

This study was performed by EKPC
prior to integration with PJM.

A Feasibility Study on the JK Smith Plant Units 6 & 7
Conversion to Combined-Cycle Operation
170-MW Increase in Generation

Transmission Planning Department

East Kentucky Power Cooperative

Winchester, Kentucky

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Executive Summary

The conversion to combined cycle operation of the J.K. Smith Generation Plant Units 6 & 7 and subsequent interconnection to the East Kentucky Power Cooperative (EKPC) transmission system has been proposed by [REDACTED]. The proposed conversion will result in a 170-MW increase in the J.K. Smith plant output. A 138-kV point of interconnection (POI) was assumed in this feasibility study for the 170-MW increase in the J.K. Smith plant output. The 138-kV POI is either an existing 138-kV bus or a new 138-kV bus at the J.K. Smith plant operating at the same electric potential, under system normal conditions, as the existing 138-kV buses for units 6 & 7. An alternate point of interconnection (POI) at 345-kV was also considered. The 345-kV POI is either an existing 345-kV bus or a new 345-kV bus at the J.K. Smith plant operating at the same electric potential, under system normal conditions, as the existing 345-kV buses.

Thermal analyses were performed under both pre-project and post-project conditions. Electric power flows on existing facilities were noted under both system normal and contingency conditions. Effects of the project on relevant power transfer capabilities were also studied. Lastly, effects of the project on existing circuit breaker duties were analyzed.

Power flow contingency analysis indicated thermally limiting conditions resulting from the conversion of the J.K. Smith Generation Plant Units 6 & 7 to combined cycle operation. Total cost estimate information, derived from results of detailed engineering power flow analysis and individual component cost estimate information, were presented in the report. These order-of-magnitude estimates are not definitive and would need to be refined in the System Impact Study and Facilities Study processes.

1.0 Introduction

The conversion to combined cycle operation of the J.K. Smith Generation Plant Units 6 & 7 and subsequent interconnection to the East Kentucky Power Cooperative (EKPC) transmission system has been proposed by [REDACTED]. The proposed conversion will result in a 170-MW increase in the J.K. Smith plant output. A 138-kV point of interconnection (POI) was assumed in this feasibility study for the 170-MW increase in the J.K. Smith plant output. The 138-kV POI is either an existing 138-kV bus or a new 138-kV bus at the J.K. Smith plant operating at the same electric potential, under system normal conditions, as the existing 138-kV buses for units 6 & 7. An alternate point of interconnection (POI) at 345-kV was also considered. The 345-kV POI is either an existing 345-kV bus or a new 345-kV bus at the J.K. Smith plant operating at the same electric potential, under system normal conditions, as the existing 345-kV buses.

In this feasibility study report, the term “project” is used to designate the conversion to combined cycle operation of J.K. Smith units 6 & 7 and the set of activities designed to bring it into full operation. The term “pre-project” is used to designate existing electric system conditions in which the conversion has not yet taken place. The term “post-project” is used to designate electric system conditions in which the conversion has been completed, and the converted units with the additional 170 MW of output, delivering real and reactive power, are actually interconnected to the EKPC system.

The comparison of pre-project and post-project conditions, *ceteris paribus*, is the essence of this feasibility study. Thermal and voltage analyses were performed on the effects of the proposed 170-MW increase in plant output to the EKPC transmission system and its facilities.

For purposes of simulating steady-state power flow post-project conditions, the combined output of J.K. Smith units 6 & 7 was increased by 170 MW, while also increasing the combined reactive power output capability in order to keep the P/Q output capability ratio unchanged. Impedances of the associated generator step-up transformers (GSUs) were adjusted accordingly. This procedure is equivalent to adding a new 170-MW unit interconnected at 138-kV to the J.K. Smith plant.

Thermal and voltage analyses were performed under both pre-project and post-project conditions. Electric power flows and bus voltage magnitudes on existing facilities were noted under both system normal and contingency conditions. Effects of the project on relevant power transfer capabilities were also studied. Lastly, effects of the project on existing circuit breaker duties were analyzed.

