WECC

UFLS Assessment Methodology

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1 Introduction

The WECC Off-Nominal Frequency Load Shedding Plan (Plan) 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, WECC staff annually performs a review of load-shedding data used in interconnection-wide power flow models and then the Underfrequency Load Shedding Work Group (UFLSWG) assesses the Plan every other year.

1.1 Purpose

The purpose of this document is to define a process by which the Plan is assessed so that critical steps are not omitted from one assessment year to the next.

1.2 Document Owner

The UFLSWG owns this document and is responsible for reviewing its content before the start of each assessment period to ensure that the included processes are still adequate for its purpose.

1.3 Scope

This process applies to entities and groups responsible for the biennial assessment of the Plan. Historically, this is the UFLSWG, which includes 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.

1.4 Responsibilities

Before each assessment, the UFLSWG will:

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

WECC staff will post this document on the UFLSWG page on the WECC website and ensure the available document is always the current approved version.

1.5 Definitions

Term or Abbreviation	Definition
UFLS	Underfrequency load shedding refers to the process of a system shedding load when the frequency is lower than nominal.
UFLSWG	Underfrequency Load Shedding Work Group. The group responsible assessing the Plan biennially.
WECC ONFLSP	WECC Off-Nominal Frequency Load Shedding Plan. The plan used in the Western Interconnection 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 Western Interconnection that include topological information such as transformers, transmission lines, generators, and loads. WECC staff compiles 11 per year; each with an associated dynamics file to be used for transient simulations.

2 UFLS Assessment Methodology

2.1 Annual UFLS Data Request

2.1.1 Every May 1st, a UFLS data request -Attachment A- is distributed to all UFLS entities in the Western Interconnection 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 UFLS assessment: (1) Distribution Providers/UFLS-Only Distribution Providers, Transmission Owners (TO), and Transmission Operators (TOP), and (2) Generator Owners (GO).

- The first group is concerned mainly with loads that are modeled in base cases and their associated load shedding models. In other words, this group creates dynamic models that can shed loads or portions of loads based on frequency settings. Submittals from this group are required by July 1.
- The second group, comprising 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 June 1.

Attachment A is a living document and 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 Plan, updates to Attachment A should be completed and presented for approval to the UFLSWG by the end of January each year.

2.1.2 After all submittals have been received from both groups identified in section 2.1.1, WECC staff reviews each one and performs various data checks. Some of the data checks include:

- Load shedding models are compared to models 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 is important that correct models are available in the MDF so dynamic simulations are as realistic as possible.
- Generator frequency ride-through models are compared to models previously submitted and included in the MDF[1]. Generating units must 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 is equally as important to update these models in the MDF as changes occur.
- The WECC Plan 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 is adequate based on Plan requirements.

[1] A comparison may also be made to Standard PRC-024 *Generator Frequency and Voltage Protective Relay Settings*. The models submitted for this standard should be in alignment with PRC-024.

2.2 Selection of Base Cases Used in Assessment

2.2.1 In preparation for each biennial Plan 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 case and one scenario case, details of which may vary to address areas of interest at the time. Historically, the heavy summer base case has been an operating case since it represents the very near-term system topologies and conditions. Also, 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 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 was chosen for evaluation - the 2024 Light Spring case.

2.3 Base Case Modification for Island Scenarios

2.3.1 In the Western Interconnection, there is the possibility of formation of islands in the north and south. Roughly, the Northern Island comprises Canada, Oregon, Washington, Montana, Idaho, Wyoming, Colorado, Utah, and northern Nevada while the Southern Island comprises southern Nevada, California, Arizona, and New Mexico. To study the North and South Island scenarios, the islands must first be created manually and a balanced steady-state condition achieved in the base case. The reason being that including the islanding operation in the dynamic simulation switching sequence is incredibly difficult and requires significant time. To get around this, we first create the two islands in the power flow and make sure there is a good generation-to-load balance. A list of current islanding break points is included in Appendix A attached to this document. Once this is achieved, the new adjusted base case is the starting point from which the island scenarios are run.

