Revised Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AC2-075

Jacksonville – Renaker 138kV

April 2021

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

The Interconnection Customer (IC), has proposed a solar generating facility located in Harrison County, Kentucky. The installed facilities for AC2-075 will have a total capability of 20 MW with 13.4 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is June 1, 2019. **This study does not imply a EKPC commitment to this in-service date.**

This project will be installed adjacent to the existing AC1-074 solar generating facility. The installed AC1-074 facilities will have a total capability of 80 MW with 56 MW of this output being recognized by PJM as capacity. The installed facilities (AC1-074 & AC2-075) will have a total capability of 100 MW with 69.3 MW of this output being recognized by PJM as capacity.

Point of Interconnection

AC2-075 will interconnect with the EKPC Transmission system along the Jacksonville – Renaker 138kV line.

Cost Summary

The AC2-075 project will be responsible for the following costs:

Description	Cost
Attachment Facilities	$ 0
Direct Connection Network Upgrades	$ 0
Non Direct Connection Network Upgrades	$ 100,000
Allocation for New System Upgrades	$ 0

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Description	Cost
Contribution for Previously Identified Upgrades	$ 0
Total Costs	**$ 100,000**

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Attachment Facilities

There are no Attachment Facilities are required to support this interconnection.

Direct Connection Cost Estimate

There are no Direct Connection Facilities are required to support this interconnection.

Non-Direct Connection Cost Estimate

The total preliminary cost estimate for the Non-Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Total Cost
Adjust remote, relaying, and metering settings.	$ 100,000
Total Non-Direct Connection Facility Costs	**$ 100,000**

Transmission Owner Scope of Work

This study assumes that the scope of work required for the existing AC1-074 project is completed before the AC2-075 project can go in service: Build 138kv switching station at Jacksonville Tap including associated transmission line work. Estimated Time: 18 months

Interconnection Customer Requirements

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.

3. The Interconnection Customer seeking to interconnect a wind generation facility shall maintain meteorological data facilities as well as provide that meteorological data which is required per item 5.iv. of Schedule H to the Interconnection Service Agreement

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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.

EKPC Requirements

The Interconnection Customer will be required to comply with all FE Revenue Metering Requirements for Generation Interconnection Customers. The Revenue Metering Requirements may be found within the "FirstEnergy Requirements for Transmission Connected Facilities" document located at the following links:

http://www.firstenergycorp.com/feconnect
http://www.pjm.com/planning/design-engineering/to-tech-standards.aspx

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Network Impacts

The Queue Project AC2-075 was evaluated as a 20.0 MW (Capacity 13.3 MW) injection into the AC1-074 Tap 138 kV substation (which is a tap of the Jacksonville Tap – Renaker 138 kV line) in the EKPC area. Project AC2-075 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC2-075 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Summer Peak Analysis - 2020

Contingency Descriptions

The following contingencies resulted in overloads:

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

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).

None

Multiple Facility Contingency

(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)

None

Short Circuit

(Summary of impacted circuit breakers)

None

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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)

#	Contingency Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Ref
1	N-1	363_B2_TOR1682	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	DC	155.48	155.57	ER	1370	1.16	1

Note: Please see Attachment 1 for projects providing impacts to flowgate violations. The values in the Reference column correspond to the proper table in the Attachment.

Steady-State Voltage Requirements

(Summary of the VAR requirements based upon the results of the steady-state voltage studies)

See Attachment 3

Stability and Reactive Power Requirement for Low Voltage Ride Through

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

See Attachment 3

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)

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Violation #	Overloaded Facility	Upgrade Description	Network Upgrade Number	Upgrade Cost	AC2-075 Allocation
#1	7TRIMBLE-06CLIFTY 345 kV line	In order to mitigate the overloads of facilities above, the following reinforcements are required: A potential constraint was identified by PJM on the Trimble – Clifty 345 kV line (LG&E/OVEC tie line). The upgrade (LG&E) on the Trimble – Clifty 345 kV line, if determined to be a constraint by LG&E, is to reconductor the line with a high temperature conductor and upgrade necessary terminal equipment to achieve ratings of 2610/2610 MVA SN/SE. Cost estimate is $17.4M with a time estimate of 18 months. Initially an LG&E affected system study was required to determine if the AC2-075 queue project causes any impacts on the LG&E system, including the Trimble-Clifty LG&E-OVEC tie line. Final LG&E Impacts and necessary LG&E system upgrade(s) would be determined once the LG&E affected system study is completed by LG&E. In November 2019, LG&E determined that an affected systems study is **not** required for the AC2-075 project. Therefore the AC2-075 project is not responsible for this upgrade.	N5469	**$ 17,400,000**	**$ 0**
				Total New Network Upgrades	**$ 0**

Potential Congestion due to Local Energy Deliverability

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

	Contingency		Affected		Bus			Power	Loading %		Rating		MW	
#	Type	Name	Area	Facility Description	From	To	Circuit	Flow	Initial	Final	Type	MVA	Contribution	Ref
2	N-1	363_B2_TOR1682	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	AC	162.84	162.95	ER	1370	1.75	

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#	Contingency Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Ref
3	Non	Non	LGEE - OVEC	7TRIMBLE-06CLIFTY 345 kV line	324114	248000	1	AC	129.8	129.94	NR	1134	1.8	

Note: Please see Attachment 1 for projects providing impacts to flowgate violations. The values in the Reference column correspond to the proper table in the Attachment.

Affected System Analysis & Mitigation

LGEE Impacts:

None.

MISO Impacts:

None.

Duke, Progress & TVA Impacts:

None

OVEC Impacts:

None

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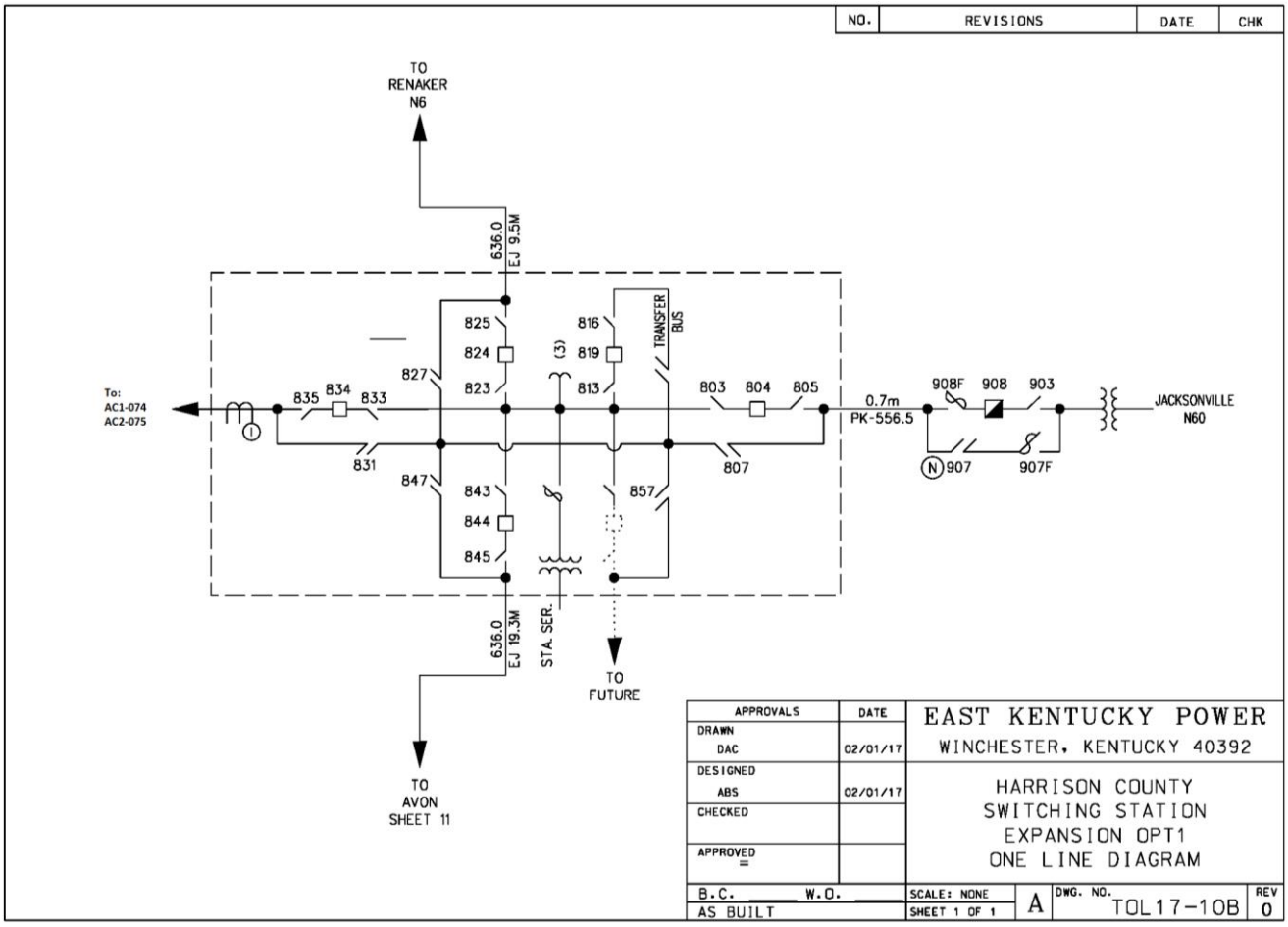
Attachment 1. Single Line Diagram



