

## Comment Form for 1<sup>st</sup> Draft of Under Frequency Load Shedding Regional Reliability Standard Characteristics — Project 2007-01

Please **DO NOT** use this form to submit comments on the proposed 1<sup>st</sup> draft of the Under Frequency Load Shedding Regional Reliability Standard Characteristics developed by the standard drafting team for Project 2007-01 – Underfrequency Load Shedding. Comments must be submitted by **August 15, 2008**. If you have questions please contact Stephanie Monzon at [stephanie.monzon@nerc.net](mailto:stephanie.monzon@nerc.net) or by telephone at 610-608-8084.

Please submit your comments by using the [Electronic Comment Form](#) posted on the Project 2007-01 Underfrequency Load Shedding Drafting Team Web site.

### Background Information

The major objectives of Project 2007-01 Underfrequency Load Shedding are to:

- 1) Ensure UFLS standards are developed that are complete and the requirements are set at an appropriate level to ensure reliability (not least common denominator).
- 2) Ensure that the standards are enforceable with clearly defined requirements and unambiguous language.
- 3) Address the issues raised by FERC Order 693 and other applicable orders.
- 4) Address the issues raised in the original Standards Authorization Request (SAR) for this project.
- 5) Address coordination between underfrequency load shedding and generator trip settings during frequency excursions.

The standard drafting team (SDT) for Project 2007-01 Underfrequency Load Shedding (UFLS) based its work on the existing NERC standards:

- PRC-006-0 — Development and Documentation of Regional UFLS Programs,
- PRC-007-0 — Assuring Consistency with Regional UFLS Program Requirements, and
- PRC-009-0 — UFLS Performance Following an Underfrequency Event.

Project 2007-01 Under Frequency Load Shedding is one of four projects<sup>1</sup> identified in the Reliability Standards Development Plan 2008-2010 as requiring a set of Regional Standards to support a continent-wide standard.

In accordance with the associated SAR, a standard drafting team was appointed to draft the continent-wide UFLS standard with consideration of developing supporting regional standards. The team is recommending that, instead of developing a continent-wide standard, NERC issue a set of UFLS performance characteristics required in regional reliability standards for implementing automatic UFLS programs to arrest declining Bulk Electric System frequency.

NERC will include the approved UFLS Regional Reliability Standard Characteristics in a directive that it provides to each regional entity requiring the regional entity to develop a regional UFLS reliability standard. NERC is authorized to direct a regional entity to develop a

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<sup>1</sup> The other three projects were, Project 2007-05 Balancing Authority Controls; Project 2007-11 Disturbance Monitoring; and Project 2008-04 Protection Systems

regional standard pursuant to section 312.2 of the Rules of Procedure of the North American Electric Reliability Corporation which states:

**Regional Reliability Standards That are Directed by a NERC Reliability Standard** — Although it is the intent of NERC to promote uniform reliability standards across North America, in some cases it may not be feasible to achieve a reliability objective with a reliability standard that is uniformly applicable across North America. In such cases, NERC may direct regional entities to develop regional reliability standards necessary to implement a NERC reliability standard. Such regional reliability standards that are developed pursuant to a direction by NERC shall be made part of the NERC reliability standards.

The standard drafting team's proposed approach of establishing common system performance characteristics rather than prescribing a uniform design specification for all UFLS programs within a continent-wide standard recognizes that the objective of the UFLS programs is to arrest and recover frequency in islanded portions of an interconnection. In addition, UFLS programs with differing design specifications can be successfully coordinated if they are designed to achieve the same system performance characteristics, even across interconnected regions.

The drafting team reviewed the existing UFLS programs from each Region and it became clear that various combinations of load steps and frequency set points exist and can achieve the objective of arresting and recovering frequency. Also, it became clear that there is not one way to design a UFLS program. Additional reasons the drafting team is recommending the development of a UFLS Regional Standard as opposed to a continent-wide standard:

- The Region's UFLS programs are repeatedly evaluated for their effectiveness;
- Applicability and responsibility for a UFLS program varies among the Regions;
- A UFLS infrastructure is already in place within each Region and to convert to one UFLS program would take time/effort and expense; and
- The expertise resides in each region to develop a UFLS Regional Standard.