2.3.2 Generally speaking, in the island that was exporting before the islanding operation, generation must be decreased so generation and load match again 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 on-line so generation and load also match and the area swing machine has a reasonable output. To the extent possible, adjustments in generation should be made equitably among all areas so one area does not shoulder more of the adjustment burden in the island in which it is located.

2.4 Dynamic Model Modifications

2.4.1 Base cases 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 Plan assessment, some updates to this dynamics file are required, so after the base cases have been selected as stated in Section 2.3, these base cases and associated dynamics files are downloaded from the WECC web site and modified with the following:

2.4.1.1 Since the dynamics files were likely created at least several months prior, it is 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 2.1.2 so they can be copied from the MDF and pasted into the dynamics files.

2.4.1.2 In order to accurately simulate the power system's response to a significant loss in generation, modeling data concerning voltage performance is collected from PCs. This includes transmission facility over-voltage relays, auto-Var control, generator over-frequency/speed, and V/Hz protection relay models. Relevant models on RAS (local detection and contingency based) are included in this collection as well.

2.4.1.3 NERC Standard PRC-006 requires V/Hz monitoring of generators. Since this model is not normally included in a WECC dynamics file, this functionality must be added in whatever manner is appropriate for the software used for the assessment.

2.4.1.4 A dynamic model or automated method of calculating load shed because of UFLS relay operation during simulations is helpful and saves time compared to manually calculating this value. The dynamic model or the method used to track load shed varies between software platforms so the manner in which this functionality is accomplished is not specified. It is important, though, to recognize that load can be shed via UFLS relay as well as the Composite Load Model, so whatever method is used to calculate total load shed has to take into account the different ways that load can be shed.

2.5 Selection of Generation to be Tripped

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

$$Imbalance = \frac{(Load - Total\ Generation\ Remaining\ After\ Trip)}{Load}$$

2.5.2 The Plan is designed to shed load as a safety net within the interconnection for up to and including an imbalance of 25%. This means that for a 25% imbalance, the Plan should be able to trip sufficient load for a new generation-to-load balance to occur 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 if desired.

2.5.3 An important aspect of the imbalance calculation in Section 2.5.1 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 about 10% of total generation dispatch in the Area (i.e., ~10% of the Area Pgen) is tripped. This ensures that generation loss is proportionally allocated in the entire base case being studied, whether for the WECC Island, Northern Island, or Southern Island.

2.5.3.1 PCs provide input on the selection of generators to be tripped in their balancing authority. Generally, the method is to select larger size generating units followed by smaller size units to achieve the aggregate generation loss corresponding to the desired imbalance.

2.6 UFLS Simulations

2.6.1 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%, and 25% are simulated. The reason for not just running the maximum 25% imbalance is that smaller imbalances are always easier to simulate than the larger ones and starting with a small simulation could 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 2.2.1 as well as the Northern Island and Southern Island of each base case. This results in a total of 18 dynamic simulations. There is also the potential for more 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.

2.6.2 Simulations of smaller imbalances are always easier than the larger imbalances, so, beginning with the lowest level imbalance, a list of generating units scheduled to be tripped is developed. 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 of the generating units that are causing solution difficulties in the simulations is sometimes a challenge but one method that helps is to plot the biggest deviations in performance such as reactive output (Qgen), real output (Pgen), rotor speed or rotor angle. If the dynamic models for a specific generating unit are causing issues, that 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. For a simulation to be considered successful, it must run to 60 seconds. At this point, frequency plots can be created.

2.7 Plot Creation

For each UFLS simulation, a set of plots must be prepared that illustrate the frequency response at various locations in the interconnection. These plots are used as the primary method of assessing the adequacy of the Plan. Historically, one set of plots is created from the Northern Island and one for the Southern Island. Then, within each island, four sub-islands have been identified as follows:

- Northern Island
  - Canada
  - MT/ID/WY
  - CO/UT/NV
  - OR/WA
- Southern Island
  - N. California
  - AZ/NM
  - S. California/NM
  - S. California/NV

Within each sub-island, six buses are selected to give a representative view of different voltage levels, locations within the sub-island, proximity to load centers, etc. This results in a total of 48 plots per set. The goal is to have a 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, Northern, Southern). Each island currently has three imbalance amounts simulated on it, then 48 plots are created for each imbalance scenario. So, for each base case, the number of plots = 3 x 3 x 48 = 432.