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Attachment 2. Flowgate Details

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

(LGEE - OVEC) The 7TRIMBLE-06CLIFTY 345 kV line (from bus 324114 to bus 248000 ckt 1) loads from 155.48% to 155.57% (DC power flow) of its emergency rating (1370 MVA) for the single line contingency outage of '363_B2_TOR1682'. This project contributes approximately 1.16 MW to the thermal violation.

Bus Number	Bus Name	Full Contribution
247286	05AND G2	0.4
247287	05AND G3	0.83
243442	05RKG1	19.13
243443	05RKG2	18.84
342900	1COOPER1 G	3.2
342903	1COOPER2 G	6.21
342918	1JKCT 1G	2.53
342921	1JKCT 2G	2.53
342924	1JKCT 3G	2.53
342927	1JKCT 4G	1.68
342930	1JKCT 5G	1.68
342933	1JKCT 6G	1.68
342936	1JKCT 7G	1.68
342939	1JKCT 9G	1.72
342942	1JKCT 10G	1.72
342945	1LAUREL 1G	1.81

Bus Number	Bus Name	Full Contribution
932551	AC2-075 C	1.16
933441	AC2-157 C	5.71
971181	J708	48.36
971521	J759	11.22
971531	J762	35.01
971571	J783	11.24
900404	X3-028 C	112.68
LTF	Y2-006	16.63
247629	Y3-038	0.52
LTF	Z1-046	19.47
LTF	AA1-001	5.68
LTF	AA1-004	15.79
922982	AB1-087 C OP	41.32
922992	AB1-088 C OP	41.32
926391	AC1-040 C	4.28
926731	AC1-074 C OP	4.9

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Attachment 3. Dynamic Simulation Analysis

Executive Summary

Generator Interconnection Request AC2-075 is for a 20 MW Maximum Facility Output (MFO) Solar PV Inverter plant. AC2-075 consists of 9 x TMEIC Solarware PHV L2700GR, 2.7 MVA Solar PV Inverters with a Point of Interconnection (POI) at the Harrison County Switchyard 138 kV substation, in the East Kentucky Power (EKPC) transmission system, Harrison County, Kentucky.

This study is based on the 2020_SP summer peak load case and modified to include applicable queue projects. PJM queue project AC2-075 was dispatched at a maximum power transfer of 20.0 MW and POI voltage of 138.4 kV, consistent with the default generator reference voltage specified in PJM Manual 03 *Transmission Operations* Section 3.3.3 for generator connections to the PJM 138.0 kV system.

AC2-075 was tested for compliance with NERC, PJM and other applicable criteria. 62 contingencies were studied, each with a 15 second simulation time period.

Based on the contingencies tested, AC2-075 meets for all criteria contingencies tested.

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Description

This study evaluates the stability, low voltage ride-through (LVRT) and dynamics for PJM queue project AC2-075 which is 20.0 MW MFO Solar Farm. The proposed POI is a three breaker ring bus which taps in/out existing Renaker – Jacksonville 138 kV circuit in EKPC area. The AC2-075 project is a Solar Farm made up of 9 x TMEIC Solarware PHV L2700GR, 2.7 MVA Solar PV Inverters.

Criteria

The stability study for AC2-075 was performed on a RTEP SP_2020 Summer Peak load case for normal operating conditions, and modified to include applicable queue projects. The range of contingencies evaluated was limited to those necessary to assess compliance with NERC, PJM and other applicable criteria. Simulation time was 15 seconds for all faults.

Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Single-line-to-ground on bus (slg) with normal clearing (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5) – not performed for this study
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P2, P3 and P6 faults will be studied on an as needed basis.

Other applicable criteria tested include:

1. TO specific criteria
2. Other criteria

The system was tested for an all lines in service condition and the faults listed above. Specific fault descriptions and breaker clearing times used for this study are provided in Appendix A.

All generators were monitored to assess transient stability and satisfactory post-contingency conditions.

Case Setup

Generators within 5 to 8 buses from the generator(s) under study are dispatched at their maximum power output and set at unity power factor at the high side of the generator step up transformer. Alternatively, generators can be adjusted to hold scheduled voltages.

Specific dispatch conditions at the generator terminals for the AC2-075 generator, as obtained in the power flow solution, are illustrated below:

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	9 TMEIC Solar War 2.3 MW Inverters
Gross power output (MW)	20.7
Reactive power output (MVARS)	0
Auxiliary Load (MW/MVARS)	0.6, 0.0
Station Service Load (MW/MVARS)	
Net real power injection (MW)	20.0
Voltage at the POI (P.U.)	1.00

Results

Simulation Initialization
The case was initialized successfully. No errors were reported.

20 second no fault test (Steady State evaluation)
The system successfully met the 20 second run test without any significant deviations in system states.

Simulation Results
Dynamics and stability was tested using Siemens/PTI PSS/E Version 33.7, the 2020 case with a Summer Peak Load condition and the data supplied by the developer.

Transient Stability: For all contingencies studied, transient stability is maintained, with all oscillations stabilized in less than 15 seconds. Also, the voltage levels returned to acceptable levels for all contingencies following the fault clearance. Hence, no transient stability issues were identified for contingencies tested.

LVRT: For the cases studied, the queue project rides through the faults shown in Appendix A thus meeting the LVRT test specified in FERC order 661 and 661A.

Small Signal (if applicable):

SPS:

Maintenance outage: No maintenance outage conditions were evaluated.

Conclusion

Transient stability is maintained for all contingencies tested.

