Automatic Underfrequency Load Shedding Program Standard PRC-006-MRO-01

Frequently Asked Questions - Practical Compliance and Implementation

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1. Introduction

The following is a draft collection of questions, and answers as developed, that the MRO UFLS SDT believes could be helpful to those implementing MRO Standard PRC-006-MRO-01 Automatic Underfrequency Load Shedding Requirements.

2. Executive Summary

This FAQ document provides definitions for a variety of terms that do not have formal definitions.

This document highlights that UFLS programs are to provide a line of defense against the collapse of credible BES islands for a wide range of underfrequency events, but should not be expected to be effective for all possible events. It also notes that although the tripping of 30% load is appropriate for most credible islands, the characteristics of some credible islands warrant the use of higher load shedding percentages.

This document discusses topics that may be used and useful toward fulfilling the requirements in PRC-006-MRO-01.

- The consideration of tripping of non-BES (e.g. distribution system) elements in the UFLS Program for the desired BES performance.
- The usage of MRO 2007 UFLS Report and the "equivalent inertia" analytical method.
- Suggestions of acceptable forms of compliance evidence
- Suggestions of appropriate reactive power device data
- Suggestions for the handling of intentional time delay
- Comments on reporting of load for the UFLS program data base
- Maximum frequency overshoot limits
- Extensions and exemptions
- ~~Exemption in R11.1~~

This document provides opinion on the types of relays that would be acceptable and the use of automatic load restoration, and the consideration of tripping reactive power devices.

3. Additional Topics for Consideration in FAQ

None

4. Terms Used in PRC-006-MRO-01

Design Plan: The collection of the system assumptions and performance criteria that are the basis for the UFLS program in a Planning Coordinator's area. The design plan includes consideration of such items as the minimum desired frequency, the range of island load versus generation balance, types of generation, generation dispatch patterns (effects of the range of system inertias), potential islanding scenarios, coordination among facilities and adjoining entities, and maximum desired overshoot frequency.

Functional Design Specification: The particular UFLS program design details that are to be implemented by Distribution Providers. The design details include such elements as the number of load shedding steps, the trigger frequency at each step, the percentage of total Distribution Provider load to be shed at each step, the maximum time delay associated with each step, and acceptable relay types.

~~**Credible Island (R1, R2, R2.1, R2.2, R2.3, R3.1, & R13)** – A portion of the transmission network that is capable of sustaining a balance of its own generation, load, and loss characteristics if synchronization with the grid is lost~~

~~**Load and Resource Balancing Method (R3.1)** – A Load and Resource Balancing Method is any . . . [Be sure to provide sufficient reactive device detail to allow proper modeling of the device in a dynamics simulation.]~~

Load Characteristics: ~~(R4) –~~ The load attributes that the Distribution Provider (DP) considers when developing or revising its portion of the UFLS plan. All Load Serving Entities within the Distribution Provider's footprint~~DP's Footprint~~ shall provide input, which should include (but not limited to), the following data points:

- Critical loads to be avoided in plan development
- Installed under frequency capability in addition to that owned by the distribution provider, frequency set points of under frequency relays in service
- Possible loads to be added to the under frequency plan
- Seasonal peak loads (Winter and Summer)
- Distributed ("behind the meter") generation locations

Reactive Power Device: Discrete electric devices that primarily provide reactive power, such as capacitor banks and inductor banks. Selected ~~**(R3.1, R6, R7, R9, & R13)** – Applicable~~ reactive power devices may need to be switched by underfrequency relays, overvoltage relays, or combination of both types of relays. This action is to mostly prevent or mitigate power system bus overvoltages that would occur due to the operation of a UFLS program (primarily the shedding of real power load) in a local area.

These reactive power devices may be bulk electric system devices that have a voltage rating of 100 kV or higher. These devices may have distribution voltage ratings. However, this does not refer to distributed reactive devices on distribution feeders that ~~include capacitor banks, static var compensators, inductor banks, for example, devices that~~ are tripped along with predominately real power load. At distribution voltages, these devices may be a dedicated capacitor bank that is connected directly to the distribution substation bus.

