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Western Electricity Coordinating Council
Off-Nominal Frequency Load Shedding
Plan

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Executive Summary

Background

In the aftermath of system-wide disturbances occurring within the Western Interconnection on July 2 and 3, and August 10, 1996, President Clinton appointed a “Blue Ribbon” panel to perform a comprehensive assessment of these disturbances and make recommendations to enhance reliability within the Western Interconnection. The investigations culminated in two reports: the *WSCC Disturbance Report for the Power System Outages that Occurred on the Western Interconnection on July 2, 1996 and July 3, 1996*; and the *WSCC Disturbance Report for the Power System Outage that Occurred on the Western Interconnection on August 10, 1996* (Disturbance Reports). The Disturbance Reports’ recommendations identified several reliability issues for further investigation. One of these issues was the efficacy of existing policies and procedures related to off-nominal frequency (underfrequency load shedding (UFLS) programs); the purposes of which are to arrest potential system collapses due to large frequency deviations, minimize associated adverse impacts caused by cascading outages, and aid in quickly restoring the system to normal operations.

Status

The Western Systems Coordinating Council’s (WSCC) Planning Coordination Committee (PCC) and Operating Committee (OC) developed a coordinated off-nominal frequency load shedding and restoration plan for the Western Interconnection in the fall of 1997 (1997 Coordinated Plan). The WSCC Board of Trustees approved the 1997 Coordinated Plan on December 4, 1997.

The WSCC was succeeded by the Western Electricity Coordinating Council (WECC) on April 18, 2002.

In 2009, the WECC PCC and OC formed a task force to review the effectiveness of the existing protection relays associated with the 1997 Coordinated Plan. The results indicated that WECC members’ relay settings conform to the 1997 Coordinated Plan performance requirements, both in arresting frequency decline before frequency reaches 58.0 Hz and in recovering frequency to 59.5 Hz or higher. These results also indicated that UFLS relays will not activate until there has been a cascading disturbance across multiple entities’ systems. In addition, none of the Western Interconnection’s sub-areas will experience an off-nominal frequency event due to either single or dual most-severe-contingency losses of generation resources if the losses occur within known island configurations.

In 2010, NERC proposed a revision to NERC Standard PRC-006-0 to create PRC-006-1, which was approved by the industry and incorporates a WECC variance that references this revised Coordinated Plan.

Comprehensive Coordinated Plan

This document is the comprehensive coordinated plan of the WECC Off-Nominal Frequency Load Shedding Plan.

A. Introduction

One objective of WECC is to achieve a high level of reliable operations within the Western Interconnection. To further this objective, the members of WECC recognize the need for a common plan for underfrequency load shedding.

The objectives of this WECC Off-Nominal Frequency Load Shedding Plan (Coordinated Plan) report are to:

1. Outline the characteristics of a well-planned interconnected bulk power supply.
2. Describe the basis for model testing.
3. List the reliability and adequacy requirements to be used to evaluate the performance of the Western Interconnection electric system.
4. Identify operating procedures necessary to maintain a reliable and efficient electric system.

The members of WECC have agreed to follow and operate their systems in accordance with this Coordinated Plan as an essential element of the well-planned and operated Western Interconnection electric system.

After the predecessor to this Coordinated Plan (the 1997 Coordinated Plan) was initially approved in 1997, either the WSCC or WECC Planning Coordination Committee and Operating Committee have reviewed the 1997 Coordinated Plan and tested its effectiveness at least once every five years.

In 2009, the WECC PCC and OC formed a task force to review the effectiveness of the 1997 Coordinated Plan as implemented, based on the installed under frequency relays as reported by entities that are required to provide off-nominal frequency protection (hereafter called UFLS Entities). The results indicated the system performance conformed to the WECC Plan's performance requirements, both in arresting frequency decline before frequency reaches 58.0 Hz and recovering frequency to 59.5 Hz or higher. The results also showed that UFLS relays will not activate until there has been a cascading disturbance. Further, it was noted that within known island configurations, no single or dual loss of generation contingency will cause an off-nominal frequency event.

B. Criteria

In accordance with this Coordinated Plan, entities required to provide off-nominal frequency protection (UFLS Entities) will establish a program of automatic load shedding that is designed to arrest frequency decays that could result in an uncontrolled failure of components of the Western Interconnection. In the event of a system-wide disturbance, the Coordinated Plan is designed to: (i) maintain the integrity of the Western Interconnection as long as possible; (ii) prevent unbalanced load shedding

(which may cause high transmission loading), extreme voltage deviations, and damage to generating equipment and other facilities; (iii) limit any islanding that might occur to as few islands as possible; and (iv) manage islanding and load loss so that operators can rapidly restore load and re-establish interconnections.

