Generator Interconnection

Transitional Cluster Study

LGE-TCS-2024

Final Report

Executive Summary

Version 1.0

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List of Abbreviations

(Includes defined FERC and NERC terms)

AFS	Affected System Study
ASPEN	Advanced Systems for Power Engineering, Inc (Short-Circuit modeling software)
BCS	Base Case Series models
BESS	Battery Energy Storage System
BP	Business Practices
CAT	Cost Allocation Tool
CEII	Critical Energy Infrastructure Information
CFPT	Contingent Facilities Planning Tool
COD	Commercial Operation Date
CS	Cluster Study
ERIS	Energy Resource Interconnection Service
ESR	Energy Storage Resource
FERC	Federal Energy Regulatory Commission
FS	Facilities Study
FTP	File Transfer Protocol
GI	Generator Interconnection
GO	Generator Owner
GSU	Generator Step-Up Transformer
IBR	Invertor Based Resource
IC	Interconnection Customer
IF	Interconnection Facilities
ISO	Independent System Operator
ITO	Independent Transmission Organization (TranServ)
LGIA	Large Generator Interconnection Agreement
LG&E/KU	Louisville Gas and Electric Co. and Kentucky Utilities Co
LSE	Load Serving Entity
LTC	Load Tap Changer
MPT	Main Plant Transformer
NERC	North American Electric Reliability Corporation
NRIS	Network Resource Interconnection Service
OASIS	Open Access Same-Time Information System
OATT	Open Access Transmission Tariff
OW	Outside World (System outside of LG&E/KU BAA)
PGL	LG&E/KU Planning Guidelines (per the document posted on OASIS)
POI	Point of Interconnection
PSS/E	Power System Simulator for Engineering (Siemens Power Technologies, Inc. or PTI)
PTDF	Power Transfer Distribution Factor
PV	Photo-voltaic (technology and/or arrays)
SCD	Short-Circuit Duty
SCR	Short Circuit Ratio

SERC	Southeastern Electric Reliability Council
SPPR	Successive Positive Peak Ratio (defined in PGL)
SUB NU	Substation Network Upgrade
SYS NU	System Network Upgrade
TCS	Transitional Cluster Study
TEP	Transmission Expansion Plan
TIF	Transmission Provider’s Interconnection Facilities
TO	Transmission Owner
TOP	Transmission Operator
TP	Transmission Planner
TSP	Transmission Service Provider
TSR	Transmission Service Request
TSI/TranServ	TranServ International, Inc

1. Executive Summary

TranServ, as the ITO of LG&E/KU, has performed this TCS of 2024 to determine the impact of the submitted cluster of GI requests on the transmission network, as directed by FERC Order 2023. This document provides the executive summary of the study. The GI requests shown in Table E-1 below were included in the TCS according to the procedure established by FERC Order 2023 for transition from the serial to cluster queue process.

Table E-1
List of TCS Requests

Queue Number	County	State	POI	COD	Type of Service (NRIS/ ERIS)	Generator Type	Max Summer Output	Max Winter Output
LGE-GIS-2022-003	Jefferson County	KY	Mill Creek Substation 345 kV bus	04/01/2027	NRIS	Natural Gas Combined Cycle	645	660
LGE-GIS-2023-002	Mercer County	KY	Brown North Substation 345 kV bus	04/01/2030	NRIS	Natural Gas Combined Cycle	645	660
LGE-GIS-2023-003	Mercer County	KY	Brown North Substation 345 kV bus	02/01/2026	NRIS	Battery	125	125
LGE-GIS-2023-007	Hopkins County	KY	161kV Earlington North Substation	12/30/2027	NRIS	Solar	138	138
LGE-GIS-2024-002	Hopkins County	KY	2MADSNV LP W to 2 EARLINGTN N 69 kV line	04/01/2027	NRIS	Natural Gas Engines	75	75
LGE-GIS-2024-004	Mercer County	KY	Bardstown - Brown CT 138 kV Line	02/01/2026	NRIS	Solar	22	22
LGE-GIS-2024-006	Jefferson County	KY	Cane Run CT Substation 138kV	05/04/2026	NRIS	Combustion Gas Turbine /Steam	94	94

As shown in Table E-1, seven GI requests were included in TCS at the depicted POIs and with the indicated CODs. During the TCS analysis, the impact of these requests, located in Jefferson, Mercer and Hopkins Counties of Kentucky, was performed.