2.0 Methodology

Pre-project versus post-project sensitivity analysis was performed for each of the eight (8) combinations and permutations of point of interconnection (POI) and year-season, as shown on the following table:

POI	Time Season
138-kV	Summer 2017
138-kV	Winter 2017-2018
138-kV	Summer 2022
138-kV	Winter 2022-2023
345-kV	Summer 2017
345-kV	Winter 2017-2018
345-kV	Summer 2022
345-kV	Winter 2022-2023

The PTI PSS/E software (Version 33.2.0) was used to perform power flow and contingency analysis. The models utilized were from EKPC's internal library of power-flow cases derived from the NERC MMWG 2011 series of base cases. These models include detailed representations of the EKPC and LG&E/KU systems, with the representations originally provided for the NERC MMWG series for the remainder of the outside world.

The Bulk Electric System (BES) is defined as the set of facilities in the electric power system operated at a voltage of 100 kV or higher. The following table shows the service areas for which sets of contingencies were simulated, and results of power flow analysis monitored, in the study:

Service Area	Simulated 69-kV Contingencies?	Simulated BES Contingencies?	Monitored 69-kV Facilities?	Monitored BES Facilities?
EKPC ¹	Yes	Yes	Yes	Yes
LG&E/KU ²	Yes	Yes	Yes	Yes
AEP ³	No	Yes	No	Yes
DAY ⁴	No	Yes	No	Yes
DEOK ⁵	No	Yes	No	Yes
TVA ⁶	No	Yes	No	Yes

¹ East Kentucky Power Cooperative

² Louisville Gas and Electric/ Kentucky Utilities

³ American Electric Power

⁴ Dayton Power and Light

⁵ Duke Energy Ohio and Kentucky

⁶ Tennessee Valley Authority

The PTI MUST software (Version 11.0) was used for the transfer capability analysis. Flow limits, together with the associated limiting facilities and contingencies, were identified for both pre-project and post-project conditions.

The ASPEN OneLiner program (Version 11) and ASPEN Breaker Rating Comparison program (Version 11) were used for the fault duty analysis, and for the pre-project versus post-project sensitivity analysis on breaker ratings, respectively.

3.0 Results

3.1 Voltage and Thermal Analysis

No voltage problems were identified as being caused by the project.

Details of thermal analysis results and comparisons of pre-project and post-project conditions, for the eight (8) combinations/permutations of post-project cases (with the corresponding pre-project cases) are shown in Appendix I. A table in Appendix I corresponds to one of the year-seasons for the 138-kV point of interconnection (POI). Results of analysis for the 345-kV POI are essentially identical to the results of the corresponding 138-kV POI analysis. In each table in Appendix I, a record indicates a limiting condition (as a pair of limiting facility and critical contingency) which would cause a thermal problem, given the 170-MW increase in output at the J.K. Smith Station. The level of increase in the J.K. Smith plant MW output due to the conversion (anywhere from 0 MW to 170 MW) at which a thermal problem will first appear for the limiting condition is also shown in Appendix I.

Summaries of the thermal analyses are presented in this subsection, along with high-level cost-estimate information, in the following tables. In these tables, the last column provides cost estimates for necessary corrective actions on existing EKPC facilities in order to solve the thermal problems caused, under contingency conditions, by the plant conversion. Note that the identified corrective actions are based on engineering judgment and expertise, but they could be replaced with other projects after further engineering analysis. These actions have not been modeled to verify that they will address the limits identified, or that additional thermal limitations will not be created by implementing these solutions. Also note that the cost estimates provided are based on generic cost numbers. No detailed engineering analysis was performed at this stage of the study process to provide a high-level of accuracy in the costs. It is anticipated that the cost estimates provided at this stage have an accuracy of +/- 50%.

For this feasibility study, EKPC did not coordinate with neighboring utilities. EKPC has used its engineering judgment to identify potential solutions and costs for the issues identified on neighboring systems. If the project proceeds to the System Impact Study phase of the process, coordination would occur with these neighboring utilities.

Appendix IV is a map showing the location of the J.K. Smith generating plant and its vicinity.