This Coordinated Plan includes (but is not limited to):

- Frequency set-points
- Size of corresponding load shedding blocks (percent of connected loads)
- Intentional and total tripping delays
- Generation protection
- Tie-tripping schemes
- Islanding schemes
- Automatic load restoration schemes
- Any other schemes that are part of or otherwise affect this Coordinated Plan

C. Objectives

The objectives of the Coordinated Plan include (but are not limited to):

- Minimize the risk of total Western Interconnection system collapse.
- Protect generating equipment and transmission facilities against damage.
- Provide for effective load shedding within the Western Interconnection to arrest frequency decline.
- Improve overall system reliability.
- Match overall generation to overall load and, where islands are created or remain, match generation and load as required to meet island area needs.
- Coordinate load-shedding with underfrequency protection of generating units.
- Coordinate load-shedding with any other actions that can be expected to occur under conditions of frequency decline.
- Base load-shedding on studies of system dynamic performance, using the latest state-of-the-art computer analytical techniques.
- Minimize the risk of further separation, loss of generation, or excessive load shedding accompanied by excessive overfrequency conditions.
- Incorporate automatic generator tripping or other remedial measures to prevent excessive high frequency that could result in uncontrolled generator tripping or equipment damage.
- Address load controlled by customer-owned relays where the load is counted toward meeting minimum load-shedding requirements.

D. Methodology

The design of the Coordinated Plan was based on the following performance criteria:

- Load/generation imbalances based upon load of up to 25 percent should be accounted for.
- Potential system separation points should reflect historical system load conditions and transfer levels.
- This Coordinated Plan should conform to the 5% loss of life of turbine blades recommendations as determined by generator manufacturers.
- Sufficient load must be dropped by UFLS Entities to keep the system frequency within the continuous operating range of the generating units (59.5 Hz and 60.5 Hz).
- Minimum permissible dynamic frequency during a disturbance is 58 Hz. The maximum permissible dynamic frequency during a disturbance is 61.0 Hz.
- Load shedding blocks will be in a five-step sequence with a minimum separation between steps of 0.1 Hz.
- Underfrequency relays must have a maximum operating time of six cycles for the high speed trip.
- System average operating time of breakers used to trip load is to be no more than fourteen cycles.
- Post-disturbance frequency ideally will settle out above 60 Hz, as opposed to below 60 Hz.
- Implementation of the Coordinated Plan should not cause other adverse system conditions that result in generation tripping that would exacerbate the loss-of-generation event.

The typical time needed to shed load in response to an underfrequency disturbance is between 0.3 and 10 seconds. As governors cannot appreciably adjust megawatt output levels in this time frame, the magnitude of frequency change is primarily dictated by system inertia characteristics.

The General Electric Positive Sequence Load Flow (GE PSLF) program was used for modeling various system conditions in WECC's reference model. If necessary, UFLS Entities may use other models if WECC approves them as being equivalent to the reference model. Simulations must still be optimized using the system average inertia and nominal load/frequency response characteristics.

This Coordinated Plan is designed to accommodate a wide range of generator inertias and load/frequency characteristics. This Coordinated Plan must be able to meet the criteria specified above with generator inertia as low as 2.5 per unit (pu) (generally associated with large steam units) and as high as 6.0 pu (generally associated with hydro units).

Load sensitivity to frequency is expressed as a ratio between the percent load changes to the percent frequency change. This Coordinated Plan used a system-wide load sensitivity value of 1.5 pu.

This Coordinated Plan is designed to fulfill the criteria, objectives, and assumptions described above for losses of generation percents of 1, 2, 3, 4, 10, 15, 20, 25, and 30.

E. Coordinated Plan Details

Currently, UFLS Entities in the WECC Region have adopted one or a combination of the following three plans where the frequency set-points are illustrated in the tables in items 1a, 1b, or 1c below. Items 2 through 22 apply to all three plans.