An Ad Hoc Study Group participated in the study process. Table E-2 summarizes the comments from the independent testing performed by the Ad Hoc Study Group.

Table E-2

Ad Hoc Study Group Independent Study Comments

Ad Hoc Group Member	Date Received	Constrained Facility	Ad Hoc Group Member Comment provided
TVA	11/06/2024	Based on Proximity	TVA requested an AFS for LGE-GI-2023-007: "TVA will need to perform an Affected System Study on LGE's NRIS project 2023-007. Once the SIS agreement is in place, the SIS will begin and it will take approximately 90 days." [Email from Kathy J. Harper, TVA, dated 11/06/2024]
MISO	04/23/2025	Based on Proximity	MISO requested AFS for LGE-GI-2022-003: "MISO will study the LGE-GIS-2022-003 project. Since this project is part of LGE's transitional cluster for FERC Order 2023 compliance purpose, MISO will defer the AFS study until the TCS study completion, and study all identified projects as one cluster." [Email from Liang Qi, MISO, dated 04/23/2025]
	05/01/2025		MISO requested AFS for a total of 6 GI projects and informed that the AFS duration will be about 120 days: "After reviewing the LGE-TCS-2024 draft report, MISO would like to perform Affected System study on the following 6 LGE projects: GIS-2022-003, GIS-2023-002, GIS-2023-003, GIS-2023-007, GIS-2024-002 and GIS-2024-006. It would take MISO about 120 days to perform the AFS study." [Email from Liang Qi, MISO, dated 05/01/2025]
PJM	04/26/2025	Based on Proximity	PJM requested AFS for LGE-GI-2023-002 and LGE-GI-2023-003: "PJM Interconnection Analysis plans to perform an Affected System Study for both the projects listed below. These projects will be studied on the TC1 Phase III model." [Email from Christopher Payne, PJM, dated 04/26/2025]
	05/09/2025		PJM provided the timeline for AFS: "PJM will be performing an Affected Systems Cluster System using the TC1 Phase III model. This study will start June 1, 2025 and will have reports end of August 2025 depending on the load flow, short circuit, and stability analysis results." [Email from Christopher Payne, PJM, dated 05/09/2025]
	05/10/2025		PJM requested AFS for a total of 6 GI projects from the TCS and 2 pre-queued GI requests: "The PJM Interconnection Analysis team has selected the projects listed below for LG&E Affected Systems Study using the TC1 Phase III model: LGE-GI-2021-019, LGE-GI-2021-020, LGE-GI-2023-002, LGE-GI-2023-003, LGE-GI-2023-007, LGE-GI-2024-002, LGE-GI-2024-004 and LGE-GI-2024-006." [Email from Christopher Payne, PJM, dated 05/10/2025]
No other Ad Hoc Members chose to provide comments or independent testing results.			

The TCS considered steady-state contingencies of NERC TPL-001-5.1 categories P0, P1, P2 EHV, P3, and P4 EHV and stability disturbances of categories P0, P1, P2, P3, P4, P5, P6, and P7, in accordance with the LG&E/KU GI Study Criteria and LG&E/KU Planning Guidelines (both documents are posted on LG&E/KU OASIS).

The TCS steady state power flow models were evaluated using 2025 Winter Peak, 2026 Summer Peak, 2026 Off-Peak, 2034 Summer Peak and 2034 Winter Peak models with roots in LG&E/KU 2025 TEP BCS models. Stability analysis was performed using 2026 Summer Max and 2026 Light Load models with roots in LG&E/KU's 2024 TEP models. The short circuit models started with LG&E/KU's 2023 TEP that include the 2024 TEP approved projects and project changes. This study modelled all earlier queued LG&E/KU GI requests and all confirmed TSRs. Planned transmission improvements associated with earlier queued GI requests were evaluated to determine if those planned transmission improvements would be contingent facilities for the TCS. The confirmed TSRs were also represented with associated planned transmission improvements. Thus, if the planned improvements would not come to fruition, it could necessitate a TCS restudy.