Part of the intent of directing the regions to develop UFLS Regional Standards is because each regional entity has specific expertise relative to defining credible islands within or between its region and neighboring regions. The regional entities also have specific expertise for assessing islands within their regions based on electrically interconnected areas. Analysis of islands occurring between regions is intended to require coordination of programs by the Regions across which an island may form.

### **Characteristics of UFLS Regional Reliability Standards**

The SDT developed the set of characteristics which each of the regional entities will be directed to include in its UFLS regional reliability standard. The SDT developed these characteristics for directing the regional entities in developing requirements that can be defined based on system performance, without prescribing specifics of how these system performance requirements should be met. This approach for identifying regional reliability standard characteristics for implementation of a regional standard by a regional entity is being used for the very first time by a NERC drafting team.

The technical basis for each of the parameters is summarized as:

- Frequency decline shall be arrested at no less than 58.0 Hz.

*The technical basis for this design parameter is coordination with generating unit protections and the generator underfrequency tripping requirements proposed by the*

*Generator Verification Standard Drafting Team. The tripping threshold proposed for NERC Reliability Standard PRC-024 is 57.8 Hz with no intentional time delay. Arresting declining frequency within an island at or above 58.0 Hz provides proper coordination to prevent tripping of generation prior to allowing the UFLS program to arrest frequency decline.*

- Frequency shall not remain below 58.5 Hz for greater than 10 seconds, cumulatively, and shall not remain below 59.5 Hz for greater than 30 seconds, cumulatively.

*The technical basis for this design parameter is coordination with generating unit protection and the generator underfrequency tripping requirements proposed by the Generator Verification Standard Drafting Team. Recovering frequency within an island in accordance with these parameters avoids operating conditions for which the generating units are subject to turbine damage and provides proper coordination to prevent tripping of generation prior to allowing the UFLS program to recover frequency.*

- Frequency overshoot resulting from operation of UFLS relays shall not exceed 61.0 Hz for any duration and shall not exceed 60.5 Hz for greater than 30 seconds, cumulatively.

*The technical basis for this design parameter is coordination with generating unit protection and the generator overfrequency tripping requirements proposed by the Generator Verification Standard Drafting Team. Controlling frequency overshoot during frequency recovery within an island in accordance with these parameters avoids operating conditions for which the generating units are subject to turbine damage and provides proper coordination to prevent tripping of generation, which could lead to additional UFLS operations and possible frequency collapse.*

- Bulk Electric System voltage during and following UFLS operations shall be controlled such that the per unit Volts per Hz (V/Hz) will not exceed 1.18 for longer than 6 seconds cumulatively, and will not exceed 1.10 for longer than 1 minute cumulatively.

*The technical basis for the V/Hz design parameter was developed through a review of relevant industry standards that include voltage and frequency limits for major electrical equipment. Low levels of overexcitation cause excessive core and non-magnetic structure heating, which can lead to loss of life and degradation of insulation. High levels of overexcitation can cause insulation failure within seconds.*

*IEEE Standard C37.102 recommends generator V/Hz protection set to trip in 45 to 60 seconds at V/Hz greater than 1.10 per unit (pu), and in 2 to 6 seconds at V/Hz greater than 1.18 pu, and that the manufacturer's limitations should be respected. IEEE Standard C37.106 includes typical generator overexcitation limitation curves from various manufacturers which show time limits of roughly 60-100 seconds at 1.10 pu V/Hz, and 6 seconds or less at 1.20-1.30 pu V/Hz. IEEE Draft Standard PC37.91 includes typical curves from three manufacturers which show transformer limits of roughly 100 minutes at 1.10 pu, 1 minute at 1.20 pu, and 6 seconds at 1.30 pu.*

*The performance requirements were selected to prevent equipment damage and to coordinate with generating unit protection. Protection coordination is critical to island survival since tripping of generation during underfrequency conditions may lead to cascading tripping and frequency collapse.*

### **Coordination with Generation Underfrequency Tripping and Existing Settings**

The SDT recognized the importance of coordination with generator underfrequency tripping. Accordingly, the drafting team choose the specific technical design parameter values in order to coordinate with a generator under (and over) frequency tripping characteristic that has been proposed for continent-wide use by the NERC standard drafting team addressing PRC-024 – Generator Verifications, and which that team has accepted for inclusion in its draft standard.