- 1a. UFLS Entities participating in the Coordinated Plan are required to shed their first block of load as soon as frequency has declined to 59.1 Hz, with additional minimum requirements for further load shedding steps as set forth in the following table:

<u>Load Shedding Block</u>	<u>Percent of Balancing Authority Area Load Dropped</u>	<u>Frequency Set-Point (Hz)</u>	<u>Tripping Time*</u>
1	5.3	59.1	no more than 14 cycles
2	5.9	58.9	no more than 14 cycles
3	6.5	58.7	no more than 14 cycles
4	6.7	58.5	no more than 14 cycles
5	6.7	58.3	no more than 14 cycles

Additional automatic load shedding to correct underfrequency stalling

2.3	59.3	15 sec
1.7	59.5	30 sec
2.0	59.5	1 min

Load automatically restored from 59.1 Hz block to correct frequency overshoot

1.1	60.5	30 sec
1.7	60.7	5 sec
2.3	60.9	0.25 sec

* Relay and breaker total trip time

- 1b. UFLS Entities participating in the Northwest Power Pool sub-area Coordinated Plan are required to shed their first block of load as soon as frequency has declined to 59.3 Hz, with additional minimum requirements for further load shedding steps as set forth in the following table:

<u>Load Shedding Block</u>	<u>Percent of NWPP Sub-Area Load Dropped</u>	<u>Frequency Set-Point (Hz)</u>	<u>Tripping Time*</u>
1	5.6	59.3	no more than 14 cycles
2	5.6	59.2	no more than 14 cycles
3	5.6	59.0	no more than 14 cycles
4	5.6	58.8	no more than 14 cycles
5	5.6	58.6	no more than 14 cycles

Additional automatic load shedding to correct underfrequency stalling

2.3	59.3	15 sec
1.7	59.5	30 sec
2.0	59.5	1 min

Load automatically restored from 59.3 Hz block to correct frequency overshoot

1.1	60.5	30 sec
1.7	60.7	5 sec
2.3	60.9	0.25 sec

* Relay and breaker total trip time

- 1c: UFLS Entities participating in the Southern Island Load Tripping sub-area Coordinated Plan shall implement the requirements as detailed year-to-year in the Southern Island Load Tripping report as provided to the WECC Reliability Assurer. In addition to participating in the Southern Island Load Tripping Sub-area Coordinated Plan, these UFLS Entities shall implement the requirements as detailed in section 1a above.
- UFLS Entities may not rely on the shedding of intermittent load unless monitoring is in place to allow changes in real time to accommodate the availability of intermittent load and ensure compliance with the load shedding requirements of this Coordinated Plan.
 - Load can be tripped at frequencies higher than 59.1 Hz provided there is no adverse impact to neighboring systems and frequency overshoot is adequately addressed.
 - It is not permissible to use frequency set-points that allow frequency to decline below 59.1 Hz before shedding the first block of load, or to shed smaller increments than is called for by the applicable Coordinated Plan.

5. It is permissible to include intermediate frequency set-points (in addition to those specified in the table above), as long as they conform to the same methodology, assumptions, and objectives of the applicable Coordinated Plan.
6. UFLS Entities with load-shedding schemes that differ from this Coordinated Plan (as described in 1a, 1b, or 1c) are responsible for conducting studies to verify that their schemes are adequately coordinated with the rest of the Western Interconnection and do not degrade performance under this Coordinated Plan. The WECC PCC and OC will review these studies to ensure consistency with the Coordinated Plan.
7. Any UFLS Entities with load-shedding blocks that include load controlled by customer-owned relays must have contractual arrangements or other means to ensure (i) appropriate set-points, (ii) adequate maintenance (sufficient to meet applicable Reliability Standards), and (iii) availability of any data or documentation needed to demonstrate compliance.
8. All UFLS Entities that intend to automatically restore load following a load-shedding event must demonstrate their compliance with applicable Reliability Standards. For any event, automatic restoration must begin no sooner than thirty minutes after the frequency has been restored to levels above 59.95 Hz and may not be implemented faster than two percent of the system load every five minutes. If a Balancing Authority Area cannot meet the WECC Area Control Error requirements when automatic or manual load restoration begins, the Balancing Authority's dispatchers must manually trip corresponding load to balance available generation and load. Manually-controlled load restoration, if available and practical, is preferable to automatic restoration.
9. To the extent load restoration depends on the availability of transmission facilities, operators must not attempt to restore load until the necessary transmission facilities are operational.
10. Intentional tripping of tie-lines due to underfrequency is permitted at the discretion of the individual UFLS Entities, provided the separation frequency is no higher than 57.9 Hz with a one-second time delay. Even though it is permissible to trip tie-lines at 57.9 Hz, it is preferable that intentional tie-line tripping not be implemented.
11. Transmission Owners shall provide automatic measures such as switching of existing capacitor banks, transmission lines, reactors, generators, or other measures, as necessary, to control overvoltage as a result of UFLS tripping.