3.1.1 Estimates for Transmission Costs Associated with J.K. Smith Units 6 & 7 Conversion to Combined Cycle Operation (138-kV Point of Interconnection)

Facility	Corrective Action	Component Cost
Dale - J.K. Smith 138-kV Line (EKPC)	Upgrade Dale 138kV A buses to 1-954 MCM.	\$18,750
	Reconductor 9.4 miles with 954 ACSS wire.	\$2,820,000
	Upgrade Dale 138kV A bus disconnect switch to 2000A.	\$12,500
	Upgrade Dale 138kV D bus disconnect switch to 2000A.	\$12,500
JK Smith - Union City Tap 138kV Line (EKPC)	Reconductor 10.26 miles with bundled 556.5 ACSR.	\$8,464,500
	Upgrade distance relay.	\$60,000
	Upgrade 138-kV Jumper to 2-795 MCM.	\$9,375
JK Smith Generating Station (EKPC)	Upgrade 138-kV 50-kA Breakers to 63-kA (add 3000pF CCVTs).	\$45,000
	Upgrade 138-kV 50-kA Breakers to 63-kA (add 12000pF CCVTs).	\$58,750
Beattyville 161/69 kV Transformer (LG&E/KU)	Replace 45-MVA transformer with 100-MVA transformer.	\$1,325,000
Fawkes Tap - Fawkes (LG&E/KU)	Reconductor from 556 MCM to 795 MCM (0.02 mi.)	\$2,875
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		\$12,829,250
	Direct Connect Facility(ies)	
	138-kV Circuit Breaker	\$175,000
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		\$13,004,250

3.1.2 Estimates for Transmission Costs Associated with J.K. Smith Units 6 & 7 Conversion to Combined Cycle Operation (345-kV Point of Interconnection)

Facility	Corrective Action	Component Cost
Dale - J.K. Smith 138-kV Line (EKPC)	Upgrade Dale 138kV A buses to 1-954 MCM.	\$18,750
	Reconductor 9.4 miles with 954 ACSS wire.	\$2,820,000
	Upgrade Dale 138kV A bus disconnect switch to 2000A.	\$12,500
	Upgrade Dale 138kV D bus disconnect switch to 2000A.	\$12,500
JK Smith - Union City Tap 138kV Line (EKPC)	Reconductor 10.26 miles with bundled 556.5 ACSR.	\$8,464,500
	Upgrade distance relay.	\$60,000
	Upgrade 138-kV Jumper to 2-795 MCM.	\$9,375
JK Smith Generating Station (EKPC)	Upgrade 138-kV 50-kA Breakers to 63-kA (add 3000pF CCVTs).	\$45,000
	Upgrade 138-kV 50-kA Breakers to 63-kA (add 12000pF CCVTs).	\$58,750
Beattyville 161/69 kV Transformer (LG&E/KU)	Replace 45-MVA transformer with 100-MVA transformer.	\$1,325,000
Fawkes Tap - Fawkes (LG&E/KU)	Reconductor from 556 MCM to 795 MCM (0.02 mi.)	\$2,875
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		\$12,829,250
	Direct Connect Facility(ies)	
	345-kV Circuit Breaker	\$512,500
		<hr/>
		\$13,341,750

3.2 Transfer Capability Analysis

Details of transfer capability analysis results and comparisons of pre-project and post-project conditions, for the eight (8) combinations/permutations of post-project cases (with the corresponding pre-project cases) are shown in Appendix II. A table in Appendix II corresponds to one of the combinations/permutations for the 138-kV point of interconnection (POI). Analysis results for the 345-kV POI are essentially identical to the corresponding 138-kV POI analysis.

Results of the transfer capability analysis indicate that the project does not adversely affect the power transfer limits into or out of the EKPC service area.

3.3 Fault Duty Analysis and Breaker Rating Comparisons

Details of fault duty analysis, breaker rating comparisons, and sensitivity analysis from pre-project to post-project conditions are shown in Appendix III.

Results of the analysis indicate that fault duties on the J.K. Smith 138-kV 50-kA circuit breakers will increase by approximately 6.9% with the point of interconnection at 138-kV, and by approximately 2.9% with the point of interconnection at 345-kV.