Mitigations:

None

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Recommendations:
None

Appendix A: Fault Table

No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
Criteria = TPL 001-4_P1					
01	AC1-074-TAP-P1-01	3ph fault on AC1-074/AC2-075 Tap – Renaker 138 kV	6.0	N/A	OK
02	AC1-074-TAP-P1-01	3ph fault on AC1-074 /AC2-075 Tap – Jacksonville – Avon 138 kV	6.0	N/A	OK
03	AC1-074-RENA-P1-01	3ph fault on Renaker – Spurlock 138 kV	6.0	N/A	OK
04	AC1-074-RENA-P1-02	3ph fault on Renaker – Bavarian / Boone 138 kV	6.0	N/A	OK
05	AC1-074-RENA-P1-03	3ph fault on Renaker 138/69 kV TF	6.0	N/A	OK
06	AC1-074-RENA-P1-04	3ph fault on Renaker – Colemansville– Bracken Co 69 kV	8.0	N/A	OK
07	AC1-074-RENA-P1-05	3ph fault on Renaker – KU Cynthiana – KU Millersburg 69 kV	8.0	N/A	OK
08	AC1-074-RENA-P1-06	3ph fault on Renaker – Three M - Headquarters69 kV	8.0	N/A	OK
09	AC1-074-RENA-P1-07	3ph fault on Renaker – Williamstown 69 kV	8.0	N/A	OK
10	AC1-074-RENA-P1-08	3ph fault on Renaker – Lees Lick – KU Scott 69 kV	8.0	N/A	OK
11	AC1-074-SPUR-P1-01	3ph fault on Spurlock – Stanley Parker 138 kV (N Bus)	6.0	N/A	OK
12	AC1-074-SPUR-P1-02	3ph fault on Spurlock – Renaker 138 kV (S Bus)	6.0	N/A	OK
13	AC1-074-SPUR-P1-03	3ph fault on Spurlock – Maysville – Plumville 138 kV (N Bus)	6.0	N/A	OK
14	AC1-074-SPUR-P1-04	3ph fault on Spurlock – Flemingsburg / Goddard 138 kV (S Bus)	6.0	N/A	OK
15	AC1-074-SPUR-P1-05	3ph fault on Spurlock – Kenton 138 kV (N Bus)	6.0	N/A	OK
16	AC1-074-SPUR-P1-06	3ph fault on Spurlock – Inland 138 kV (S Bus)	6.0	N/A	OK
17	AC1-074-SPUR-P1-07	3ph fault on Spurlock G1	6.0	N/A	OK
18	AC1-074-SPUR-P1-08	3ph fault on Spurlock 138/345 kV TF 9	6.0	N/A	OK
19	AC1-074-SPUR-P1-09	3ph fault on Spurlock 138/345 kV TF 10	6.0	N/A	OK
20	AC1-074-SPUR-P1-10	3ph fault on Spurlock 138/345 kV TF 12	6.0	N/A	OK
21	AC1-074-AVON-P1-01	3ph fault on Avon – Jacksonville – AC2-075 Tap 138 kV	6.0	N/A	OK
22	AC1-074-AVON-P1-02	3ph fault on Avon – Fayette 138 kV	6.0	N/A	OK
23	AC1-074-AVON-P1-03	3ph fault on Avon – Beck – Boonesboro N – Dale 138 kV	6.0	N/A	OK
24	AC1-074-AVON-P1-04	3ph fault on Avon 138/345 kV TF	6.0	N/A	OK
25	AC1-074-AVON-P1-04	3ph fault on Avon – KU Loudon 138kV	6.0	N/A	OK
Criteria = TPL 001-4_P2					
26	AC1-074-TAP-P2-01	SLG fault on AC1-074 Tap, Loss of AC1-074 Tap 138 kV Bus	6.0	N/A	OK
27	AC1-074-RENA-P2-01	SLG fault on Renaker 138 kV Bus, Loss of Renaker 138 kV Bus	6.0	N/A	OK
28	AC1-074-RENA-P2-02	SLG fault on Renaker 69 kV Bus, Loss of Renaker 69 kV Bus	8.0	N/A	OK
29	AC1-074-SPUR-P2-01	SLG fault on Spurlock 138 kV North Bus, Loss of Spurlock 138 kV North Bus (11,13,15,17 and 18)	8.0	N/A	OK
30	AC1-074-SPUR-P2-02	SLG fault on Spurlock 138 kV South Bus, Loss of Spurlock 138 kV South Bus (12,14,16 and 19,20)	8.0	N/A	OK
		Avon is Ring Bus. Bus fault will impact one element / circuit at a			

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No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
		time			
Criteria = TPL 001-4_P4					
31	AC1-074-TAP-P4-01	SLG fault on AC1-074 Tap – Renaker 138 kV, SB '824' at AC1-074, Loss of AC1-074 138 kV Bus	6.0	14.0	OK
32	AC1-074-TAP-P4-02	SLG fault on AC1-074 Tap – Jacksonville – Avon 138 kV, SB '844' at AC1-074, Loss of AC1-074 138 kV Bus	6.0	14.0	OK
33	AC1-074-TAP-P4-03	SLG fault on AC1-074 Tap – unit 138 kV, SB '834' at AC1-074, Loss of AC1-074 138 kV Bus	6.0	14.0	OK
34	AC1-074-RENA-P4-01	SLG fault on Renaker – Spurlock 138 kV, SB '844' at Renaker 138 kV, Loss of Renaker 138 kV Bus	6.0	15.0	OK
35	AC1-074-RENA-P4-02	SLG fault on Renaker – Bavarian / Boone 138 kV, SB '824' at Renaker 138 kV, Loss of Renaker 138 kV Bus	6.0	15.0	OK
36	AC1-074-RENA-P4-03	SLG fault on Renaker 138/69 kV TF, SB '808' at Renaker 138 kV, Loss of Renaker 138 kV Bus	6.0	15.0	OK
37	AC1-074-RENA-P4-04	SLG fault on Renaker – AC2-075 Tap 138 kV, SB '814' at Renaker 138 kV, Loss of Renaker 138 kV Bus	6.0	15.0	OK
38	AC1-074-RENA-P4-05	SLG fault on Renaker 69/138 kV TF, SB '648' at Renaker 69 kV, Loss of Renaker 69 kV Bus	8.0	19.0	OK
39	AC1-074-RENA-P4-06	SLG fault on Renaker – Colemansville –Bracken Co69 kV, SB '624' at Renaker 69 kV, Loss of Renaker 69 kV Bus	8.0	19.0	OK
40	AC1-074-RENA-P4-07	SLG fault on Renaker – KU Cynthiana 69 kV, SB '664' at Renaker 69 kV, Loss of Renaker 69 kV Bus	8.0	19.0	OK
41	AC1-074-RENA-P4-08	SLG fault on Renaker – Three M - Headquarters69 kV, SB '604' at Renaker 69 kV, Loss of Renaker 69 kV Bus	8.0	19.0	OK
42	AC1-074-RENA-P4-09	SLG fault on Renaker-Williamstown 69kV, SB '634' at Renaker 69kV, Loss of Renaker 69kV Bus	8.0	19.0	OK
43	AC1-074-RENA-P4-10	SLG fault on Renaker – Lees Lick – KU Scott 69 kV, SB '614' at Renaker 69 kV, Loss of Renaker 69 kV Bus	8.0	19.0	OK
44	AC1-074-SPUR-P4-01	SLG fault on Spurlock – Stanley Parker 138 kV (N Bus), SB '814' at Spurlock 138 kV North Bus, Loss of Spurlock 138 kV North Bus	6.0	14.0	OK
46	AC1-074-SPUR-P4-02	SLG fault on Spurlock – Maysville – Plumville 138 kV (N Bus), SB '834' at Spurlock 138 kV North Bus, Loss of Spurlock 138 kV North Bus	6.0	14.0	OK
47	AC1-074-SPUR-P4-03	SLG fault on Spurlock – Kenton 138 kV (N Bus), SB '854' at Spurlock 138 kV North Bus, Loss of Spurlock 138 kV North Bus	6.0	14.0	OK
48	AC1-074-SPUR-P4-04	SLG fault on Spurlock G1, SB '18G' at Spurlock 138 kV South Bus, Loss of Spurlock 138 kV South Bus	6.0	14.0	OK
49	AC1-074-SPUR-P4-05	SLG fault on Spurlock 138/345 kV TF 9, SB '878' at Spurlock 138 kV North Bus, Loss of Spurlock 138 kV North Bus	6.0	14.0	OK
50	AC1-074-SPUR-P4-05	SLG fault on Spurlock – Renaker 138 kV (S Bus), SB '824' at Spurlock 138 kV South Bus, Loss of Spurlock 138 kV South Bus	6.0	15.0	OK
50	AC1-074-SPUR-P4-05	SLG fault on Spurlock – Flemingsburg / Godard 138 kV (S Bus), SB '844' at Spurlock 138 kV South Bus, Loss of Spurlock 138 kV South Bus	6.0	15.0	OK
51	AC1-074-SPUR-P4-05	SLG fault on Spurlock – Inland 138 kV (S Bus), SB '864' at Spurlock 138 kV South Bus, Loss of Spurlock 138 kV South Bus	6.0	15.0	OK
52	AC1-074-SPUR-P4-05	SLG fault on Spurlock 138/345 kV TF 10, SB '888' at Spurlock 138 kV S Bus, Loss of Spurlock 138 kV South Bus	6.0	15.0	OK
53	AC1-074-AVON-P4-01	SLG fault on Avon – Jacksonville – AC2-075 Tap 138 kV, SB '844' at Avon 138 kV, Loss of Avon-KU Loudon 138kV line	6.0	15.0	OK
54	AC1-074-AVON-P4-02	SLG fault on Avon – Jacksonville – AC2-075 Tap 138 kV, SB '834' at Avon 138 kV, Loss of Avon 138/345 kV TF	6.0	15.0	OK