In addition to coordination with generator under and over frequency tripping, the drafting team also considered the existing regional UFLS set points and time delays in aggregate. The drafting team did not wish to force adjustments to UFLS relay settings and time delays simply to give the appearance of uniformity. There exists a degree of latitude over which the technical design parameters may vary and yet remain in coordination with the proposed generator tripping characteristics. Most existing regional UFLS programs should find conformance to the technical design parameters requires minimal or no adjustment of relay settings and time delays.

The above two factors, coordination with generator under and over frequency tripping as first priority, and then minimization of adjustments to existing relay settings, constituted the basis for choosing the technical design parameter values related to frequency.

Compliance with the regional standards will fulfill the intent of PRC-007-0 — Assuring Consistency with Regional UFLS Program Requirements, in that the performance characteristics will be detailed in the Regional Standards, along with associated compliance elements.

As for the event reporting required by PRC-009-0 — UFLS Performance Following an Underfrequency Event, the standard drafting team is recommending that this should be covered under the NERC Rules of Procedure and be included as a delegated responsibility for the Regional Entities as many other reporting tasks.

The following questions will assist the SDT in finalizing the development of the Under Frequency Load Shedding Regional Reliability Standard Characteristics. For questions where you agree with the SDT, please state that you agree and if available, please provide supporting documentation. If you disagree with the SDT, please explain why you disagree and provide data to support your position. To improve the Under Frequency Load Shedding Regional Reliability Standard Characteristics, the SDT would appreciate responses to as many of these questions as you can answer.

**You do not have to answer all questions. Enter All Comments in Simple Text Format.**

*Insert a "check" mark in the appropriate boxes by double-clicking the gray areas.*

### **Characteristics of UFLS Regional Reliability Standards**

1. The SDT determined that there is no need to have a continent-wide standard, and proposes that all UFLS requirements be contained within the regional UFLS standards developed in accordance with the Characteristics of UFLS Regional Reliability Standards.

The SDT developed a set of characteristics which each of the regional entities will be directed to include in its UFLS regional reliability standard. The SDT developed these characteristics in an attempt to direct the regional entities to develop requirements

based on system performance, without prescribing specifics of how to meet the specified performance.

Do you agree with the drafting team?

Yes

No

Yes and No

Comments: The MRO believes that the Regions should determine the details of the UFLS. We believe the regions are best situated to perform the studies and determine the total amount of load shed required, how many blocks, at what frequency, etc. This includes setting regional performance objectives for UFLS design, and deciding on generator under/over frequency minimum time delays and frequency setpoints.

The MRO believes that the Under Frequency Load Shedding Standard Drafting Team is headed in the right direction as far as allowing the regions to create their own UFLS program within continental wide characteristics. It's the MRO's contention that while the 11 general characteristics are reasonable they may be too specific to accommodate the needs of every region or they may be too extreme for every region. The MRO asks that the UFLS SDT allow the regions a reasonable amount of time to determine the specific number which would accommodate the general NERC objectives but would address regional conditions.

There are some inconsistencies in the document as the Characteristics listed in the "UFLS Regional Reliability Standard Characteristics" document do not match with those listed in this comment form in the "Characteristics of UFLS Regional Reliability Standards" section. Specifically, 1) What is the technical justification for the frequency overshoot limit of 61 Hz? (third bullet) 2) What is the technical justification for the time durations for the Volts/Hz? (Fourth Bullet)

The MRO interprets that the STD is proposing the withdrawal of the PRC-006-0, PRC-007-0, and PRC-009-0 standards when applicable Regional replacement standard(s) are established and become effective. The MRO also interprets that the STD is proposing UFLS Regional Reliability Standard Characteristics, rather than revising the NERC UFLS standards, because NERC standards can not be applicable to Regional Entities and the Characteristics may be a means for NERC to require the Regions to develop appropriate Regional standards that share key continent-wide characteristics. The MRO agrees that the existing NERC standards could be replaced with appropriate Regional standards and believe that some UFLS program requirements should be different in different Regions.

