



Planning Coordinator

Automatic Under Frequency Load Shedding Program Design and Assessment

Effective Date: October 1, 2016

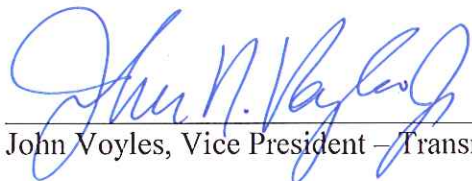
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Revision History

Date	Description	Revision
October 1, 2013	Initial development.	
October 1, 2015	Changes required for new PRC-006-2; Added Section 11.0 per the new standard; documented program change within Section 4. Added minimum frequency criteria during simulation Section 5.1	
October 1, 2016	Per the LG&E and KU Compliance Document Annual review program initialed in 2016 defined the use of version numbers, Removed requirements prior to April 15, 2016 Section 6 and 8. Revising language to accommodate an expanded PA/PC area which includes KMPA who are the City of Princeton and Paducah, KY; as well as other transmission only municipal customers (added Table 2). Added a pick up or delay time to Table 1 and 2 Section 4.	1.0

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1.0 Purpose

This document is intended to describe the design and documentation requirements for the LG&E/KU automatic underfrequency load shedding (UFLS) program to arrest declining frequency, assist recovery of frequency following underfrequency events and provide last resort system preservation measures. This document is the procedure document for compliance with PRC-006-2 and PRC-006-SERC-01.

2.0 Definitions

Definitions can be found in the NERC Glossary for italicized terms.

Corrective Action Plan – *A list of actions and an associated timetable for implementation to remedy a specific problem.*

Planning Coordinator (PC) – *See Planning Authority*

Planning Authority (PA) – *The responsible entity that coordinates and integrates transmission facility and service plans, resource plans, and protection systems.*

Bulk Electric System (BES) – *As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100 kV or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.*

Special Protection System (SPS) – *An automatic protection system designed to detect abnormal or predetermined system conditions, and take corrective actions other than and/or in addition to the isolation of faulted components to maintain system reliability. Such action may include changes in demand, generation (MW and Mvar), or system configuration to maintain system stability, acceptable voltage, or power flows. An SPS does not include (a) underfrequency or undervoltage load shedding or (b) fault conditions that must be isolated or (c) out-of-step relaying (not designed as an integral part of an SPS). Also called Remedial Action Scheme.*

Interconnection – *When capitalized, any one of the three major electric system networks in North America: Eastern, Western, and ERCOT.*

Transmission Owner (TO) – *The entity that owns and maintains transmission facilities.*

Load – *An end-use device or customer that receives power from the electric system.*

Peak Demand – 1. The highest hourly integrated Net Energy for Load within a Balancing Authority Area occurring within a given period (e.g., day, month, season, or year). 2. The highest instantaneous demand within the Balancing Authority Area.

UFLS Entity: UFLS entities shall mean all entities that are responsible for the ownership, operation, or control of UFLS equipment as required by the UFLS program established by the Planning Coordinators. Such entities may include on or more of the following:

- *Transmission Owners*
- *Distribution Providers*

For purposes of the LG&E and KU UFLS program owner, all UFLS relays are on the distribution facilities and not the Transmission Owner facilities. Therefore, Distribution Providers and some LSEs per the Network Operating Agreement are required to have UFLS relays are UFLS entities.

3.0 Criteria for Island Selection

The LG&E and KU Planning Coordinator (PC) will consider historical events, if any, and system studies to select portions of the Bulk Electric System (BES), including interconnected portions of the BES in adjacent PC areas and Regional Entity areas that may form islands.¹ At a minimum, the PC for LG&E and KU will include the SERC subregion as an identified island for selecting portions of the Bulk Power System (BPS) that may form islands.²

LG&E and KU participates in the SERC Dynamics Study Group (DSG) and provides data on its UFLS program to the DSG for use in the group's UFLS program study that is performed, at a minimum, every five years. The methodology for determining the islands is described in the SERC DSG report. Per the SERC DSG LG&E and KU is included in three islands, including the SERC subregion, as a participant in this study. The islands as identified by the SERC DSG are:

¹ PRC-006-2 R1

² PRC-006-SERC-01 R1 and PRC-006-2 R2.3

4. Islands and Scenarios

Eight different generation-deficiency islanding scenarios are analyzed in this study. Table 4-1 shows the definition of these eight SERC Regional Islands and Table 4-2 provides the description for each SERC area.