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No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
55	AC1-074-AVON-P4-03	SLG fault on Avon 138/345 kV TF, SB '834' at Avon 138 kV, Loss of Avon – Jacksonville – AC2-075 Tap 138 kV	6.0	15.0	OK
56	AC1-074-AVON-P4-04	SLG fault on Avon 138/345 kV TF, SB '814' at Avon 138 kV, Loss of Avon – Becknerville – Boonesboro – Dale 138 kV	6.0	15.0	OK
57	AC1-074-AVON-P4-05	SLG fault on Avon – Becknerville – Boonesboro – Dale 138 kV, SB '814' at Avon 138 kV, Loss of Avon 138/345 kV TF	6.0	15.0	OK
58	AC1-074-AVON-P4-06	SLG fault on Avon – Becknerville – Boonesboro – Dale 138 kV, SB '824' at Avon 138 kV, Loss of Avon – Fayette 138 kV	6.0	15.0	OK
59	AC1-074-AVON-P4-07	SLG fault on Avon – Fayette 138 kV, SB '824' at Avon 138 kV, Loss of Avon – Becknerville – Boonesboro – Dale 138 kV	6.0	15.0	OK
60	AC1-074-AVON-P4-08	SLG fault on Avon-Fayette 138kV, SB '864' at Avon 138kV, Loss of Avon – KU Loudon 138kV	6.0	15.0	OK
Criteria = TPL 001-4_P5					
		Not required – Communication redundancy			
Criteria = TPL 001-4_P7					
61	AC1-074-SPUR-P7-01	SLG fault on Spurlock – Stanley Parker 138 kV (N Bus) + Spurlock – Renaker 138 kV (S Bus)	6.0	N/A	OK
62	AC1-074-SPUR-P7-02	SLG fault on Spurlock – Maysville – Plumville 138 kV (N Bus) + Spurlock – Flemingsburg / Goddard 138 kV (S Bus)	6.0	N/A	OK

Appendix B: Project Model

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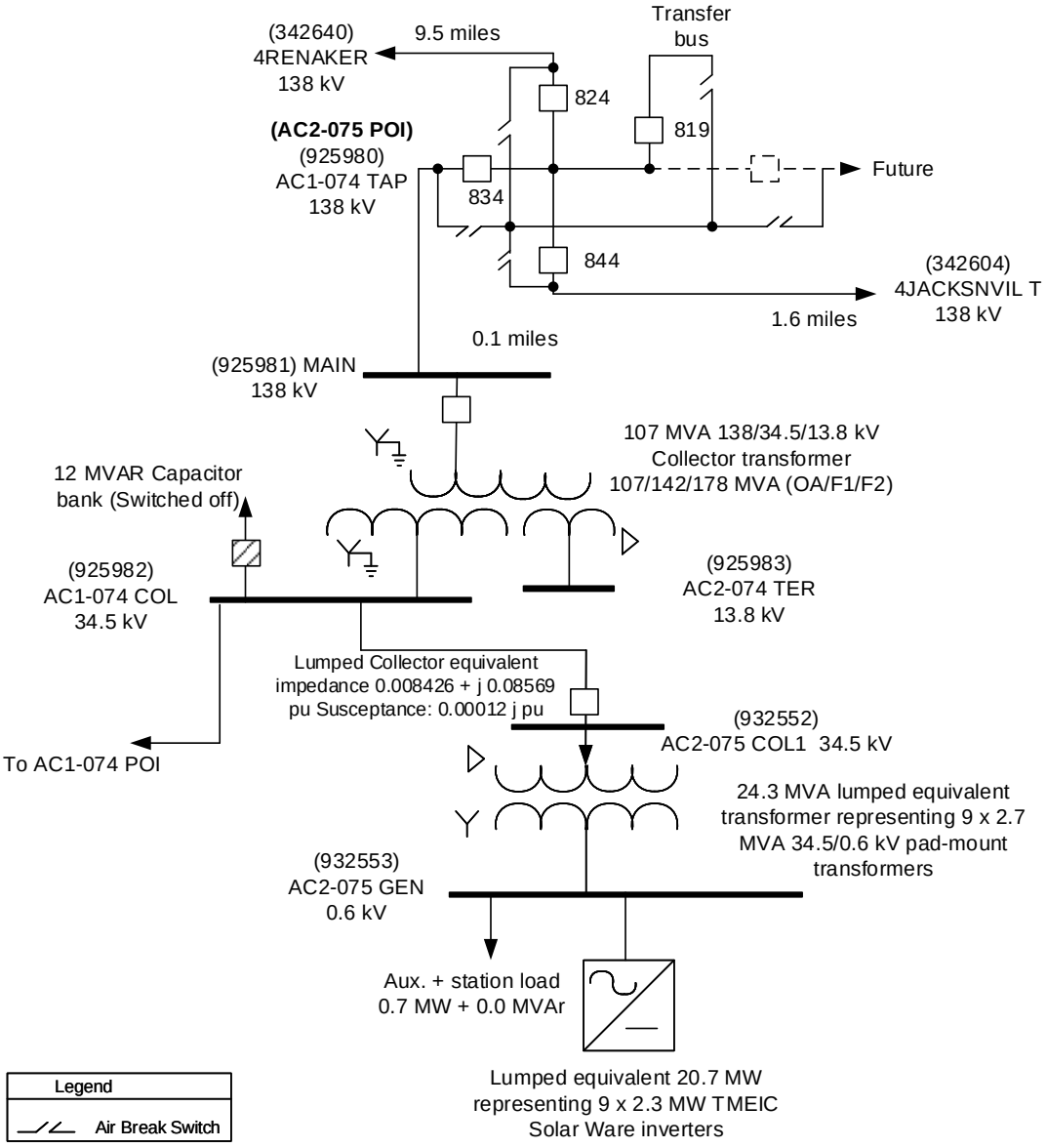