The MRO disagrees that the Characteristics should direct Regional Entities to be based on continent-wide system performance values. Appropriate system performance levels and appropriate percentage of load shedding will vary for each potential island and depend on the composition of load, generation, and system protection within the island. The continent-wide Characteristics should deal with such broader issues such as: identification of potential islands, coordination among accountable entities, identification of appropriate load shedding percentage, identification and coordination with island-specific generation-related limits and system protection settings, responsibility for UFLS program design and implementation, responsibility for and frequency of UFLS program assessment, etc.

2. As proposed, each regional UFLS standard must require that, for underfrequency conditions resulting from an imbalance between load and generation of at least 25 percent within an interconnection, region, or identified island(s) within or between regions, the UFLS must arrest frequency decline at no less than 58.0 Hz.

Do you agree with this design parameter? If you disagree, please identify whether you believe this design parameter should be deleted or revised.

- Yes  
 No – Delete the design parameter  
 No – Revise the design parameter as noted in the comments

Comments: The system performance (Requirement 4) prescribed by the SDT is based on typical values and their engineering judgement, and do not reflect how individual systems (or islands) were planned and designed (and what were/are deemed as acceptable risks). We believe it more appropriate for the Planning Coordinators associated with the individual regions/islands to decide what are the appropriate design values (for 4.1 to 4.4), while still coordinating with other regions/islands. We also believe most if not all of the UFLS characteristics can be performed under the auspices of the Planning Coordinator function.

Throughout NERC characteristic list, the words “conditions resulting from an imbalance between load and generation of at least 25%” are used in relation to stated performance objectives. The words “of at least” create confusion as well as the undefined term “imbalance”. The MRO has assumed this means that criteria must be met at the maximum overload level each Regions UFLS program is designed to cover, with all Regions having to shed a minimum of at least 25% of system load. However, this could also mean that criteria only has to be met for a 25% imbalance. This needs to be more clearly stated.

The MRO agrees with the concept of NERC establishing a minimum load shedding level for all regions, but we do not know what a 25% imbalance is supposed to be. The definition of imbalance is not given but there is a definition that is common to the subject of UFLS, where  $overload = OL = (remaining\ generation - load) / (remaining\ generation)$ . To us,  $imbalance = OL$ , then:

$$OL = -.25 = (gen - load) / gen = (.8 - 1) / .8$$

This implies 20% load shedding

A 20% load shedding requirement seems a little low. A 25% minimum load shedding requirement seems more reasonable, but each Region would need to consider if that is adequate to satisfy their internal needs. In any event, minimum load shedding requirements should be explicitly stated as X% of load.

The 58.0 Hz appears to have more of a philosophical basis rather than being solely related to generation protection needs. If generation protection is the issue, then a 58 Hz minimum frequency criteria would not be appropriate for all islands. An island consisting of hydro units could easily accept minimum frequencies below 58 Hz for extended periods.

As a practical matter, 58 Hz, as average system frequency, is probably a reasonable minimum frequency target for design work, at least for programs that shed 30% load or less. UFLS programs which need to shed more load can increase starting frequencies to improve the minimum frequency to some extent, but may need to accept momentary dips below 58 Hz provided this coordinates with overall generation protection. If this becomes

NERC performance criteria, then we anticipate there needs to be a way to allow exceptions when appropriate.

We also have concerns that minimum frequency seen in simulations is quite subjective, it depends on many specific details such as the specific overload level modeled, as well as the assumptions made for load damping, system inertia, UFLS details including total tripping times of load, capacitor tripping, governor response, etc. It is easier at the Regional level to resolve what range of conditions/assumptions/modeling issues need to be considered.

If any generators have unreasonable frequency characteristics that can be changed, then the Standard should require them to make appropriate changes.

3. As proposed, each regional UFLS standard must require that, for underfrequency conditions resulting from an imbalance between load and generation of at least 25 percent within an interconnection, region, or identified island(s) within or between regions, the UFLS must act such that frequency does not remain below 58.5 Hz for greater than 10 seconds, cumulatively, and frequency does not remain below 59.5 Hz for greater than 30 seconds, cumulatively.

Do you agree with this design parameter? If you disagree, please identify whether you believe this design parameter should be deleted or revised.