Table 4-1: Definition of SERC Region Islands

Island Name	Load Flow Area Names in the Island	Load Flow Area Numbers
SERC_1	TVA, DOE, EKPC, BREC, LGEE, EES, DENL, DERS, PUPP, BUBA, CONWAY, WESTMEM P, LAGN, BCA, OMLP, PLUM, AECI, AMIL, AMMO, EEI, SIPC, CWLP, CWLD, Southern, SMEPA, AEC, CP&L-E, CP&LW, DUKE, SCEG, SCPSA, DVP, YAD, SEHA, SERU, SETH, SWPA, AEPW, GRDA, MIPU, KACP, EMDE, INDN, SPRM, ALTW	347,348,320,314,363,351,339, 338,337,336,335,334, 332, 331,329,328,330,357, 356,362,361,360,333, 346,349,350,340,341,342, 343,344,345,352,353,354, 355, 515,520,523,540,541, 544, 545,546,627
SERC_2	TVA, DOE, EKPC, BREC, LGEE, EES, DENL, DERS, PUPP, BUBA, CONWAY, WESTMEM P, LAGN, BCA, OMLP, PLUM, AECI, AMIL, AMMO, EEI, SIPC, CWLP, CWLD Southern, SMEPA, AEC CP&L-E, CP&L-W, DUKE, SCEG, SCPSA, DVP, YAD, SEHA, SERU, SETH	347,348,320,314,363 351,339,338,337,336,335,334, 332,331,329,328,330 357,356,362,361,360,333 346,349,350, 340,341,342,343,344,345,352, 353, 354,355
Central	TVA, DOE, EKPC, BREC, LGEE	347,348,320,314,363
Delta_1	EES, DENL, DERS, PUPP, BUBA, CONWAY, WESTMEM P, LAGN, BCA, OMLP, PLUM, AECI, AMMO, CWLD, SWPA, AEPW, GRDA, MIPU, KACP, EMDE, INDN, SPRM, ALTW	351,339,338,337,336,335, 334,332,331,329,328,330, 356,333,515,520,523,540, 541,544,545,546,627
Delta_2	EES, DENL, DERS, PUPP, BUBA, CONWAY, WESTMEM P, LAGN, BCA, OMLP, PLUM, AECI	351,339,338,337,336,335, 334,332,331,329,328,330
Gateway	AMIL, AMMO, EEI, SIPC, CWLP, CWLD	357,356,362,361,360, 333
Southeastern	Southern, SMEPA, AEC	346,349,350
VACAR	CP&L-E, CP&L, W, DUKE, SCEG, SCPSA, DVP, YAD, SEHA, SERU, SETH	340,341,342,343,344, 345,352,353,354,355

In addition to the DSG study, LG&E and KU may develop additional islands for assessment.³ LG&E and KU does not operate any Special Protection Systems (SPS) or relay schemes that would detach its BES from the interconnection as a result of an UFLS event.⁴

4.0 Under Frequency Load Shed Program

³ PRC-006-2 R2.1

⁴ PRC-006-2 R2.2

The LG&E and KU has a UFLS program, and notifies UFLS entities within its area of the program including a schedule for implementation. The UFLS program for LG&E and KU PC area is designed such that the frequency within its PC area will meet the following performance characteristics in simulations of underfrequency conditions resulting from an imbalance between load and generation of 13%, 22%, and 25% for all identified island(s) where such imbalance equals $[(\text{load minus actual generation output}) / \text{load}]$:⁵

- Frequency shall remain above the Underfrequency Performance Characteristic curve in PRC-006-2 – Attachment 1, either for 60 seconds or until a steady-state condition between 59.3 Hz and 60.7 Hz is reached.
- Frequency shall remain below the Overfrequency Performance Characteristic curve in PRC-006-2 – Attachment 1, either for 60 second or until a steady-state condition between 59.3 Hz and 60.7 Hz is reached.
- Volts per Hz (V/Hz) shall not exceed 1.18 per unit for longer than two seconds cumulatively per simulated event, and shall not exceed 1.10 per unit for longer than 45 seconds cumulatively per simulated event at each generator bus and generator step-up transformer high-side bus associated with each of the following:
 - Individual generating units greater than 20 MVA (gross nameplate rating) directly connected to the BES
 - Generating plants/facilities greater than 75 MVA (gross aggregate nameplate rating) directly connected to the BES
 - Facilities consisting of one or more units connected to the BES at a Common bus with total generation above 75 MVA gross nameplate rating.

