

UFLS Assessment Methodology

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# Introduction

The WECC Off-Nominal Frequency Load Shedding Plan (ONFLSP) is designed to protect the Bulk Electric System (BES) against major losses of generation through planned and controlled load tripping until load levels match remaining generation. A periodic modeling simulation and assessment of this plan is not only prudent and a ‘best practice’ to verify adequacy of the amount of load that is armed to be shed, but is also required in NERC Reliability Standard PRC-006. To this end, the Under-Frequency Load Shedding Work Group (UFLSWG) annually performs a review of load-shedding data used in interconnection-wide power flow models and then every other year performs an assessment of the WECC ONFLSP.

## Purpose

The purpose of this methodology document is to define a process by which the WECC ONFLSP is assessed so that critical steps aren’t omitted from one assessment year to the next.

## Document Owner

The WECC UFLSWG is the owner of this document and is responsible for annually reviewing its content to ensure that the included processes are still adequate for its purpose.

## Scope

This process applies to entities and groups responsible for the biennial assessment of the WECC ONFLSP. Historically, this is the WECC UFLSWG, which includes WECC Planning Coordinators (PCs) and other NERC-defined Planning entities as well as WECC staff. This document is not meant to prescribe a mandatory Under-Frequency Load Shedding (UFLS) assessment process for other groups or utilities who may perform their own UFLS assessments but could be used as helpful input.

## Responsibilities

The WECC UFLSWG shall perform the following before each biennial assessment:

* + - Review this methodology document for adequacy;
    - Provide recommended updates during regularly scheduled UFLSWG meetings;
    - Approve edits that have been agreed upon by the UFLSWG

WECC Staff shall post this document on the UFLSWG page on the WECC website and ensure that the available document is always the current approved version.

## Definitions

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| Term or Abbreviation | Definition |
| UFLS | Under-Frequency Load Shedding. Refers to the process of a system shedding load when the frequency is lower than nominal. |
| UFLSWG | Under-Frequency Load Shedding Work Group. The group that is responsible for the biennial assessment of the WECC ONFLSP. |
| WECC ONFLSP | WECC Off-Nominal Frequency Load Shedding Plan. The plan that is used in WECC to protect the BES against major losses of generation through planned and controlled load tripping. This plan also includes load restoration in the event of over-frequency conditions. |
| WECC Base Cases | Power Flow Models of the WECC Interconnection that include topological information such as transformers, transmission lines, generators, loads, etc. WECC staff currently compiles 11 per year; each with an associated dynamics file to be used for transient simulations. |

# UFLS Assessment Methodology

### Attachment A data requests are distributed every year to UFLS entities but an assessment of the WECC ONFLSP is performed every other year. Even though the assessment is performed every other year, the annual Attachment A submittals are reviewed every year by WECC staff and any changes to previous year’s submittals are made in the WECC Master Dynamics File (MDF). The MDF contains dynamic models for generators and other electrical equipment such as Under-Frequency Load Shedding Relays. As equipment changes take place in the Western Interconnection, it’s critical to update the associated models in the MDF so that transient dynamic simulations are as accurate as possible.

### With the MDF updates noted above, the hope is that the included UFLS models are always as up-to-date and accurate as possible. Each WECC base case compiled after the MDF is updated makes use of the newly modified UFLS models with the belief that the most accurate implementation of the ONFLSP is included.

## Annual UFLS Data Request

### Annually on May 1st, a UFLS data request (Attachment A) is distributed to all UFLS entities in WECC by Stakeholder Services. Attachment A is an Excel spreadsheet that is used by two groups of UFLS entities to submit the information necessary for the performance of a UFLS Assessment; (1) Distribution Providers/UFLS-Only Distribution Providers, Transmission Owners, and Transmission Operators, and (2) Generator Owners.

* + - The first group is concerned mainly with loads that are modeled in base cases and their associated load shedding models. In other words, this first group creates dynamic models that can shed loads or portions of loads based on frequency settings. Submittals from this group are required by June 1st.
    - The second group, comprised of GOs, provides dynamic models that can trip generators if the system frequency exceeds accepted limits for specific generators. Submittals from this group are required by July 1st.

Attachment A is a living document, and as such, is modified regularly to incorporate better methods of data checking or the request of additional information. So that WECC stakeholders who use this document to submit data have adequate time to review potential updates to the document or the WECC ONFLSP, updates to Attachment A should be completed and presented for approval to the UFLSWG by the end of January each year.