2.8 Unsuccessful Assessment Results

As mentioned in section 2.6.2, a simulation must run all the way out to 60 seconds for it to be considered successful. If it fails to run for the required time, some problem has occurred in the dynamic simulation and results are causing the simulation to crash. Often, a modeled generator has gone unstable and is causing growing oscillations to spread throughout the interconnection. In another case, voltage collapse could be occurring in an area, which then causes numerical instability in the power flow program. Whatever the reason, the problem must be investigated to try and determine if this is a legitimate concern or a modeling problem.

Another example is that of a generator experiencing a V/Hz violation. While this doesn't usually cause a simulation to fail, it is usually an example of an incorrect power flow or dynamic model of the generator in question. In this case, the generator model must be examined and updated if necessary.

If problems are found during the assessment that don’t allow one of the simulations to complete or if requirements defined in NERC Reliability Standard PRC-006 are not met, it is necessary to contact the pertinent PC to inquire if a fix to the problem is available. The StS and RAC member of the entity flagged should be included on this correspondence.

3 Appendices

3.1 Appendix A – North and South Island Formation

To form the North and South Islands in the base case models, the following transmission elements are opened in accordance with the WECC-1 RAS

- Malin – Round Mountain #1 & #2 500 kV lines
- Captain Jack – Olinda #1 500 kV line
- Delta – Cascade #1 115 kV line
- Pinto – Four Corners #1 345 kV line
- Red Butte – Harry Allen #1 345 kV line
- Walsenburg – Gladstone #1 230 kV line
- Silver Peak – Control #1 & #2 55 kV lines
- Summit/Drum – Cascade #1 60 kV and #1 & #2 115 kV lines
- Robinson Summit – Harry Allen #1 500 kV line
- Glen Canyon – Sigurd 230 kV line
- Shiprock – Lost Canyon 230 kV line
- Glade – Hesperus 115 kV line
- San Juan – Hesperus 345 kV line

3.2 Appendix B – Monitored Buses

Table 1 - North Island Monitored Buses

Canada	MT/ID/WY	WA/OR	CO/UT/NV
Williston 500 kV	Garrison 500 kV	Coulee 500 kV	Valmy 345 kV
Nicola 500 kV	Midpoint 500 kV	John Day 500 kV	Terminal 345 kV
Langdon 240 kV	Bridger 345 kV	Bethel 230 kV	Daniels Park 230 kV
Kelly Lake 230 kV	Wyodak 230 kV	Boundary 115 kV	Sigurd 230 kV
Clover Bar 240 kV	Crossover 230 kV	Talbot Hill 115 kV	Hayden 230 kV
Ruth Lake 260 kV	DRAM 138 kV	Port Angeles 69 kV	North 115 kV

Table 2 - South Island Monitored Buses

N. California	S. California/Mexico	S. California/NV	AZ/NM
Round Mountain 500 kV	Vincent 500 kV	Harry Allen 500 kV	Moenkopi 500 kV
Midway 500 kV	Imperial Valley 500 kV	McCullough 500 kV	Rio Puerco 345 kV
Gregg 230 kV	Sylmar 230 kV	Victorville 500 kV	Gladstone 230 kV
Folsom 230 kV	Rosita 230 kV	Decatur 230 kV	Phoenix 230 kV
Newark 115 kV	Mesa Rim 69 kV	El Segundo 230 kV	Alamogordo 115 kV
Rector 66 kV	San Onofre 12.47 kV	Millers 57.5 kV	Tucson 47.2 kV

4 Revision History

Date	Version	Reviewer	Revision Description
3/29/2022	1	UFLSWG	New Document
4/18/2023	2	UFLSWG	Additional Requirements Added

5 Approvals

Date	Version	Approver
3/29/2022	1	UFLSWG
4/18/2023	2	UFLSWG

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