The LG&E and KU PC Area includes the LG&E and KU affiliate LSE and DP; Princeton, Paducah municipal utilities; municipal utilities expected to no longer be served by KU (Paris, Corbin, Barbourville, Berea, Bardwell, Madisonville, Benham, Frankfort, Providence). Owensboro Municipal Utilities is not in the LG&E and KU PC area.

The UFLS Entity with greater than 100 MW annual peak load will use Table 1 for their UFLS program. The UFLS Entity with less than 100 MW annual peak load may use either Table 2 or Table 1 for their UFLS program. If entities with load less than 100 MW already incorporated the UFLS program for Table 1, they are not required to change the UFLS program to Table 2.

⁵ PRC-006-2 R3 and PRC-006-SERC-01 R3

Table 1 UFLS Program for Entities > 100 MW Load

Load Shedding Steps	% Demand Per Step	% of Total Demand	Frequency Steps (Hz)	Range of Actual Load Shed Amount	Time Delay	Schedule
3	10% of Previous Years Peak Demand	30% of Previous Years Peak Demand	59.5, 59.3, 59.1	-1% to +5%	10 cycles (0.167 seconds)	4/1/2016

Table 2 UFLS Program for Entities < 100 MW Load

Load Shedding Steps	% Demand Per Step	% of Total Demand	Frequency Steps (Hz)	Range of Actual Load Shed Amount	Time Delay	Schedule
1	30% of Previous Years Peak Demand	30% of Previous Years Peak Demand	59.3	+/- 5%	10 cycles (0.167 seconds)	4/1/2016

5.0 UFLS Program Design Assessment by Simulation

The SERC DSG conducts a UFLS assessment by simulation with inputs from the LG&E and KU UFLS program. This assessment is performed at least once every five years and LG&E and KU is a full participant in the study. LG&E and KU may elect to perform additional UFLS simulations in order to do additional assessments of the LG&E and KU UFLS program beyond that performed by the SERC DSG. The studies and assessments shall simulate the UFLS scheme for an imbalance between load and generation of 13%, 22% and 25% for all identified island(s) where such imbalance equals [(load minus actual generation output)/load]. The simulations performed by the SERC DSG and LG&E and KU (if applicable) will model each of the following:⁶

- Underfrequency trip settings of individual generating units with a gross nameplate rating greater than 20 MVA directly connected to the BES that trip above the Generator Underfrequency Trip Modeling curve in PRC-006-2 – Attachment 1.⁷

⁶ PRC-006-2 R4

⁷ PRC-006-2 R4.1 through R4.6 will be enforceable one year following the receipt of the generation data required in Reliability Standard PRC-024-1 (once approved and enforceable), but no sooner than October 1, 2013.

- Underfrequency trip settings of generating plants/facilities with a gross aggregate nameplate rating greater than 75 MVA directly connected to the BES that trip above the Generator Underfrequency Trip Modeling curve in PRC-006-2 – Attachment 1.⁷
- Underfrequency trip settings of any facility consisting of one or more units connected to the BES at a common bus with a total gross nameplate rating above 75 MVA that trip above the Generator Underfrequency Trip Modeling curve in PRC-006-2 – Attachment 1.⁷
- Overfrequency trip settings of individual generating units with a gross nameplate rating greater than 20 MVA directly connected to the BES that trip below the Generator Overfrequency Trip Modeling curve in PRC-006-2 – Attachment 1.⁷
- Overfrequency trip settings of generating plants/facilities with a gross aggregate nameplate rating greater than 75 MVA directly connected to the BES that trip below the Generator Overfrequency Trip Modeling curve in PRC-006-2 – Attachment 1.⁷
- Overfrequency trip settings of any facility consisting of one or more units connected to the BES at a common bus with total gross nameplate rating above 75 MVA that trip below the Generator Overfrequency Trip Modeling curve in PRC-006-2 – Attachment 1.⁷
- Any automatic Load restoration that impacts frequency stabilization and operates within the duration of the simulations run for the assessment.