Figure B-1: PJM AC2-075 modeling details

Appendix C: Power Flow and Dynamic Models

C.1) Power Flow Model Data

Table 1: AC2-075 Plant Model

	Impact Study Data	Model
Solar PV Inverter	Lumped equivalent representing 9 x 2.3 MW TMEIC Solarware PHV-L2700GR Solar PV Inverter MVA base = 2.7 MVA Vt = 0.6 kV Unsaturated sub-transient reactance = not provided MVAr limits = +/- 12.7 MVAr	Lumped equivalent representing 9 x 2.3 MW TMEIC Solarware PHV-L2700GR Solar PV Inverters Pgen = 20.7 MW Pmax = 20.7 MW Pmin = 0 MW Qmax = 6.831 MVAr [1] Qmin = -6.831 MVAr Mbase = 24.3 MVA Zsorce = 999999 pu @ Mbase
GSU Transformer	9 x 34.5/0.6 kV transformer Rating = 2.7 MVA Transformer base = 2.7 MVA Impedance: High to Low: 0.0045 +j 0.067 pu Number of taps = N/A Tap step size = N/A	Lumped equivalent representing 9 x 34.5/0.6 kV 2.7 MVA transformer Rating = 24.3 MVA Transformer base = 24.3 MVA Impedance: High to Low: 0.0045 +j 0.067 pu Number of taps = 5 Tap step size = 2.5 %
Auxiliary Load	0.02 MW + 0.005 MVAr	Auxiliary + Station service load 0.6 MW + 0.0 MVAr connected to the low voltage side of GSU transformer
Station Load	0.02 MW + 0.008 MVAr	
Lumped Collector Equivalent Impedance	Impedance : 0.008426 + j 0.08569 pu Charging Susceptance: 0.00012 j pu @ 100 MVA base	Impedance : 0.008426 + j 0.08569 pu Charging Susceptance: 0.00012 j pu @ 100 MVA base

[1] MVAr limits were obtained from file :-"AC2-075 Data Review.xlsx"

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```
VERSION 33
RDCH
1
932552,'AC2-075 COL1',  34.5000,1, 320,   1,   1,1.00987,  14.0843,1.10000,0.90000,1.10000,0.90000
932553,'AC2-075 GEN1',   0.6000,2, 320,   1,   1,1.01100, -12.8153,1.10000,0.90000,1.10000,0.90000
0 / END OF BUS DATA, BEGIN LOAD DATA
932553,'1 ',1, 320,   1,     0.600,     0.000,     0.000,     0.000,     0.000,     0.000,   1,1,0
0 / END OF LOAD DATA, BEGIN FIXED SHUNT DATA
0 / END OF FIXED SHUNT DATA, BEGIN GENERATOR DATA
932553,'1 ',    20.7000,    -0.381,     6.831,    -6.831,1.01087,925980,    24.300, 0.00000E+0,
9.9999900E+5, 0.00000E+0, 0.00000E+0,1.00000,1,  100.0,    20.700,     0.000,   1,1.0000,   0,   1.0,
  0,   1.0,   0,   1.0,1, 1.0000
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
925982,932552,'1 ', 8.42600E-3, 8.56900E-2,   0.00012,    0.00,    0.00,    0.00,  0.00000,  0.00000,
 0.00000,  0.00000,1,2,   0.00,   1,1.0000
0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA
932552,932553,     0,'1 ',3,2,1, 0.00000E+0, 0.00000E+0,2,'1           ',1,   1,1.0000,   0,1.0000,
0,1.0000,   0,1.0000,'Dy1
 4.50000E-3, 6.70000E-2,    24.30
1.00000,  34.500,  30.000,    24.30,    24.30,    24.30, 0,      0, 1.05000, 0.95000, 1.05000,
0.95000,   5, 0, 0.00000, 0.00000,  0.000
1.00000,   0.600
0 / END OF TRANSFORMER DATA, BEGIN AREA DATA
 320,     0,     0.000,    10.000,'EKPC        '
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
0 / END OF VSC DC LINE DATA, BEGIN IMPEDANCE CORRECTION DATA
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA
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0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
   1,'CHICAGO     '
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
   1,'CENT HUD    '
0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA
0 / END OF FACTS DEVICE DATA, BEGIN SWITCHED SHUNT DATA
0 / END OF SWITCHED SHUNT DATA, BEGIN GNE DATA
0 / END OF GNE DATA, BEGIN INDUCTION MACHINE DATA
0 / END OF INDUCTION MACHINE DATA
Q
```

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Dynamic Data

```
/*****************************************************
/*** Project: AC2-075  - MFO   20 MW
/*** POI: Harrison county switchyard kV substation
/*** Fuel:  Solar
/*** Inverter:  TMEIC Solarware PHV-L2700GR
/*** Size: 20 MW (9 x  2.3 MW  Solar PV Inverter)
/*** PSSE Version 33
/*****************************************************