Yes

No – Delete the design parameter

No – Revise the design parameter as noted in the comments

Comments: The system performance (Requirement 4) prescribed by the SDT is based on typical values and their engineering judgement, and do not reflect how individual systems (or islands) were planned and designed (and what were/are deemed as acceptable risks). We believe it more appropriate for the Planning Coordinators associated with the individual regions/islands to decide what are the appropriate design values (for 4.1 to 4.4), while still coordinating with other regions/islands. We also believe most if not all of the UFLS characteristics can be performed under the auspices of the Planning Coordinator function.

We do not agree with the specified maximum operating times associated with the specified off-nominal frequencies. The proposal to limit time below 59.5 Hz and above 60.5 Hz to 30 seconds looks like a typo. 59.5 Hz to 60.5 Hz is the range where units can run continuously with no accelerated loss of life. Perhaps “30 seconds” should have read “30 minutes” which is still only 66% of the time specified by the MRO program for  $f \leq 59.5$  Hz. As written, the proposed criteria for time spent below 59.5 Hz and above 60.5 Hz is unacceptable.

The MRO UFLS report states that generation protection cannot trip any quicker than shown below, and that utilities that need to shed more than 30% of connected load will have to relax these times to allow their load shedding to play out.

MRO generation protection time delay requirement:

- 45 minute, frequency  $\leq 59.5$  Hz
- 5 minute, frequency  $\leq 59.3$  Hz
- 1.33 minute, frequency  $\leq 59$  Hz
- 30 second, frequency  $\leq 58.4$  Hz
- 7.5 second, frequency  $\leq 58.0$  Hz

- instant trip at 57.6 Hz

In the MRO UFLS study simulations, we estimated our worst-case time below 58.5 Hz would be approximately 9 seconds. Of course, this has to be qualified by saying “for our given assumptions”. These types of simulations only give approximate results. The proposal to limit time below 58.5 Hz to 10 seconds is going to be tight for a program which sheds more than 30% load. What we assume for governor action will have considerable effect on how much time is spent below 58.5 Hz. The MRO tried to design a program that will ensure frequency recovery even if we get no net governor response.

The MRO study looked at a range of imbalances that an UFLS program has to respond to, and factored in uncertainties. 100’s of cases were run to cover a range of imbalances, range of damping assumptions, and a range of system based inertia. In looking at all of the results in total, the resulting time spent below a given frequency took on the form of a probability density function. Typical times below a given frequency are perhaps more representative of what the typical exposure is for generation. However we coordinated generation protection according to the worst case times with enough margin to provide a degree of comfort. The actual loss of life a generator will be exposed to for some arbitrary UFLS event will most often be less than what these generator protection trip settings reflect as the first line of defense is the load shedding program itself. Under most circumstances, we will never spend enough time in the frequency trip bands to actually trip generation.

To view the full report of the MRO UFLS please see the MRO website:

[http://www.midwestreliability.org/03\\_reliability/assessments/report\\_draft\\_03\\_12\\_final\\_clean.pdf](http://www.midwestreliability.org/03_reliability/assessments/report_draft_03_12_final_clean.pdf)

4. As proposed, each regional UFLS standard must require that, for underfrequency conditions resulting from an imbalance between load and generation of at least 25 percent within an interconnection, region, or identified island(s) within or between regions, the UFLS must act such that the frequency overshoot resulting from operation of UFLS relays will not exceed 61.0 Hz for any duration and will not exceed 60.5 Hz for greater than 30 seconds, cumulatively.

Do you agree with this design parameter? If you disagree, please identify whether you believe this design parameter should be deleted or revised.

- Yes  
 No – Delete the design parameter  
 No – Revise the design parameter as noted in the comments

Comments:

This a subjective performance criteria as modeling details such as load damping assumptions, inertia assumptions, and governor response assumption will all have considerable effect on performance. This type of performance objective is best evaluated and determined at the Regional level, or some mechanism needs to be in place to allow aggressive load shedding programs some latitude on this. There are cases where overshoots above 61 Hz could be accepted for short periods. The type of units in the island also have to be considered. Hydro systems have fewer off-nominal frequency restrictions

The 30 second time limit for operating above 60.5 Hz is not at all appropriate. Units can operate continuously at 60.5 Hz with no accelerated loss of life. They can run slightly above this for a long time. Could this be a typo? Was the intention to establish at 30 minute limit?