### After all submittals have been received from both groups identified in section 2.2.1, WECC staff reviews each one and performs various data checks. Some of the data checks include the following:

* Load shedding models are compared to models that were previously submitted and included in the MDF. This is an important activity because every year, many UFLS frequency trip settings are modified to trip at different frequencies, shed different amounts of load at their prescribed frequency blocks, or may even be associated with a different load as modeled in WECC base cases. On occasion, UFLS relays can be removed or newly installed. In any of the above situations, it’s important that correct models are available in the MDF so that dynamic simulations are as realistic as possible.
* Generator frequency ride-through models are compared to models that were previously submitted and included in the MDF. Generating units are required to stay on-line and maintain synchronism with the rest of the interconnection within a specified bandwidth of frequency levels. Some generators are unable to meet the prescribed requirement and will trip sooner than expected. Dynamic models are available that can model this behavior and are requested via Attachment A. Generator frequency ride-through parameters are subject to change just like the UFLS relay settings mentioned above so it’s equally as important to update these models in the MDF as changes occur.
* The WECC ONFLSP specifies the amount of load that should be armed to be shed at different frequency levels. Armed load per base case area and frequency block is reviewed to verify that it’s adequate based on ONFLSP requirements.

## Selection of Base Cases Used in Assessment

### In preparation for each biennial ONFLSP assessment, base cases are chosen from the library of approved WECC base cases on the WECC web site. Typically, base cases for two loading levels and corresponding generation dispatch scenarios are chosen; one peak load (Heavy Summer) case and one light load (Light Spring) case. Historically, the heavy summer base case has been an Operating case since it represents the very near-term system topologies and conditions. In addition, the UFLS information submitted via Attachment A represents existing underfrequency load shedding relay settings for the previous year’s peak load, so a Heavy Summer (or Heavy Winter) Operating base case would have the best conformity with Attachment A submittals. Going forward, additional planning horizon peak load and/or light load base case(s) may be chosen for the assessment due to the rapidly occurring resource-mix and grid transformation. At least one three-to-five years out planning base case is recommended – two such base cases may be desirable. (For the 2020-22 UFLS assessment cycle, one planning horizon base case has been chosen for evaluation – the 2024 Light Spring case.)

## Base Case Modification for Island Scenarios

### In WECC, there is the possibility of formation of North and South islands. Roughly, the North Island is comprised of Canada, Oregon, Washington, Montana, Idaho, Wyoming, Colorado, Utah and northern Nevada while the South Island is comprised of southern Nevada, California, Arizona and New Mexico.

### Generally speaking, in the island that was exporting before the islanding operation, generation must be decreased so that there is a match again between generation and load and the area swing machine has a reasonable output. In the island that was importing before the islanding operation, generation must be increased or brought online so that there is also a match between generation and load and the area swing machine has a reasonable output. To the extent possible, adjustments in generation should be made equitably among all areas so that one area doesn’t shoulder more of the adjustment burden within the island it’s located.

## Dynamic Model Modifications

### Base cases that are available in the library on the WECC web site always include a power flow base case and an associated dynamics file. During the base case compilation process, the dynamics file is updated to work well with its base case. For the ONFLSP assessment, some updates to this dynamics file are required, so after the base cases have been selected in section 2.3, these base cases and associated dynamics files are downloaded from the WECC web site and modified with the following:

### Since the dynamics files were likely created at least several months prior, it’s necessary to update them with the new load shedding and generating unit frequency ride-through models that were just received via the Attachment A submittals. The first step is to remove all load shedding and generating unit frequency ride-through models from the dynamics files. Updates of these models have recently been added to the MDF as indicated in section 2.2.2 so they can be copied from the MDF and pasted into the dynamics files.

### NERC Standard PRC-006 requires V/Hz monitoring of generators and since this model isn’t normally included in a WECC dynamics file, another addition to the dynamics files is the creation of a V/Hz monitor. Currently, a PSLF “vfmgen” model is created and added to each dynamic file and it monitors each generating unit in the base case for V/Hz performance.

### To assist with calculation of load that is shed during simulations, the addition of a PSLF “lsmon” model is necessary. One model only is required in each dynamics file and provides an output of how much load is tripped by power flow area due to operation of UFLS relays during a simulation.

### Finally, an additional model is required to get one remaining summary of load that is shed and this is the PSLF “ldtrpmon” model. One model is required for each base case power flow area and provides an output of how much load is tripped by the Composite Load Models in the dynamics file.