1.1 Description of TCS Requests

Summaries for each TCS request are provided below.

GI-2022-003: in order to obtain 660 MW injection at the POI for winter & off-peak and 645 MW for summer, the study determined that the gross generation at the plant would need to be 676 MW for winter and off-peak and 661 MW for summer which was modeled for TCS and is supported by the data provided by customer. The generator reactive power capability of +430.4/-381.4 MVAR met the ±0.95 power factor at the POI as required in both the steady state and stability models.

GI-2023-002: in order to obtain 660 MW injection at the POI for winter & off-peak and 645 MW for summer, the study determined that the gross generation at the plant would need to be 676 MW for winter and off-peak and 661 MW for summer which was modeled for TCS and is supported by the customer data. The generator reactive power capability of +440/-320 MVAR meets the ±0.95 power factor at the POI as required in both the steady state and stability models.

GI-2023-003: in order to obtain 125 MW injection at the POI, the study determined that the gross generation at the plant would need to be 130.4 MW which was modeled for TCS and is supported by customer data. The generator reactive power capability of ±92.02 MVAR met the ±0.95 power factor at the high side of the MPT as required in both the steady state and stability models.

GI-2023-007: to obtain 138 MW injection at the POI, the gross generation at the plant inverter bus would need to be 140.7 MW, which was modeled for TCS and is supported by customer data.

The generator reactive power capability of ±76 MVAR met the ±0.95 power factor at the high side of the MPT as required in both the steady state and stability models.

GI-2024-002: in order to obtain 75 MW injection at the POI, the gross generation at the plant generator terminal bus(s) would need to be 75.6 MW which was modeled for TCS and is supported by the data provided by customer. The generator reactive power capability of ±32 MVAR met the ±0.95 power factor at the POI as required in both the steady state and stability models.

GI-2024-004: in order to obtain an additional 22 MW injection at the POI, the gross generation at the plant inverter bus would need to be increased by 22.1 MW, which was modeled for TCS. The data provided by the customer supports this gross generation level. The additional generation with reactive power capability of ±10.1 MVAR met the ±0.95 power factor at the high side of the MPT as required in both the steady state and stability models.

GI-2024-006: Cane Run 7 plant capacity was increased by 94 MW (87 MW for summer). The study determined that the Cane Run units with reactive power capability of +475/-345 MVAR for summer and +400/-300 MVAR for winter and off-peak meet the ±0.95 power factor requirement at the POI in the steady state and stability models.

1.2 Steady-State Analysis Results

Prior to completion of the TCS-2024 study, LGIA termination of GI-2019-029 (100 MW request) became effective. This was followed by the indefinite termination of its related TSR-2021-003 (100 MW DNR). Since GI-2019-029 had an associated confirmed TSR and was a part of the 2025 TEP BCS models, it was included in all the TCS models. The ITO subsequently performed a sensitivity analysis of the impact of GI-2019-029 termination on the TCS-2024 constraints for all years.

Annulment of TSR-2023-009 (23 MW Load) project became effective while the TCS-2024 study was ongoing. This TSR being confirmed was included in all the TCS models. The ITO subsequently performed a sensitivity analysis of the impact of TSR-2023-009 termination on the TCS-2024 constraints for all years.

Before the completion of TCS-2024 study, temporary termination of TSR-2023-002 (138 MW DNR and 280 MW DNR) till 01/01/2027 became effective. The 138 MW DNR was studied as GI-2023-007 in TCS in the post models and was not included in the pre models. So, the temporary termination of the 138 MW DNR would not impact the models. The 280 MW DNR being a confirmed TSR was included in all the TCS models. Its temporary termination can impact the

2026S constraints The ITO subsequently performed a sensitivity analysis of the impact of TSR-2023-002 temporary termination on the TCS-2024 constraints for the near-term models only.
Impact of the GI-2019-029 LGIA termination, TSR-2023-009 annulment and TSR-2023-002 temporary termination on the TCS thermal and voltage constraints were studied. The analysis was performed by updating accordingly the models and re-studying the thermal and voltage constraints. The termination of GI-2019-029, annulment of TSR-2023-009 and temporary termination of TSR-2023-002 were replaced by LG&E/KU generation in merit order. All the results provided in this executive summary are from the limited sensitivity analysis.