5. As proposed, each regional UFLS standard must require that, for underfrequency conditions resulting from an imbalance between load and generation of at least 25 percent within an interconnection, region, or identified island(s) within or between regions, the UFLS must act such that the Bulk Electric System voltage during and following UFLS operations is controlled such that the per unit Volts per Hz (V/Hz) does not exceed 1.18 for longer than 6 seconds cumulatively, and does not exceed 1.10 for longer than 1 minute cumulatively.

Do you agree with this design parameter? If you disagree, please identify whether you believe this design parameter should be deleted or revised.

- Yes  
 No – Delete the design parameter  
 No – Revise the design parameter as noted in the comments

Comments:

The MRO believes the V/Hz characteristic is premature and should be investigated further. The simulation results depend on the degree of details of system dynamics characteristics, therefore it is hard to determine its authenticity.

With respect to the 6-second or 1-minute V/Hz values (Characteristic 4.4), these values may be reasonable at generator and transformer terminals. However, for the some potential islands the appropriate volt/hertz limits might vary based on the composition of generators and transformers, an absolute, continent-wide value may not be appropriate. For instance another approach from a continent-wide perspective may be to specify a minimum margin (e.g. 5%) above the minimum 6-second and 1-minute volt/hertz level for each potential island. The Characteristics might require that the minimum critical 6-second and 1-minute V/Hz limits need to be investigated and identified. If any generators have unreasonable V/Hz characteristics that can be changed, then the Standard should require them to make appropriate changes.

6. If there are any other characteristics in the UFLS Regional Reliability Standard Characteristics document that you disagree with, please identify them here, and either identify that they should be deleted, or recommend an alternative.

- Agree with all proposed characteristics  
 Disagree with one or more of the characteristics as noted in the comments  
Comments: The system performance (Requirement 4) prescribed by the SDT is based on typical values and their engineering judgement, and do not reflect how individual systems (or islands) were planned and designed (and what were/are deemed as acceptable risks). We believe it more appropriate for the Planning Coordinators associated with the individual regions/islands to decide what are the appropriate design values (for 4.1 to 4.4), while still coordinating with other regions/islands. We also believe most if not all of the UFLS characteristics can be performed under the auspices of the Planning Coordinator function.

The MRO would ask that characteristics 5 and 6 remove the reference to PRC-024, but do agree with the need for coordination between UFLS and generation protection and expressing the characteristics 5 and 6 in more general terms.

7. The SDT proposes that the regional standards include the database requirements contained in existing Reliability Standard PRC-007. Do you agree that database requirements should be addressed within the Regional Standards?

- Yes  
 No  
 Yes and No

Comments: The MRO agrees that any database requirements should be addressed within the Regional Standards. However, we hope that the database requirements among regions within the same Interconnection are the same. In addition, we would expect that the database would be required to be updated every year.

8. Are you aware of any conflicts between the proposed regional standards and any regulatory function, rule, order, tariff, rate schedule, legislative requirement, or agreement?

- Yes  
 No  
 Yes and No

Comments:

9. Do you have any other questions or concerns with the proposed Under Frequency Load Shedding Regional Reliability Standard Characteristics that have not been addressed? If yes, please explain.

- Yes  
 No  
 Yes and No

Comments: In general we believe it should be left to the Regions to determine what the UFLS limits should be.

As noted in this questionnaire, the SDT found that there are many ways to perform the UFLS function, depending on the characteristics of the Region. We believe that NERC should insure that there is a UFLS program in place in each region, that there is adequate technical justification for each region's UFLS program, the program is reviewed annually and the necessary changes made, etc. The Regions should be responsible to perform the necessary studies, determine the UFLS setpoints, undershoot/overshoot targets, etc. and enforce them. We believe that will deliver the most flexible and efficient method to implement UFLS.

Requirement 10.1: Change "through dynamic simulations" to "through analytical studies" because verification of meeting some performance requirements can be performed with other types of methods and simulations.

There needs to be an awareness that overvoltages will affect the performance of UFLS loadshedding due to the increases in system load. One approach is to trip capacitors along with load (or take comparable actions) to try to keep voltages reasonable. Switchable high voltage line shunts and reactors also need to be considered where appropriate. Obviously, the goal would be to keep voltages close to initial levels as load is shed yet we recognize that despite best efforts, we will get considerable fluctuation in voltage as load is shed.