The reactive power devices are to be modeled as discrete elements in the power system base case that can be controlled independently due to low ~~by~~ frequency or high voltage levels. relays. These devices are typically rated 100 kV or higher. Reactive power devices that are rated less than 100 kV should be considered if they have a significant effect on the BES. [Be sure to provide sufficient reactive device detail to allow proper modeling of the device in a dynamics simulation.]

Other System Protection Schemes: System protection**Scheme (R9)** Applicable schemes that may affect UFLS programs could include: non-Fault clearing schemes, tie-tripping schemes, or islanding schemes. [If an other protection scheme is, or additional Load shedding schemes. [Be sure to be modeled, then the entity should provide sufficient protection scheme detail to allow proper modeling of the scheme in a dynamic power flow softwaredynamics simulation.]

Underfrequency Load Shedding (UFLS) Program: A program of functional actions to provide last resort preservation measures in order to assist in the recovery of frequency to acceptable levels following underfrequency events. These measures include underfrequency relays that trip end user load in a given island. Normally, the UFLS Program involves tripping distribution feeder loads and sometimes loads connected to directly the transmission voltage level buses.

The switching of reactive power devices, such as capacitor banks, plays an important role in providing proper support for and coordination with the UFLS program. Reactive power tripping is to resolve consequential voltage level issues that may result due to the operation of the UFLS Program.

5. Frequently Asked Questions

5.1 We have an Underfrequency Load Shedding system in place that prevents one of our distribution substations from supplying load in the case of an underfrequencyUnderfrequency excursion. If the load is not part of the BES, does this load fall within this standard?

If an underfrequency excursion is on the BES, or impacts the BES, then this frequency excursion needs to be mitigated by shedding load at whatever voltage levels may be most appropriate. The participation of this load is determined by the UFLS program and not dependent on whether it meets a particular voltage rating.

5.2 Is the UFLS Program expected to prevent the collapse of all possible islands of the Bulk Electric System (any islanded portion of the BES) for all possible underfrequency events?

No. The UFLS program providesis to provide a line of defense against unknown islanding events that might cause a the collapse of portionsany islanded portion of the BES. It is impossible to know what islands will form (e.g. due to snow storms, tornadoes, etc.) or whether they would be different from our assumptions. No single UFLS Program can for a wide range of possible system conditions. However, it is not practical or reasonable to expect a UFLS Program to be effective for every possible BES island, possible system condition, or possible and underfrequency event.

5.3 Can the UFLS Program be designed to trip more than a 30% of the island load?

Yes, the UFLS Program can trip more than 30% when it would be appropriate. Some portionscredible islands of the BES have facility characteristics and system conditions that would be better protected better by a UFLS Program that trips 40% or more than 30% of the load. The guiding objective is to provide a line of defense against collapse of the island for the best range of possible system conditions. Areas that are less tightly networked or have large concentrations of generation compared to load (e.g. Canada) may attain better overall benefits from tripping more than 30%.

However, it should be noted that load shedding has its limits and the difficultly of assuring proper coordination of load and generation increases as the percentage of possible island load versus generation balance increases. Load shedding can not cover every possible system condition and contingency, so there are times when one must accept a percentage of island load that is reasonable, rather than perfect.

5.4 Is there more than one approach to evaluating system frequency dynamics and UFLS issues?

The industry recognizes more than one approach to evaluating UFLS issues and the underlying dynamics. No modeling approach is perfect. Different approaches have different strengths and weaknesses and may serve different purposes. The final UFLS analysis can involve a combination of different dynamic simulation approaches, as well as hand calculations. In general, the most desirable engineering analysis is one that uses the simplest dynamic approach and model that properly captures the phenomena of interest. Engineering judgment needs to be applied appropriately to choose the analytical approach or approaches that answers the questions of interest, provides the desired answer accuracy, and considers what is of significance to the phenomena being studied (e.g.. load damping, inertia, overload, governor action, etc.).