The addition of 3000pF coupling capacitor voltage transformers (CCVTs) on each of the circuit breakers 48G and 58G (for units 4 & 5 respectively), and of 12000pF coupling capacitor voltage transformers (CCVTs) on each of the circuit breakers 68G and 78G (for units 6 & 7 respectively) will address the potential breaker over-duty problems associated with the project.

4.0 Conclusions

Power flow contingency analysis indicated thermally limiting conditions resulting from the conversion of J.K. Smith Units 6 & 7 to combined cycle operation. Total cost estimate information for necessary upgrades to existing facilities, derived from results of detailed engineering power flow analysis and individual component cost estimate information, were presented in the report. These order-of-magnitude estimates are not definitive and would need to be refined at later stages of the generator interconnection study process. Coordination with neighboring utilities will also be required in the next stages of the study process.

Appendix I

Power Flow Analysis Results

POI at 138-kV, Summer 2017

Monitored Element	LTE	Pre-Project Flows			Post-Project Flows			Delta	Generation Limit (MW)
		Base	Emergency	% of LTE	Base	Emergency	% of LTE		
Contingency	(MVA)	(MVA)	(MVA)		(MVA)	(MVA)			
342574 4DALE 138.00 342607 4JK SMITH 138.00 1	296	200.74	284.89	96.25%	223.53	310.18	104.79%	8.54%	75
BROWN UNIT 3:NORTH CLARK - AVON 345KV LINE (EKPC)									
342688 4UNION CTY T138.00 180 LK REB T 138.00 1	297	203.88	316.30	106.50%	219.53	337.57	113.66%	7.16%	
BROWN UNIT 3:FAWKES-JK SMITH & FAWKES-THREE FORKS JCT 138 KV (EKPC)									
529 FINCHVIL 69.000 901 SOUTHVL 69.000 1	35	25.01	38.80	110.85%	23.74	37.57	107.34%	- 3.51%	
BROWN UNIT 3:TYRONE - LAWRENCEBURG 69KV LINE (LG&E/KU)									
334 BONDS ML 69.000 901 SOUTHVL 69.000 1	28	18.96	32.17	114.91%	17.69	30.96	110.59%	- 4.32%	
BROWN UNIT 3:TYRONE - LAWRENCEBURG 69KV LINE (LG&E/KU)									

POI at 138-kV, Winter 2017-2018

Monitored Element	LTE	Pre-Project Flows			Post-Project Flows			Delta	Generation Limit (MW)
		Base	Emergency	% of LTE	Base	Emergency	% of LTE		
Contingency									
	(MVA)	(MVA)	(MVA)		(MVA)	(MVA)			
342574 4DALE 138.00 342607 4JK SMITH 138.00 1	337	245.19	316.2	93.83%	267.11	341.53	101.34%	7.51%	140
BROWN UNIT 3:UNION CITY TAP - KU LAKE REBA TAP 138KV LINE (LG&E/KU)									
342688 4UNION CTY T138.00 180 LK REB T 138.00 1	396	260.67	400.12	101.04%	275.66	421.29	106.39%	5.35%	
BROWN UNIT 3:FAWKES-JK SMITH & FAWKES-THREE FORKS JCT 138 KV (EKPC)									
342607 4JK SMITH 138.00 342688 4UNION CTY T138.00 1	435	273.82	414.08	95.19%	288.85	435.3	100.07%	4.88%	168
BROWN UNIT 3:FAWKES-JK SMITH & FAWKES-THREE FORKS JCT 138 KV (EKPC)									
216 RODBURN 138.00 843 RODBURN 69.000 1	72	59.82	83.98	116.64%	59.83	82.29	114.29%	-2.35%	
BROWN UNIT 3:RODBURN - SHARKEY TAP 138KV LINE (LG&E/KU)									

POI at 138-kV, Summer 2022

Monitored Element	LTE	Pre-Project Flows			Post-Project Flows			Delta	Generation Limit
		Base	Emergency	% of LTE	Base	Emergency	% of LTE		
Contingency									
	(MVA)	(MVA)	(MVA)		(MVA)	(MVA)			
148 FAWK TAP 138.00 149 FAWKS KU 138.00 1	237	94.05	222.37	93.83%	105.56	242.72	102.41%	8.59%	122
BROWN UNIT 3: FAWKES (EKPC) - FAWKES (LG&E/KU)									

For this season, the calculated power flow on the Dale – JK Smith 138-kV line will exceed the associated LTE rating of the line (during a simultaneous outage of the Brown Unit #3 and the North Clark – Avon 345-kV line) with or without the project.