1.2.1 Thermal Analysis

LG&E/KU TCS-2024 potential P0 NRIS thermal constraints are given in Table E-3. These constraints were found for many maximization scenarios, with only the highest post TCS loading results included.

Table E-3

TCS-2024 LG&E/KU P0 Thermal Constraints

Model	Facility	Rating (MVA)	Pre TCS		Post TCS		MVA Impact/Rating (%)	MVA Impact
			MVA	%	MVA	%		
2026S	4CANERN NGCC138.00 TO 4INTRNTL TAP138.00 23	208	192.2	92.4	210.6	101.2	8.9	18.4
2034S	4CANE RUN SW138.00 TO 4CANERN NGCC138.00 22	187	171.3	91.6	187.4	100.2	8.6	16.1
2034S	4CANERN NGCC138.00 TO 4INTRNTL TAP138.00 23	208	196.8	94.6	213.0	102.4	7.8	16.2

LG&E/KU TCS-2024 P1-P3 contingency thermal constraints are given in Table E-4. These constraints were observed for many dispatch/contingency combinations. Only results with the highest post-TCS loading are shown.

Table E-4

TCS-2024 LG&E/KU P1-P3 Thermal Constraints

Model	Facility	Rating (MVA)	Pre TCS		Post TCS		MVA Impact/Rating (%)	MVA Impact
			MVA	%	MVA	%		
2026S	2DIXON KU 69.000 TO 2NEBO 69.000 1	18	13.0	72.4	19.0	105.5	33.1	6.0
2026S	2E DIAMOND 69.000 TO 2DOZIER H 69.000 1	28	20.6	73.4	32.3	115.4	42.0	11.8
2026S	2EARLINGTN N69.000 TO 2DOZIER H 69.000 1	28	25.7	91.9	37.6	134.4	42.5	11.9
2026S	2EARLINGTN N69.000 TO 2SENTRY TAP 69.000 1	67	23.9	35.7	67.5	100.7	65.0	43.5
2026S	2EARLINGTON 69.000 TO 2WALKER KU 69.000 1	41	21.9	53.3	49.9	121.7	68.4	28.0
2026S	2MADSNV LP W69.000 TO 2NEBO 69.000	53	0.3	0.5	60.2	113.6	113.1	60.0
2026S	2MANITOU 69.000 TO 2SENTRY TAP 69.000 1	57	17.8	31.3	59.0	103.4	72.1	41.1
2026S	2RVR QUEEN T69.000 TO 2TEXAS GAS T69.000 1	32	9.0	28.2	36.2	113.2	85.0	27.2
2026S	5WALKER 161.00 TO 2WALKER KU 69.000 1	129	98.0	76.0	129.8	100.6	24.7	31.8
2026S	2WEBCOAL 4 69.000 TO 2WARRIOR CL 69.000 1	40	10.4	26.1	47.1	117.7	91.6	36.7
2034S	2DIXON KU 69.000 TO 2NEBO 69.000 1	18	11.4	63.4	19.1	106.0	42.6	7.7
2034S	2E DIAMOND 69.000 TO 2DOZIER H 69.000 1	28	20.2	72.1	32.0	114.2	42.1	11.8
2034S	2EARLINGTN N69.000 TO 2MADSNV LP E69.000 1	105	90.6	86.3	106.5	101.4	15.1	15.8
2034S	2EARLINGTON 69.000 TO 2ISLAND MINE69.000 1	41	15.1	36.8	43.7	106.6	69.9	28.6
2034S	2EARLINGTON 69.000 TO 2WALKER KU 69.000 1	41	26.1	63.6	54.6	133.1	69.6	28.5
2034S	2GREEN RIVER69.000 TO 2RVR QUEEN T69.000 1	32	2.5	7.9	35.2	110.0	102.1	32.7
2034S	2GREENV W TP69.000 TO 2GREENVILLE 69.000 1	28	10.5	37.5	28.6	102.1	64.6	18.1
2034S	2ISLAND MINE69.000 TO 2TEXAS GAS T69.000 1	41	14.2	34.6	42.4	103.4	68.8	28.2
2034S	2MADSNV LP W69.000 TO 2NEBO 69.000	53	0.3	0.5	60.0	113.2	112.7	59.7
2034S	2RVR QUEEN T69.000 TO 2TEXAS GAS T69.000 1	32	12.0	37.5	40.0	124.9	87.4	28.0
2034S	2WEBCOAL 4 69.000 TO 2WARRIOR CL 69.000 1	40	9.6	23.9	45.0	112.5	88.6	35.4
2034S	4CANE RUN SW138.00 TO 2024TSR1POI 138.00 1	365	334.9	91.7	384.1	105.2	13.5	49.3
2034S	4CANE RUN SW138.00 TO 2024TSR1POI 138.00 2	365	335.9	92.0	385.4	105.6	13.5	49.4
2034S	4CANE RUN SW138.00 TO 4CANERN NGCC138.00 22	237	218.8	92.3	237.9	100.4	8.1	19.1
2034S	5WALKER 161.00 TO 2WALKER KU 69.000 1	129	99.4	77.0	131.4	101.8	24.8	32.0
2034S	7MILL CREEK 345.00 TO 7CANE RUN TP345.00 1	936	854.8	91.3	1052.3	112.4	21.1	197.4