One approach is to perform a full scale dynamic simulation analysis on a model that has been modified as needed for these types of studies. Another approach is to use an equivalent inertial analysis method on a single equivalent bus model.

5.45.5 Can the "equivalent inertia" analysis method be used to assess the expected performance of a UFLS Program?

Yes. The "equivalent inertia" method is a very fast and an effective approach for calculatingassessing the expected frequency performance of a UFLS Program for a wide range of facility characteristics and system operating conditions. However, it can not other methods, such as dynamic simulation must be used to monitorevaluate the possible transientsystem bus voltage levels at specific buses throughout the system.

The equivalent inertia method applies simplifying assumptions to equivalize the dynamics analysis into its simplest analytical form. In this dynamic simulation method, the load, generation, and inertia of the entire island is represented as a single bus. The average frequency response for an entire island is calculated on a single bus basis.

Some notable features of the equivalent inertia dynamic simulation method are:

- This dynamic simulation method is generally recommended by underfrequency relay application guides.
- The inertial effects of all significant generator units are aggregated into one simple equivalent machine and then used to predict an average system frequency response. Although machine-to-machine oscillations occur when the island frequency abruptly changes, the specific frequency at different buses in an actual island are expected to differ by about +0.2 and for very high unbalance situations (e.g. greater than 40%) as high as +0.5 Hz. [The expected frequency variations should be considered when interpreting the average frequency results.]
- This dynamic simulation does not include the effects of voltage transients because all of the transmission buses are aggregated into a single bus equivalent with voltage held at the initial value.
- A simplistic generator governor can be added as needed.
- This approach gives considerable "big picture" insight and is useful for evaluating alternatives, exploring sensitivities, and fast prototyping.
- By running a series of cases which cover a wide range of inertia and overload assumptions, the analysis can inherently model the characteristics of several different islanding patterns in one set of casework. This can free the design work from having to be overly customized to one specific islanding pattern.

5.6 Can the "full scale dynamic simulation" analysis method always be used to assess the expected performance of a UFLS Program?

Yes. The "full scale dynamic simulation" method can be used to analyze the expected performance (e.g. frequency and voltage response) of a UFLS Program for nearly every possible set of system characteristics (e.g. system inertia, generator governor settings, UFLS Program settings, etc.) and conditions (e.g. percent of load and generation imbalance). However, it takes a considerable effort to model, simulate, and evaluate each specific set of system characteristics and conditions. So, it is difficult and challenging to choose a few full scale dynamic simulations to properly assess the expected performance of a UFLS Program for a wide range of possible system characteristics and conditions. Good engineering judgment is needed to select a reasonable number of appropriate full scale dynamic simulations.

Full scale dynamic simulation calculates transient frequencies and/or transient voltages within an island on a bus-by-bus basis. This bus-by-bus modeling allows a system planner to simulate and evaluate the expected voltage at any bus or buses in an island.

Some notable features of full scale dynamic simulation method are:

- For UFLS analysis, a full scale dynamic simulation program is a detailed tool but creating islands may still involve some simulation approximations, which may bias the results. For instance, an island event is usually modeled by tripping multiple lines at the same instant. The results of using this technique may not be more accurate than results obtained using other analytical approaches.
- A full scale dynamic stability case is needed for studying very specific disturbances in detail (i.e. study of a tightly defined initial disturbance that leads to islanding, study of a single initial overload level in the island, study of voltage deviations at a specific bus, etc).

- The full scale dynamic modeling approach gives insights into how system bus voltages may change as load is shed.
- "Too much detail" makes it difficult to use a full scale stability program to generalize trends associated with UFLS Program performance or design.
- Generally a more complicated model is needed to model systems which make extensive use of special control actions such as Special Protection Schemes, unique DC line control functions, etc. For example, a full scale stability case may be an appropriate tool to study the Manitoba system as DC line controls play a critical role, while the US portion of the MRO may be able to use simpler models for analysis.
- As with any modeling approach, users have to ensure the significant factors are modeled. Stability programs may be missing or poorly representing some detail that is relevant to the study of large frequency deviations. For instance, work may be needed to improve on generic governor modeling and to model capacitor tripping in response to underfrequency or overvoltages.