POI at 138-kV, Winter 2022-2023

Monitored Element	LTE	Pre-Project Flows			Post-Project Flows			Delta	Generation Limit (MW)
		Contingency	Base	Emergency	% of LTE	Base	Emergency		
	(MVA)	(MVA)	(MVA)		(MVA)	(MVA)			
342688 4UNION CTY T138.00 180 LK REB T 138.00 1	396	286.09	438.56	110.75%	301.03	461.26	116.48%	5.73%	
BROWN UNIT 3:FAWKES-JK SMITH & FAWKES-THREE FORKS JCT 138 KV (EKPC)									
342577 4FAWKES EK 138.00 342607 4JK SMITH 138.00 1	337	231.87	325.21	96.50%	245.95	343.32	101.88%	5.38%	111
BROWN UNIT 3:UNION CITY TAP - KU LAKE REBA TAP 138KV LINE (EKPC -LG&E/KU)									
342574 4DALE 138.00 342607 4JK SMITH 138.00 1	396	274.39	380.92	96.19%	296.24	402.71	101.69%	5.50%	118
BROWN UNIT 3:AVON 345/138KV TRANSFORMER (EKPC)									
342577 4FAWKES EK 138.00 342607 4JK SMITH 138.00 1	337	231.87	329.15	97.67%	245.95	347.22	103.03%	5.36%	74
BROWN UNIT 3:JK SMITH - UNION CITY TAP 138KV LINE (EKPC)									
342607 4JK SMITH 138.00 342688 4UNION CTY T138.00 1	435	301.11	454.58	104.50%	316.08	475.47	109.30%	4.80%	
BROWN UNIT 3:FAWKES-JK SMITH & FAWKES-THREE FORKS JCT 138 KV (EKPC)									
342697 5BEATTYV J 161.00 357 BTTYV KU 69.000 1	72	39.24	70.63	98.10%	39.23	72.78	101.08%	2.98%	108
COOPER UNITS 1&2:KU BEATTYVILLE TAP - KU DELVINTA 161KV LINE (EKPC-LG&E/KU)									
216 RODBURN 138.00 843 RODBURN 69.000 1	72	58.78	84.84	117.83%	58.78	83.21	115.57%	-2.26%	
BROWN UNIT 3:RODBURN - SHARKEY TAP 138KV LINE (LG&E/KU)									

Appendix II

Transfer Capability Analysis

POI at 138-kV, Summer 2017

From Area	To Area	Limiting Element	FCITC (MW)		Delta (MW)
		Contingency	Pre-Project	Post-Project	
PJM	EKPC	37 ALCALDE 161 49 ELIHU 161 1	2057	2114	57
		Open 342826 5WOLF CRK J 161 360448 5WOLF CRK HP 161 1			
TVA	EKPC	360103 5PHIPPS B NP 161 360705 5JSEV C34 TP 161 3	581	601	20
		Open 360097 8VOLUNTEER 500 360102 8PHIPPS B NP 500 1			
LG&E/KU	EKPC	23 TRIMBLCO 345 248000 06CLIFTY 345 1	1301	1243	-58
		Open 243208 05JEFRSO 765 243209 05ROCKPT 765 1			
EKPC	PJM	23 TRIMBLCO 345 248000 06CLIFTY 345 1	1838	1706	-132
		Open 243208 05JEFRSO 765 243209 05ROCKPT 765 1			
EKPC	TVA		>3000	>3000	N.C.
EKPC	LG&E/KU		>3000	>3000	N.C.

