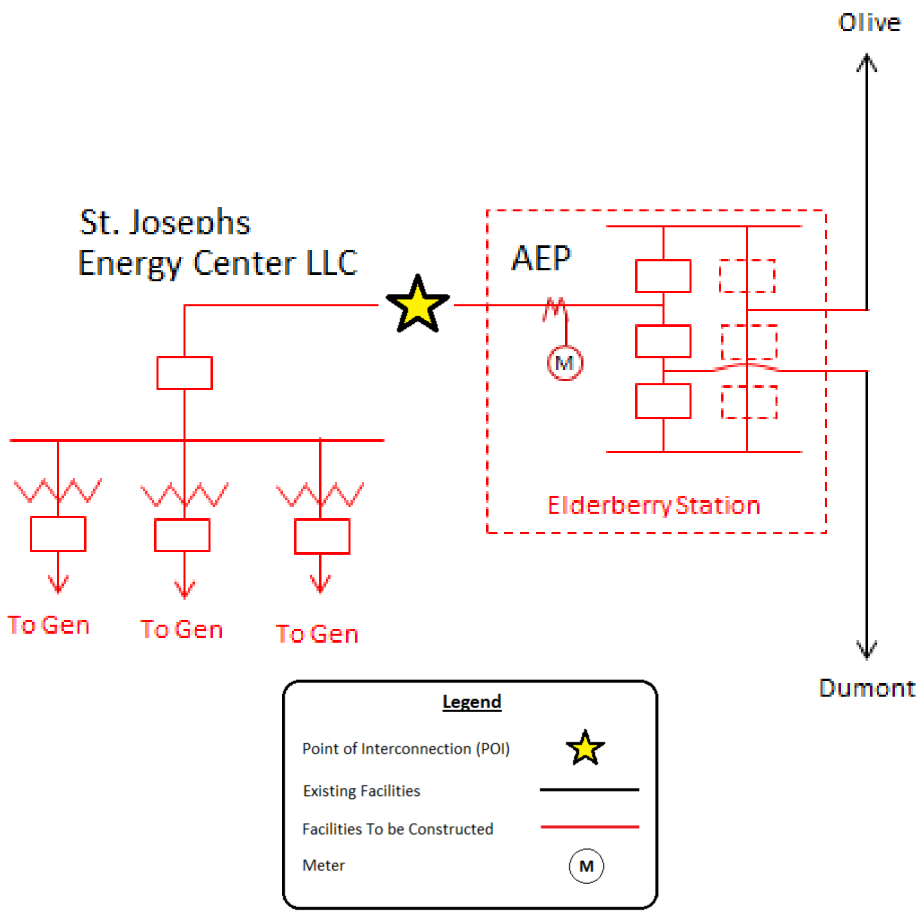

Figure 2: Simplified diagram of proposed interconnection