~~5.5~~5.7 Can the MRO 2007 UFLS Report be used to fulfill ~~any of the~~ PRC-006-MRO-01 standard requirements?

Yes. The MRO report may be helpful in developing Design Plans for Planning Coordinator areas and Functional Design Specifications for Distribution Providers. The report describes the effects of many different UFLS program considerations, such as facility characteristics, number of load shedding steps, frequencies of load shedding steps, time delays of load shedding steps, expected island unbalance levels, and system performance trade-offs. ~~The MRO report may be used to fulfill portions of the performance methodology requirement, the assessment requirement, and other requirements generally until it becomes more than 5 years old (2013). The report identifies recognized credible islands, suggests design and performance methodology, and assesses the expected performance of the proposed UFLS program.~~

~~5.6~~5.8 What forms of compliance evidence may be~~are~~ acceptable?

Possible~~Acceptable~~ forms of acceptable evidence may include ~~but are not limited to~~:

- Reports of program performance assessments
- Functional Design Specifications
- ~~Process document or plan~~
- Data (such as relay settings sheets, photos, SCADA).
- Database screen shots that demonstrate compliance information.
- Diagrams, engineering prints, schematics, maintenance and testing records, etc.
- Logs (operator, substation, and other type of log)~~.~~
- U.S. mail, memos, or email proving the required information was exchanged, coordinated, submitted or received.
- Database files and lists.

Potential evidence~~Evidence~~ of the distribution of information to applicable entities:

- U.S. mail letters

- Business memos
- Emails with its associated distribution listsEmail proving

These forms of communication should demonstrate that the required information was exchanged, coordinated, submitted, or received.

5.75.9 What data should be provided on applicable reactive power devices (R9)?

Reactive power device data should be provided that would allow the Planning Coordinator to properly model it in the dynamic simulations. This information would normally include:

- Point of interconnection on the transmission system where the reactive power device effect can be modeled
- A block quantity and size for each reactive power device
- Set points for any frequency or voltage tripping function associated with the reactive power device
- Time delay duration for each frequency or voltage tripping function

5.10 What does total intentional time mean?

The total intentional tripping time is the time delay between when the event occurred and when the intended end-use load is tripped. This time delay includes at least three key components: the maximum relay detection time, the intentional time delay, and the maximum breaker clearing time.

- Voltage range of reactive power devices and their voltage step sizes

5.85.11 How should intentional time delay of large motor loads or distributed generation be handled?

Generally, an intentional relay time delay for large motors loads or distributed generation with underfrequency protection relays should be not more than ten cycles, with certain documented exceptions. The documentation for exceptions shouldshall consist of reports of mis-operations, or distributed generation issues, or analysis of large motor Loads:

- For installations where large motor Loads may be isolated, undercurrent supervision shall be used to avoid false operation during Fault isolation. If this is not available, planned total time delay may be increased to no greater than 29 cycles.
- For installations where distributed generation may be isolated, undercurrent supervision shall be used to avoid false operation during Fault isolation. If this is not available, planned total time delay may be increased to no greater than 29 cycles.

However, the Planning Coordinator will determine appropriate intentional time delay for its area based on its Design Plan and provide the specific time delays that each Distribution Provider must implement in its Planning Coordinator area.

5.95.12 What types of relays may be used in a UFLS Program?

The type of relays that may be used in a UFLS program should be considered when adequately described in each Planning Coordinator develops its Design Plan.Coordinators design methodology. The MRO 2007 UFLS Report and Recommendations document suggestssuggest using high speed digital or computer based relays because they are faster and more effective in responding to underfrequency events than electromechanical relays.