5.1 Criteria

The simulation must ensure that the frequency does not drop below 58 Hz during the simulation. If the simulation sees a frequency drop below 58 Hz, a change to the UFLS program must be incorporated to prevent the frequency from dropping below 58 Hz.

6.0 Coordination with Other Planning Coordinators

LG&E and KU PC relies on the SERC DSG assessment and therefore conducts the coordination required by submitting the LG&E and KU UFLS Program to SERC DSG. In the event that SERC or the PC for LG&E/KU identifies islands that include additional PC areas or portions of those areas, LG&E and KU will coordinate its UFLS program design with these PC through one of the following:⁸

- Develop a common UFLS program design and schedule for implementation per section 4.0, or
- Conduct a joint UFLS design assessment per section 5.0 by utilizing the SERC DSG studies which assess the adequacy of the SERC UFLS program, or
Conduct an independent UFLS design assessment per section 5.0 for the identified island. In the event the UFLS design assessment fails to meet the requirements of section 4.0, identify modifications to the UFLS program(s) to meet the requirements of section 4.0 and report these modifications to the other PC whose areas or portions of whose areas are also part of the same identified island and the ERO.

⁸ PRC-006-2 R5

If the PC for LG&E/KU determines that switching of existing capacitor banks, Transmission Lines, and reactors to control over-voltage as a result of underfrequency load shedding is required by the UFLS program the TO will provide this capability per the schedule for application determined by the PC.⁹

7.0 UFLS Program Implementation

The LG&E and KU system has a total load more than 100 MW; therefore, SERC-006-SERC-01 R4 does apply and SERC-006-SERC-01 R5 does not apply to LG&E and KU.

The LG&E and KU UFLS entities will implement the UFLS scheme developed by its PC. The scheme will meet the following requirements on May 1 of each calendar year:¹⁰

- The percent of load shedding to be implemented will be based on the actual or estimated distribution substation or feeder demand (including losses) of the UFLS entity at the time coincident with the previous year actual Peak Demand. By May 1, the UFLS entity shall report to the PC, the previous year's actual Peak Demand.
- The amount of load in each load shedding step shall be within the percentage specified range in Table 1 or 2 by the PC. By May 1, the UFLS entity shall report the estimated amount of load on a frequency load shed program at each frequency based on the previous year's actual Peak Demand.
- The amount of total UFLS load of all steps combined shall be within the percentage range specified by the PC in Table 1 and 2 for the total UFLS load in the UFLS scheme.
- By May 1, the UFLS entity shall report the relay time delay for each load amount and frequency.

By at least May 1 of each year, the UFLS entity must email the required information to the LG&E and KU Planning Coordinator using the following distribution email:

NERC.PlanningCoordinator@lge-ku.com

If the LG&E and KU PC directs the UFLS entity to incorporate a UFLS scheme or changes to its UFLS scheme, the UFLS entity shall implement the UFLS scheme directive that involve frequency settings, relay time delays, or changes to the percentage of load in the scheme within 18 months of notification by the PC.¹¹

8.0 UFLS Database

⁹ PRC-006-2 R10

¹⁰ PRC-006-SERC-01 R4

¹¹ PRC-006-SERC-01 R6

The PC for LG&E/KU maintains a UFLS database in coordination with its UFLS entities. This database contains the data necessary to model the UFLS program for use in event analyses and assessments of the UFLS program. This database is reviewed and updated, as necessary, at least once per calendar year with no more than 15 months between maintenance activities.¹²

The UFLS database will be made available to other PC within its Interconnection within 30 calendar days of a request.¹³

The UFLS entities for LG&E/KU will provide data to the PC for LG&E/KU within 30 calendar days of a request to support maintenance of the PC's database.¹⁴

Each UFLS entity must provide data documenting three load shed steps, shedding approximately 10% of the seasonal Peak Demand at each step at frequencies of 59.5 Hz, 59.3 Hz, and 59.1 Hz. This is a combined load shed of 30% of the seasonal Peak Demand. The pickup or delayed time for each step is 10 cycles (0.167 seconds).