932553 'USRMDL' '1' 'PVGU1' 101         1 0 9 3 3
0.02    0.02    0.0     0.1     2.0
2               1.0     2.0     0.02 /
932553 'USRMDL' '1' 'PVEU1' 102 0 4 24 10 4
925980  0       1       0
0.1             13              2                       0                       0
0               0.08    0.415           -0.415          0.91
0.02            1               -1                       0.05           0.1
0.9             1.1     120                     0.05            0.02
1.01            0.852   1                       27 /
93255301 'VTGTPAT' 925980 932553 1 -1 1.200 0 0.0 /
93255302 'VTGTPAT' 925980 932553 1 -1 1.175 0.2 0.0 /
93255303 'VTGTPAT' 925980 932553 1 -1 1.15 0.5 0.0 /
93255304 'VTGTPAT' 925980 932553 1 -1 1.10 1 0.0 /
93255305 'VTGTPAT' 925980 932553 1 0.1 5 0.600 0.0 /
93255306 'VTGTPAT' 925980 932553 1 0.35 5 1.4 0.0 /
93255307 'VTGTPAT' 925980 932553 1 0.600 5 2.2 0.0 /
93255308 'VTGTPAT' 925980 932553 1 0.85 5 3.0 0.0 /
93255309 'FRQTPAT' 925980 932553 1 -100 61.8 0 0.0 /
93255310 'FRQTPAT' 925980 932553 1 -100 60.5 600.66 0.0 /
93255311 'FRQTPAT' 925980 932553 1 57.8  100 0 0.0 /
93255312 'FRQTPAT' 925980 932553 1 59.5  100 1792.049 0.0 /
```

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C.2) PSS/E Single Line Diagram

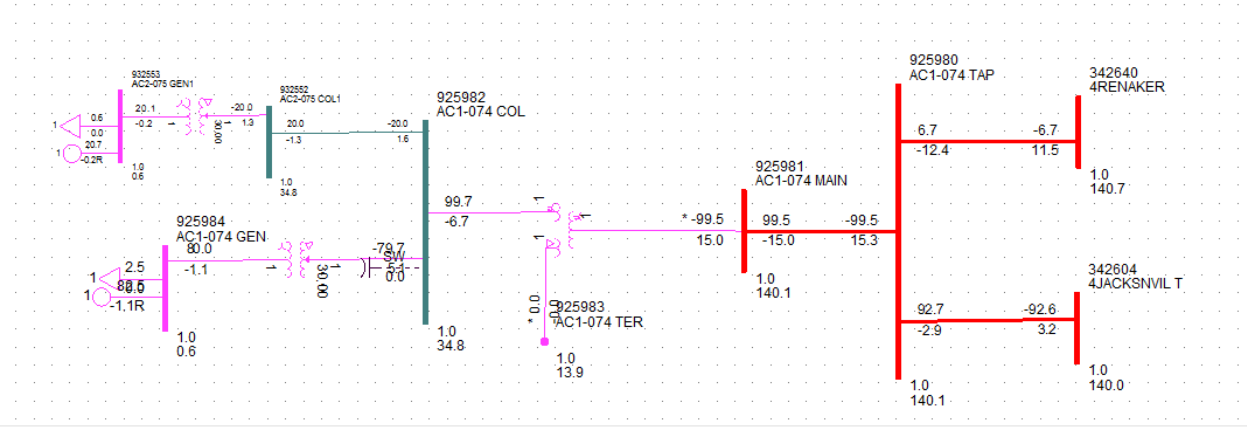

Figure C-1: Single-line diagram for AC2-075 2020-SP case (Breaker information not shown)

C.3) Area Generation

Bus Number	Bus Name	Id	VSched (pu)	Remote Bus Number	In Service	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)	Mbase (MVA)
248005	06KYGER 345.00	1	1.02	0	1	72.0	72.6	22.2	11.8	20.3	-22.6	100.0
248005	06KYGER 345.00	2	1.02	0	1	72.0	72.6	22.2	11.8	20.3	-22.6	95.0
248005	06KYGER 345.00	3	1.02	0	1	72.0	72.6	22.2	11.8	20.3	-22.6	95.0
248005	06KYGER 345.00	4	1.02	0	1	72.0	72.6	22.2	11.8	20.3	-22.6	95.0
248005	06KYGER 345.00	5	1.02	0	1	72.0	72.6	22.2	11.8	20.3	-22.6	95.0
248005	06KYGER 345.00	6	1.02	0	1	123.0	123.6	37.8	20.2	34.5	-38.6	117.7
248005	06KYGER 345.00	7	1.02	0	1	123.0	123.6	37.8	20.2	34.5	-38.6	123.4
248005	06KYGER 345.00	8	1.02	0	1	123.0	123.6	37.8	20.2	34.5	-38.6	123.4
248005	06KYGER 345.00	9	1.02	0	1	123.0	123.6	37.8	20.2	34.5	-38.6	123.4
248005	06KYGER 345.00	A	1.02	0	1	123.0	123.6	37.8	20.2	34.5	-38.6	123.4
251968	08ZIMRHP 26.000	1	1.0261	249577	1	870.0	872.0	420.0	205.0	205.0	-86.6	975.0
251969	08ZIMRLP 22.000	1	1.0261	249577	1	476.0	478.0	230.0	102.1	102.1	-43.1	780.0
253038	09KILLEN 345.00	2	1.0377	0	1	610.0	612.0	230.0	199.0	199.0	-63.0	734.0
253038	09KILLEN 345.00	3	1.0377	0	1	16.9	18.0	15.7	18.0	18.0	-10.2	33.7
253077	09STUART 345.00	1	1.0145	0	1	580.0	580.6	300.0	5.6	280.0	-17.0	678.0
253077	09STUART 345.00	2	1.0145	0	1	580.0	580.0	300.0	5.6	280.0	-30.0	678.0
253077	09STUART 345.00	3	1.0145	0	1	580.0	580.4	300.0	8.0	280.0	8.0	678.0
253077	09STUART 345.00	4	1.0145	0	1	577.0	577.0	300.0	5.6	280.0	-30.0	678.0