## Selection of Generation to be Tripped

### In the biennial ONFLSP assessment, several levels of generation-to-load imbalance are simulated and reviewed. Generation-to-load imbalance is calculated as:

### The ONFLSP is designed to shed load as a safety net within the interconnection for up to and including imbalance of 25%. This means that for a 25% imbalance , the ONFLSP should be able to trip sufficient load so that a new generation-to-load balance occurs and a return to a system frequency of close to 60 Hz will result. Currently, imbalance levels of 10%, 20% and 25% are simulated but other levels could be studied as well if desired.

### An important aspect of the imbalance calculation in section 2.6.1 is that the amount of generation loss (i.e. tripped) should be appropriately allocated in each of the Areas within the base case. For example, for a 10% imbalance simulation, each base case area should reflect generation loss as close to 10% as possible. For 10% imbalance, the generation loss is considered proportionally allocated if approximately 10% of total generation dispatch in the Area (i.e. ~10% of the Area Pgen) is tripped – this ensures that generation loss gets proportionally allocated in the entire base case being studied, whether for WECC Island or North Island or South Island. Generally, the selection of generators to be tripped in any given Area is achieved by choosing larger size generating units followed by smaller size units to achieve the aggregate generation loss corresponding to the desired imbalance.

## UFLS Simulations

### Concerning the dynamic simulations, the first thing to consider is which simulations are going to be run. R3 in NERC PRC-006 requires UFLS simulations with imbalance levels of up to 25%. For the WECC Assessment, imbalance levels of 10, 20 & 25 percent are simulated. The underlying thinking behind not just simply running the maximum 25% imbalance is that smaller imbalances are always easier to simulate than the larger ones and by starting with a small simulation, it could potentially uncover problems with the power flow or dynamics data that has to be reconciled. It should be noted that the three imbalance levels identified above are run on both of the base cases identified in section 2.3.1 as well as the North and South Islands of each base case. This results in a total of 18 dynamic simulations. There is also the potential for additional simulations. Historically, other islands as well as different load compositions have been studied. The UFLSWG provides input on additional contemporary items of interest that can be added to the assessment.

### Simulations of smaller imbalances are always easier than the larger imbalances, so beginning with the lowest level imbalancecreate a list of generating units scheduled to be tripped. From this list, an application-specific outage file can be created. Simulation run-time must be set for at least 60 seconds per R3 in NERC PRC-006. The first attempted simulations will almost certainly stop before completion. A disturbance of the magnitude studied in this assessment pushes dynamic modeling capability to its limits and can expose problems with both the steady-state model and dynamics. Finding the models that are causing solution difficulties in the simulations is sometimes a challenge but one method that helps is to turn on the Convergence Monitor in the PSLF program. This can be easily done in the DYTOOLS “.cases” control file. This monitor identifies generating units that are producing the biggest deviations in performance such as reactive output (Qgen) or real output (Pgen). Outputs of these units should then be plotted to verify if they are causing solution problems or not. If the dynamic models for a specific generating unit are causing issues, this generating unit can be added to the list of generating units to be tripped and the simulation is run again. Also, the dynamic models for these generating units will be flagged for review by the appropriate planning entity or data submitter for model verification and validation. At some point, the simulation will run all the way to 60 seconds and frequency plots can be created.

## Plot Creation

### For each UFLS simulation, a set of plots has to be prepared that illustrates the frequency response at various locations within the interconnection. These plots are used as the primary method of assessing the adequacy of the WECC ONFLSP. Historically, one set of plots is created from the North Island and one for the South Island. Then, within each island, four sub-islands have been identified as follows:

* North Island
  + Canada
  + MT / ID / WY
  + CO / UT / NV
  + OR / WA
* South Island
  + N. California
  + AZ / NM
  + S. California / NM
  + S. California / NV

### Within each sub-island, six buses are then selected to give a good representative view of different voltage levels, locations within the sub-island, proximity to load centers, etc., etc. This results in a total of 48 plots per set. The goal is to have a good variety of plots to look at. An example of what a set of plots should look like is included in Appendix B. To get an idea of how many plots are created for presentation in the assessment report, here is a breakdown; for each base case used in the report, simulations are run on three islands (WECC, North, South). Each island currently has three imbalance amounts simulated on it, and then 48 plots are created for each imbalance scenario. So, for each base case, the number of plots = 3 x 3 x 48 = 432.

# Revision History

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| Date | Version | Reviewer | Revision Description |
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# Approvals

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