No potential third-party P0 or P1-P3 thermal constraints were identified.

1.2.2 Voltage Analysis

No LG&E/KU P0 voltage constraints were identified. Potential LG&E/KU TCS-2024 P1-P3 voltage constraints observed are given in Table E-5.

Table E-5

TCS-2024 LG&E/KU P1-P3 Potential Voltage Constraints

Model	Facility	kV	Pre TCS Voltage (pu)	Post TCS Voltage (pu)	Delta Volt (%)
2026S	2MADSNV GE	69	0.940	0.893	-4.7
2026S	2MADSNV HO	69	0.951	0.892	-5.9
2026S	2MADSNV N	69	0.949	0.892	-5.7
2026S	2MADSNV W	69	0.940	0.892	-4.7
2034S	2MADSNV GE	69	0.935	0.893	-4.2
2034S	2MADSNV HO	69	0.946	0.892	-5.4
2034S	2MADSNV N	69	0.944	0.893	-5.1
2034S	2MADSNV W	69	0.935	0.893	-4.2

No potential third-party voltage constraints were observed in the study.

1.2.3 Mitigation Analysis

Mitigations provided by LG&E/KU for the observed constraints are detailed in the full report, Section 4.1.4. After applying these mitigations, no LG&E/KU or third-party thermal or voltage constraints were identified.

1.3 Contingent Facility Analysis Results

As required by the GI Criteria, contingent facility analysis was performed to determine potential impact of TCS-2024 on the contingent facilities (and associated network upgrades) determined for the prior queued GI requests. Results of the analysis are shown in Table E-6. None of the facilities met the requirements for “contingent facilities” as defined by the GI Criteria, of being overloaded and the load increase post- TCS-2024 by at least five percent (5%) of the applicable thermal rating. Therefore, no TCS-2024 contingent facilities have been determined.