253077	09STUART 345.00	5	1.0145	0	1	7.7	9.2	0.0	0.1	8.8	-5.2	13.0
253110	09ADKINS 345.00	1	1.0022	0	1	82.0	82.0	38.0	24.0	24.0	-15.0	108.0
253110	09ADKINS 345.00	2	1.0022	0	1	82.0	82.0	38.0	22.0	22.0	-16.0	108.0
253110	09ADKINS 345.00	3	1.0022	0	1	81.0	81.0	38.0	22.0	22.0	-13.0	108.0

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Bus Number	Bus Name	Id	VSched (pu)	Remote Bus Number	In Service	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)	Mbase (MVA)
253110	09ADKINS 345.00	4	1.0022	0	1	80.0	80.0	38.0	22.0	22.0	-14.0	108.0
253110	09ADKINS 345.00	5	1.0022	0	1	82.0	82.0	38.0	27.0	27.0	-13.0	108.0
253110	09ADKINS 345.00	6	1.0022	0	1	79.0	79.0	38.0	25.0	25.0	-14.0	108.0
324017	1GHNT 1 18.000	1	1.018	324253	1	519.0	519.0	180.0	115.4	226.0	-156.0	640.0
342018	1GHNT 2 22.000	2	1.0203	324105	1	528.0	528.0	168.0	96.5	255.0	-68.0	618.2
342019	1GHNT 3 22.000	3	1.0203	324105	1	528.0	528.0	168.0	96.5	255.0	-68.0	618.2
342020	1GHNT 24 22.000	4	1.0203	324105	1	512.0	512.0	181.0	96.5	268	-43.0	618.0
342918	1JKCT 1G 13.800	1	1	0	1	110.0	110.0	0.0	-2.3	78.0	-60.3	140.0
342921	1JKCT 2G 13.800	1	1	0	1	110.0	110.0	0.0	-2.4	78.0	-60.3	140.0
342924	1JKCT 3G 13.800	1	1	0	1	110.0	110.0	0.0	-2.4	78.0	-60.3	140.0
342927	1JKCT 4G 13.800	1	1	0	1	73.0	73.0	0.0	18.5	40.0	-34.5	103.0
342930	1JKCT 5G 13.800	1	1	0	1	73.0	73.0	0.0	18.5	40.0	-34.5	103.0
342933	1JKCT 6G 13.800	1	1	0	1	73.0	73.0	0.0	17.7	72.5	-42.7	103.0
342936	1JKCT 7G 13.800	1	1	0	1	73.0	73.0	0.0	17.7	72.5	-42.7	103.0
342939	1JKCT 9G 13.800	1	1	0	1	73.0	76.0	0.0	38.8	41.8	-76.0	127.3
342942	1JKCT 10G 13.800	1	1	0	1	76.0	76.0	0.0	39.3	41.8	-76.0	127.3
342957	1SPURLK1G 22.000	1	1	0	1	344.0	344.0	100.0	127.4	175.0	-142.0	360.0
342960	1SPURLK2G 22.000	1	1	0	1	554.0	555.0	210.0	208.0	290.0	-227.0	636.6
342963	1SPURLK3G 18.000	1	1	0	1	304.0	306.0	80.0	128.6	268.0	-138.2	387.5
342966	1SPURLK4G 18.000	1	1	0	1	304.0	306.0	80.0	128.6	268.0	-138.2	387.5
894753	V3-045 G1 13.800	1	1.0109	250154	1	37.3	37.3	0.0	1.4	16.0	-16.0	40.3
894754	V3-045 G2 13.800	1	1.0109	250154	1	37.3	37.3	0.0	1.4	16.0	-16.0	40.3
894755	V3-045 G3 13.800	1	1.0109	250154	1	37.3	37.3	0.0	1.4	16.0	-16.0	40.3
932553	AC2-075 GEN 0.6000	1	1	0	1	20.7	20.7	0.0	-1.0	6.831	-6.831	24.3
925984	AC1-074 GEN 0.6000	1	1	0	1	82.5	82.5	0.0	-1.0	33.7	-33.7	89.1
931183	AB1-169 CT1 25.000	1	1.0145	253077	1	341.0	341.0	0.0	99.7	165.6	-112.4	380.0
931184	AB1-169 ST1 25.000	1	1.0145	253077	1	243.6	243.6	0.0	99.7	300.0	-177.0	437.0
931185	AB1-169 CT2 25.000	1	1.0145	253077	1	341.0	341.0	0.0	99.7	165.6	-112.4	380.0
931186	AB1-169 ST2 25.000	1	1.0145	253077	1	243.6	243.6	0.0	99.7	300.0	-177.0	437.0

C.4) Area Plants

Bus Number	Bus Name	Code	PGen (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)	VSched (pu)	Remote Bus Number	Remote Bus Name	Voltage (pu)	RMPCT
248005	06KYGER 345.00	2	975	160	274	-306	1.02	0		1.02	100
251968	08ZIMRHP 26.000	-2	870	205	205	-86.6	1.0261	249577	08ZIMER 345.00	1.0166	58