Electromechanical relays generally operate on the rate of frequency change and they are too slowHowever, to effectively coordinate with digital relays. In addition, they do not assure reliable and accurate underfrequency tripping performance.

To prevent false trips, the electronic relay operating time delay of electronic relays should be set to at least 6 cycles of detection time.

5.105.13 What kind of load levels should be reported for the UFLS program database?

The load level information that should be kind of load levels to be reported for the UFLS Program database will be requested byshould be adequately described in each Planning Coordinator. However, 's design methodology. Each design methodology is expected to indicate that the load level information that is presently collected by the MRO is projected peak load and the amount of load shed at for each reported UFLS step at each load's systemBES interconnection bus location (bus ID). The is the forecasted peak load for the next projected peak load season and is usually updated each year based onto be derived from the latest actual, historical data from previous peak seasons. The load data should not be a simplistic assigned percentage of total station load at the associated BES interconnection location.

5.115.14 Should the automatic load restoration be considered along with a UFLS Program?

Not generally. Although . The automatic load restoration can be a method of correcting overfrequency conditions that can arise when automatic load shedding occurs, automatic load restoration can easily may aggravate island frequency oscillations. Load should be restored carefully through manual means after the island frequency has recovered to 60 Hz to maintain acceptable frequency levels.

The MRO UFLS program does not allow automatic load restoration as a way of restoring system load, but it is something that can be considered solely for the purpose of mitigating frequency overshoot. Such load blocks would have to be quite small and this would have to be carefully studied. Any program which tries to shed more than 30% of system load may have to consider automatic load shedding.

5.125.15 Should the automatic tripping of reactive power devices be considered along with a UFLS Program?

Yes. Overvoltage conditions may occur when significant amounts of load are automatically tripped in an area where reactive power devices, particularly capacitor banks are in service to provide adequate pre-event voltage. The proper tripping of bulk power capacitor banks and/or distribution substation capacitor banks can prevent severe overvoltage

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conditions. However, capacitor bank trip settings should be chosen carefully because the bank cannot be restored for at least 5 minutes after it is tripped. Keep in mind that in some cases, the tripping of lower voltage capacitor banks can be more effective than tripping higher voltage capacitor banks.

An entity can have a system design practice to automatically insert reactors and trip cap banks to minimize over-voltage issues.

5.135.16 What would warrant a higher overshoot frequency limit?

Any UFLS Program that hasAn answer to trip more than 30% load may warrant the use of a higherthis question about frequency overshoot limit. However, this should be very carefully considered. The Design Plan should avoid causing uncontrolled tripping of generator due to overfrequency. For the 30% load shedding programs, the MRO 2007 (per R3.1) is covered in the UFLS Report and Recommendations document providedSection 7: The Proposed MRO UFLS Program, which indicated the following commentaryacceptable range:

> "The maximum frequency and final frequency are sufficient and meet the desired targets (maximum frequency remains less than approximately 61.2-61.4 Hz and final frequencies remain in the range of 59.5 Hz to 60.5 Hz)."

5.17 For generators that can not meet the generator off-nominal frequency coordination requirement in Table 1, what generator MW dispatch is used to determine the appropriate amount of corresponding load to be shed?

5.14 Is the generator MW dispatching a fixed or variable value (R11.1)?

For intermediate and peaking type units, the output or dispatch is not a fixed value, but can change rapidly and widely from nearly zero to full MW output. This situation can present a significant challenge to those generator owners who want to arrange to automatically trip an appropriate amount of corresponding loadof the exemption described in R11.1 because the offsetting load may have to change rapidly and widely.

5.15 Would a SPS be required for a Generator Owner to fulfill the load offset requirement inR11.1?

5.18 If the standard?

Few generating units are expected to not meetamount of load shedding is dependent on the off-frequency limits in Table 1 and be small enough to qualify for an exemption. However, if a generator output levels of the generator needs to set up a scheme that will shed the right amount of compensating load at the right time, then the compensatingit is likely that the additional load tripping system may need towould be a Special Protection System.