Table E-6

Contingent Facility Analysis Results

Request	Model	Facility	Rating (MVA)	Pre TCS		Post TCS		MVA impact/Rating (%)
				MVA	%	MVA	%	
GI-2021-008	2026S	7BUCKNER 345.00 TO 7MIDDLETOWN 345.00 1	1195	1131.1	94.7	814.5	68.2	-26.5
GI-2021-008	2026S	7BUCKNER 345.00 TO 7MIDDLETOWN 345.00 1	1195	810.0	67.8	607.3	50.8	-17.0
GI-2021-008	2034S	7BUCKNER 345.00 TO 7MIDDLETOWN 345.00 1	1195	1321.0	110.5	995.0	83.3	-27.3
GI-2021-008	2034S	7MIDDLETOWN 345.00 TO 7TRIMBLE CO 345.00 1	1195	1208.5	101.1	875.0	73.2	-27.9
GI-2021-008	2025W	7BUCKNER 345.00 TO 7MIDDLETOWN 345.00 1	1195	1060.9	88.8	708.9	59.3	-29.5
GI-2021-008	2034W	7BUCKNER 345.00 TO 7MIDDLETOWN 345.00 1	1195	1330.1	111.3	964.7	80.7	-30.6
GI-2021-019	2026OP	2BOYLE CO 69.000 TO 2DANVILLE 1 69.000 1	69	18.1	26.3	18.1	26.3	0.0
GI-2021-019	2026OP	2DANVILLE 1 69.000 TO 2DANVILLE E 69.000 1	89	11.8	13.3	11.8	13.3	0.0
GI-2021-019	2026S	2BOYLE CO 69.000 TO 2DANVILLE 1 69.000 1	52	33.3	63.9	33.3	63.9	0.0
GI-2021-019	2026S	2DANVILLE 1 69.000 TO 2DANVILLE E 69.000 1	67	21.8	32.5	21.8	32.5	0.0
GI-2021-019	2034S	2BOYLE CO 69.000 TO 2DANVILLE 1 69.000 1	52	33.3	63.9	33.2	63.9	0.0
GI-2021-019	2034S	2DANVILLE 1 69.000 TO 2DANVILLE E 69.000 1	67	22.3	33.2	22.3	33.2	0.0
GI-2021-020	2034S	5COLEMAN TAP161.00 TO 5PADUCAH PRI161.00 1	245	151.2	61.7	138.4	56.5	-5.2
GI-2021-020	2034S	5COLEMAN TAP161.00 TO 5PADUCAH PRI161.00 1	245	142.9	58.3	129.6	52.9	-5.4

1.4 Short Circuit Analysis Results

The Short Circuit Analysis results indicate that the transmission system has adequate interrupting capabilities to accommodate the addition of the new generators for 2024 TCS study.

1.5 Stability Analysis Results

For all tested disturbances, all monitored voltages and angles were found to be within acceptable limits with the addition of all the TCS-2024 generation at their respective point of interconnections. No stability criteria violations were observed during the study as discussed in detail in Section 5 of the full report.

1.6 Stiffness Verification due to IBR Interconnection

No grid stiffness constraints were identified in the 2024 TCS study as discussed in detail in Section 7 of the full report.

1.7 EMT Data Validation

EMT model deficiencies were observed and need to be resolved by the GI customers prior to execution of LGIA. For further details please refer to Section 8 of the full report.

1.8 Conclusions

LG&E/KU thermal and voltage constraints identified in TCS are shown in Tables E-3 through E-5. Mitigations provided by LG&E/KU resolved all of the constraints.

No short circuit or stability constraints were identified.

No third-party thermal and voltage constraints were observed. However, as indicated in Table E-2, MISO, PJM and TVA have requested an AFS to be performed. Therefore, the corresponding customers must follow with the appropriate third parties in order to perform the studies and address all the arising issues.

A non-binding good faith cost estimate for the TCS GI requests is provided by LG&E/KU for the interconnection facilities, TIF and NIF that were identified in the full report. Further, the cost estimates of SYS NUs as provided by the TO and the cost allocation for each GI are provided in the full report. The total costs for each of the GIs under study are provided in Table E-7.

Table E-7

Total Cost Estimates for GIs under study in TCS

Subject Request	Total Cost Estimate (USD)
GI-2022-003	$11,957,934
GI-2023-002	$6,938,546
GI-2023-003	$3,938,095
GI-2023-007	$20,668,253
GI-2024-002	$29,656,890
GI-2024-004	$0
GI-2024-006	$872,237

More details about the cost estimates and allocations are provided in Section 9 of the full report.

The full report is available on the LG&E/KU CEII FTP site. Refer to study report title posting on OASIS for instructions for accessing LG&E/KU CEII FTP site. The LG&E/KU secure CEII FTP site URL is: https://eftws.lge-ku.com/EFTClient/Account/Login.htm.