251969	08ZIMRLP 22.000	-2	476	102.1	102.1	-43.1	1.0261	249577	08ZIMER 345.00	1.0166	42
253038	09KILLEN 345.00	-2	626.9	217	217	-73.2	1.0377	0		1.025	100
253077	09STUART 345.00	2	2324.7	24.9	1128.8	-74.2	1.0145	0		1.0145	25

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Bus Number	Bus Name	Code	PGen (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)	VSched (pu)	Remote Bus Number	Remote Bus Name	Voltage (pu)	RMPCT
253110	09ADKINS 345.00	-2	486	142	142	-85	1.0022	0		0.9981	100
324017	1GHNT 1 18.000	2	519	115.4	226	-156	1.018	324253	4GHENT 138.00	1.018	100
342918	1JKCT 1G 13.800	2	110	-2.3	78	-60.3	1	0		1	100
342921	1JKCT 2G 13.800	2	110	-2.4	78	-60.3	1	0		1	100
342924	1JKCT 3G 13.800	2	110	-2.4	78	-60.3	1	0		1	100
342927	1JKCT 4G 13.800	2	73	18.5	40	-34.5	1	0		1	100
342930	1JKCT 5G 13.800	2	73	18.5	40	-34.5	1	0		1	100
342933	1JKCT 6G 13.800	2	73	17.7	72.5	-42.7	1	0		1	100
342936	1JKCT 7G 13.800	2	73	17.7	72.5	-42.7	1	0		1	100
342939	1JKCT 9G 13.800	2	73	38.8	41.8	-76	1	0		1	10
342942	1JKCT 10G 13.800	2	76	39.3	41.8	-76	1	0		1	10
342957	1SPURLK1G 22.000	2	344	127.4	175	-142	1	0		1	100
342960	1SPURLK2G 22.000	2	554	208	290	-227	1	0		1	100
342963	1SPURLK3G 18.000	2	304	128.6	268	-138.2	1	0		1	100
342966	1SPURLK4G 18.000	2	304	128.6	268	-138.2	1	0		1	100
894753	V3-045 G1 13.800	2	37.3	1.4	16	-16	1.0109	250154	08MELDLS 138.00	1.0109	100
894754	V3-045 G2 13.800	2	37.3	1.4	16	-16	1.0109	250154	08MELDLS 138.00	1.0109	100
894755	V3-045 G3 13.800	2	37.3	1.4	16	-16	1.0109	250154	08MELDLS 138.00	1.0109	100
932553	AC2-075	2	20.7	1	6.381	-6.381	1.01	0		1	100
925984	AC1-074 GEN 0.6000	2	82.5	-1	33.6	-33.6	1	0		1	100
931183	AB1-169 CT1 25.000	2	341	99.7	165.6	-112.4	1.0145	253077	09STUART 345.00	1.0145	100
931184	AB1-169 ST1 25.000	2	243.6	99.7	300	-177	1.0145	253077	09STUART 345.00	1.0145	100
931185	AB1-169 CT2 25.000	2	341	99.7	165.6	-112.4	1.0145	253077	09STUART 345.00	1.0145	100
931186	AB1-169 ST2 25.000	2	243.6	99.7	300	-177	1.0145	253077	09STUART 345.00	1.0145	100

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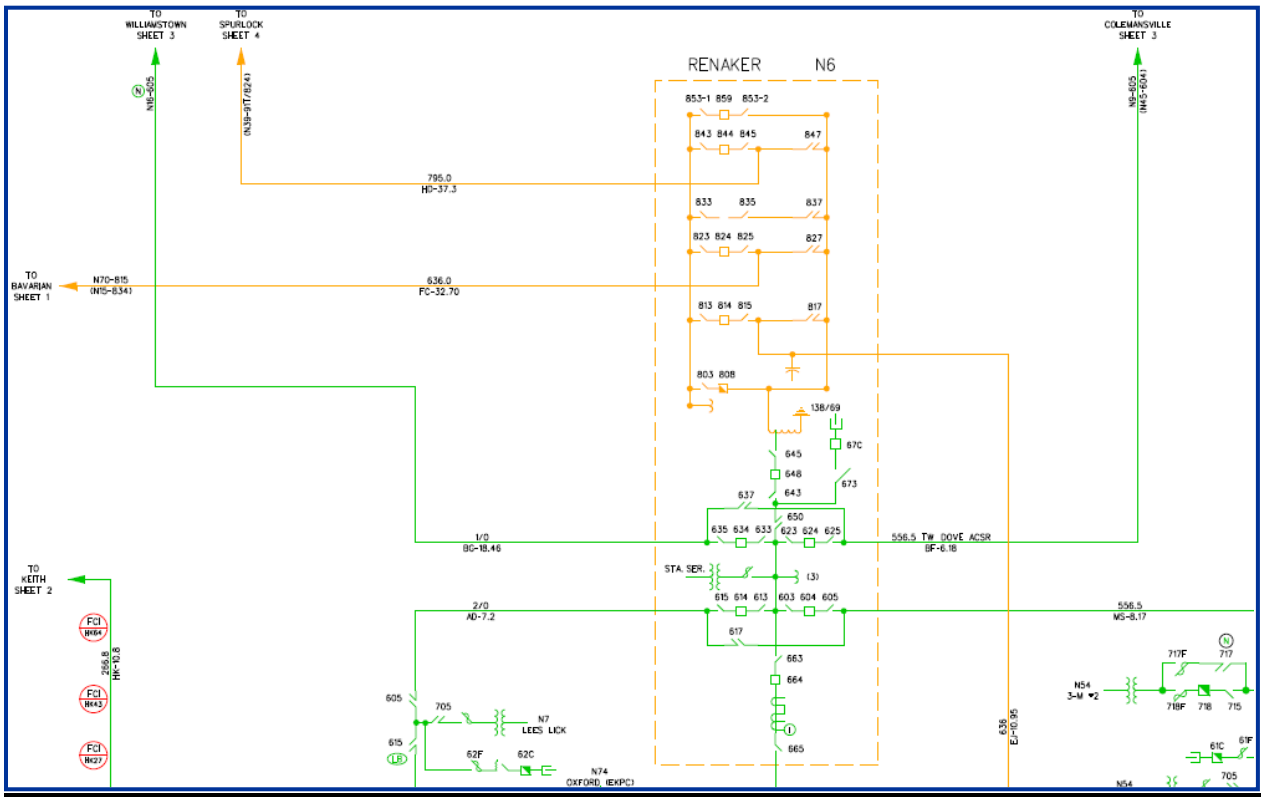
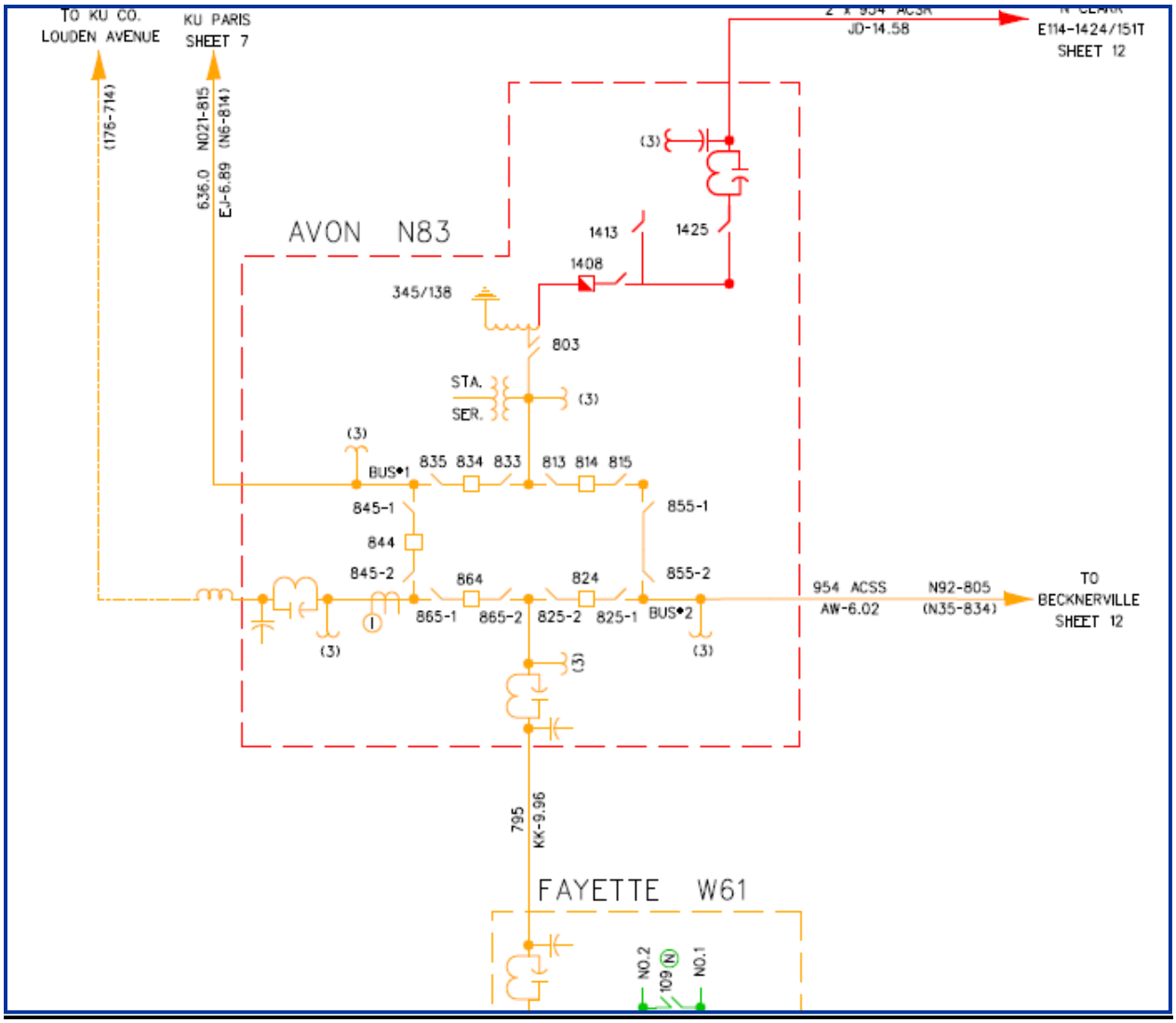
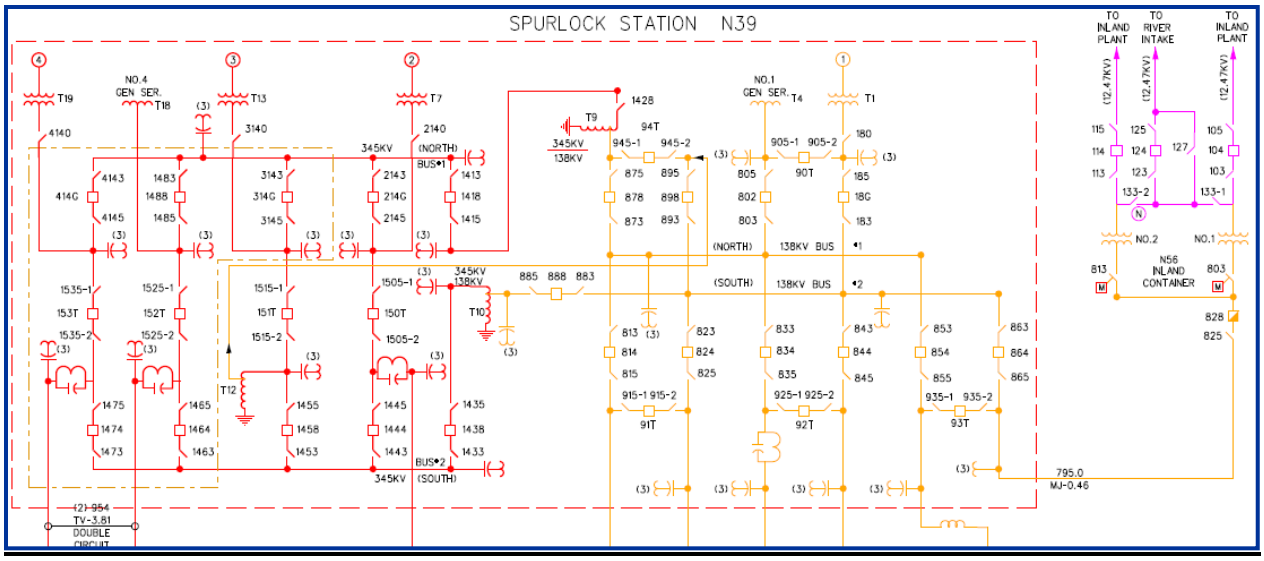
C.5) Switching Diagrams




TO KU CO.
LOUDEN AVENUE
KU PARIS
SHEET 7
(176-714)
636.0 N021-815 (N6-814)
EJ-6.89
2 x 954 ACSR
JD-14.58
E114-1424/151T
SHEET 12
AVON N83
(3)
1413
1425
1408
345/138
803
STA.
SER.
(3)
(3)
BUS•1
835 834 833 813 814 815
845-1
855-1
844
845-2
855-2
864
824
865-1 865-2 825-2 825-1 BUS•2
(3)
(3)
(3)
954 ACSS
AW-6.02
N92-805
(N35-834)
TO
BECKNERVILLE
SHEET 12
795
KK-9.96
FAYETTE W61
NO.2
109 (N)
NO.1


SPURLOCK STATION N39
TO INLAND PLANT
TO RIVER INTAKE
TO INLAND PLANT
(12.47KV)
NO.4 GEN. SER.
NO.1 GEN. SER.
T19
T18
T13
T7
T9
T4
T1
T12
T10
345KV
138KV
(NORTH) BUS•1
(SOUTH) BUS•2
(NORTH) 138KV BUS •1
(SOUTH) 138KV BUS •2
91T
92T
93T
94T
90T
NO.2
NO.1
N56 INLAND CONTAINER
(2)-954 TV-3.81 DOUBLE CIRCUIT
795.0 MJ-0.46