POI at 138-kV, Winter 2017-2018

From Area	To Area	Limiting Element	FCITC (MW)		Delta (MW)
		Contingency	Pre-Project	Post-Project	
PJM	EKPC	37 ALCALDE 161 49 ELIHU 161 1	2310	2319	9
		Open 342826 5WOLF CRK J 161 360448 5WOLF CRK HP 161 1			
TVA	EKPC	342811 5SUMM SHAD T 161 360334 5SUMMER SHAD 161 1	1852	1889	37
		Open 342814 5SUMM SHADE 161 360334 5SUMMER SHAD 161 1			
LG&E/KU	EKPC	37 ALCALDE 161 49 ELIHU 161 1	2990 (DC)	>3000	>10
		Open 342826 5WOLF CRK J 161 360448 5WOLF CRK HP 161 1			
EKPC	PJM		>3000	>3000	N.C.
EKPC	TVA		>3000	>3000	N.C.
EKPC	LG&E/KU		>3000	>3000	N.C.

POI at 138-kV, Summer 2022

From Area	To Area	Limiting Element	FCITC (MW)		Delta (MW)
		Contingency	Pre-Project	Post-Project	
PJM	EKPC	37 ALCALDE 161 49 ELIHU 161 1	1902	1868 (DC)	-34
		Open 342826 5WOLF CRK J 161 360448 5WOLF CRK HP 161 1			
TVA	EKPC	360103 5PHIPPS B NP 161 360705 5JSEV C34 TP 161 3	844	866	22
		Open 360097 8VOLUNTEER 500 360102 8PHIPPS B NP 500 1			
LG&E/KU	EKPC	23 TRIMBLCO 345 248000 06CLIFTY 345 1	1577	1532	-45
		Open 243208 05JEFRSO 765 243209 05ROCKPT 765 1			
EKPC	PJM	23 TRIMBLCO 345 248000 06CLIFTY 345 1	2201	2072	-129
		Open 243208 05JEFRSO 765 243209 05ROCKPT 765 1			
EKPC	TVA		>3000	>3000	N.C.
EKPC	LG&E/KU		>3000	>3000	N.C.

POI at 138-kV, Winter 2022-2023

From Area	To Area	Limiting Element	FCITC (MW)		Delta (MW)
		Contingency	Pre-Project	Post-Project	
PJM	EKPC	37 ALCALDE 161 49 ELIHU 161 1	2120	2102 (DC)	-18
		Open 342826 5WOLF CRK J 161 360448 5WOLF CRK HP 161 1			
TVA	EKPC	342811 5SUMM SHAD T 161 360334 5SUMMER SHAD 161 1	1256	1317	61
		Open 342814 5SUMM SHADE 161 360334 5SUMMER SHAD 161 1			
LG&E/KU	EKPC	23 TRIMBLCO 345 248000 06CLIFTY 345 1	2542	2505	-37
		Open 243208 05JEFRSO 765 243209 05ROCKPT 765 1			
EKPC	PJM		>3000	>3000	N.C.
EKPC	TVA		>3000	>3000	N.C.
EKPC	LG&E/KU		>3000	>3000	N.C.

Appendix III

Circuit Breaker Fault Duty Analysis

Breaker Rating Comparison

Sensitivity Analysis

POI at 138-kV

Bus Name	Device Name	Pre-Project Duty %	Post-Project Duty %	Delta %	Rating
JK SMITH 138.kV	48G UNIT 4	83.3	90.2	6.9	50 kA
JK SMITH 138.kV	58G UNIT 5	83.3	90.2	6.9	50 kA
JK SMITH 138.kV	68G UNIT 6	83.3	90.2	6.9	50 kA
JK SMITH 138.kV	78G UNIT 7	83.3	90.2	6.9	50 kA

POI at 345-kV

Bus Name	Device Name	Pre-Project Duty %	Post-Project Duty %	Delta %	Rating
JK SMITH 138.kV	48G UNIT 4	83.3	86.2	2.9	50 kA
JK SMITH 138.kV	58G UNIT 5	83.3	86.2	2.9	50 kA
JK SMITH 138.kV	68G UNIT 6	83.3	86.2	2.9	50 kA
JK SMITH 138.kV	78G UNIT 7	83.3	86.2	2.9	50 kA

Appendix IV

Vicinity Map of J.K. Smith Station