Between October 1, 2014 and April 1, 2016, it is expected that a combination of the prior UFLS program will exist until all UFLS relay settings are adjusted to the new April 1, 2016 UFLS program.

9.0 Event Analysis

In the event that a BES islanding event resulting in system frequency excursions below the initializing set points of the UFLS program occurs in the LG&E/KU PC area, the PC will conduct and document an assessment of the event within one year of event actuation to evaluate:¹⁵

- The performance of the UFLS equipment,
- The effectiveness of the UFLS program.

If a UFLS event assessment identifies program deficiencies the PC will conduct and document a UFLS design assessment to consider the identified deficiencies within two year of event actuation.¹⁶

If a BES islanding event occurs that also includes the area(s) or portions of area(s) of other PCs in the same islanding event and that resulted in system frequency excursions below the initializing set points of the UFLS program, the PC for LG&E/KU will coordinate its event

¹² PRC-006-2 R6

¹³ PRC-006-2 R7

¹⁴ PRC-006-2 R8

¹⁵ PRC-006-2 R11

¹⁶ PRC-006-2 R12

assessment with all other PCs whose areas or portions of whose areas were also included in the same islanding event through one of the following:¹⁷

- Conduct a joint assessment per PRC-006-2 R11 among the PCs whose areas or portions of whose areas were included in the same islanding event, or
- Conduct an independent event assessment per PRC-006-2 R11 that reaches conclusions and recommendations consistent with those of the event assessments of the other PCs whose areas or portions of whose areas were included in the same islanding event, or
- Conduct an independent event assessment per PRC-006-2 R11 and where the assessment fails to reach conclusions and recommendations consistent with those of the event assessments of the other PCs whose areas or portions of whose areas were included in the same islanding event, identify differences in the assessments that likely resulted in the differences in the conclusions and recommendations and report these differences to the other PCs whose areas or portions of whose areas were included in the same islanding event and the ERO.

10.0 Notification of Changes to UFLS Program

The PC for LG&E/KU will send out for comment any recommended changes to the UFLS program to its entities, as a result of a design assessment, to the UFLS entity and TO in its PC area prior to finalizing the changes. The PC will respond to written comments in writing whether changes will be made or reasons why changes will not be made to the following:¹⁸

- UFLS program, including a schedule for implementation
- UFLS design assessment
- Format and schedule of UFLS data submittal

11.0 UFLS Deficiency Corrective Action Plan

When the LG&E and KU PC conducts the UFLS design assessment under PRC-006-2 R4, R5 or R12 and determine that the UFLS program does not meet the performance characteristics in PRC-006-2 R2, the deficiency will be documented and the LG&E/KU PC will develop a Corrective Action Plan which includes a schedule for implementing the revised UFLS program¹⁹. The schedule will include requirements for written notification per Section” 10.0 Notification of Changes to UFLS Program”.

For UFLS design assessments performed under Requirement R4, or R5, the Corrective Action Plan shall be developed within the five-year time frame identified in PRC-006-2 R4²⁰.

¹⁷ PRC-006-2 R13

¹⁸ PRC-006-2 R14

¹⁹ PRC-006-2 R15

²⁰ PRC-006-2 R15.1

For UFLS design assessments performed under Requirement R12, the Corrective Action Plan shall be developed within the Two-year time frame identified in PRC-006-2 R12²¹.

12.0 SERC Reporting

The LG&E and KU PC will provide the following information to SERC according to the schedule specified by SERC:²²

- Underfrequency trip set points (Hz)
- Total clearing time (delay or pickup time) associated with each set point (sec). This includes the time from when frequency reaches the set point and ends when the breaker opens.
- Amount of previous year actual or estimated load associated with each set point, both in percent and in MW. The percentage and the Load demand (MW) shall be based on the time coincident with the previous year actual Peak Demand.

²¹ PRC-006-2 R15.2

²² PRC-006-SERC-01 R7