12. It is preferred that online generators that protect for off-nominal frequency operation should have relaying protection that accommodates, as a minimum, underfrequency and overfrequency operation for the time frames specified in the following table:

<u>Underfrequency Limit</u>	<u>Overfrequency Limit</u>	* <u>Minimum Time</u>
>59.4 Hz	< 60.6 Hz	N/A (continuous operation)
≤59.4 Hz	≥60.6 Hz	3 minutes
≤58.4 Hz	≥61.6 Hz	30 seconds
≤57.8 Hz		7.5 seconds
≤57.3 Hz		45 cycles
≤57.0 Hz	≥61.7 Hz	Instantaneous trip

* Minimum Time is the time the generator should stay interconnected and producing power.

13. Generator Owners that have generators that do not meet the requirements in Item 12 must either (a) automatically trip load (in addition to the amounts required by Item 1a, 1b, 1c, or combinations thereof of this Section E) to match the anticipated generation loss at comparable frequency levels, or (b) have contractual relationships providing for automatic load shedding.
14. Generator Owners that own or operate generating facilities must provide data regarding the off-nominal frequency protection settings of their units, in accordance with applicable Reliability Standards, and must also report any changes in settings.
15. UFLS Entities may use only solid state or microprocessor underfrequency relays to implement load shedding in accordance with this Coordinated Plan. Load tripped by any other means will not be considered in determining compliance with this Coordination Plan.
16. Generators providing off-nominal frequency protection in the range of 57.9-61.0 Hz in compliance with this Coordinated Plan may use only solid state or microprocessor frequency relays.
17. Generators may use electro-mechanical frequency relays only for settings outside the 57.9-61.0 Hz range.
18. All frequency relays must use the definite time characteristic specified in this Coordinated Plan. They should not be disabled for voltages 80 percent of nominal or higher, but may be disabled for voltages below 80 percent of nominal (at the discretion of the setting entity).
20. UFLS Entities may use direct load tripping if it complements this Coordinated Plan.

21. UFLS Entities within a sub-area of the Western Interconnection may combine their armed load with other UFLS Entities to collectively meet the requirements of the Coordinated Plan. UFLS Entities that elect to meet the requirements of the Coordinated Plan by combining their armed load with others shall have documentation demonstrating that their sub-area plan is adequately coordinated with the rest of the Western Interconnection and does not degrade performance under this Coordinated Plan.
22. The WECC Reliability Coordinator has developed comprehensive and detailed guides for the restoration of load following a load shedding event.

F. Sub-Areas

The WECC PCC and OC recognize the potential for sub-areas to form within the Western Interconnection. These sub-areas may have different set-points and associated armed load, but they must conform to the same methodology, assumptions, and objectives of the Coordinated Plan. Sub-areas with their own plans must demonstrate through simulation that the Western Interconnection does not suffer any degradation due to the sub-area plan. Sub-areas may not have settings that fall below the settings specified in this Coordinated Plan.

Sub-areas must present their plans to the WECC PCC and OC in detail, and in a format similar to Section E of this Coordinated Plan, along with simulation results using the GE PSLF program or another WECC-approved program. There are two sub-area plans that have been accepted by the WECC as compliant with this Coordinated Plan: the Northwest Power Pool Underfrequency Load Shedding Plan, and the Southern Islanding Load Tripping Plan. These two sub-area plans are illustrated above in Section E, items 1b and 1c.

G. Members and Data

A key component of the Coordinated Plan is data submittal by UFLS Entities. This Coordinated Plan relies on each Balancing Authority Area's load to determine the amount of load that must be dropped. The Balancing Authority or its Agent(s) must coordinate among all effective UFLS Entities within its area to assure all requirements of the Coordinated Plan are met.

Each Distribution Provider, Transmission Operator, Generation Owner, and Transmission Owner must:

1. Implement and coordinate its actions; and create, maintain, and submit documentation as necessary to carry out this Coordinated Plan.
2. Annually compile data and dynamics files for their entire loads, in the format specified by WECC and in accordance with applicable Reliability Standards.

3. Submit their compiled data and dynamics files upon request.

The WECC PCC and OC, or a designated subcommittee, will annually review the Coordinated Plan submittals to confirm that all the required information is in the format necessary to comply with applicable Reliability Standards.

H. Individual and Groups

Any WECC member may elect to demonstrate its conformance to this Coordinated Plan on the basis of its own individual program. Other UFLS Entities may elect to work together to meet the requirements of this Coordinated Plan.

Any groups of UFLS Entities constituted for purpose of implementing coordinated load shedding in conformance with this Coordinated Plan:

1. Will have the same responsibilities and obligations as individual UFLS Entities to monitor and meet the plan's requirements.
2. Must specify in a written document each participant's responsibilities.
3. Must designate an agent to be responsible for all data submission requirements and simulations to demonstrate compliance.

The WECC PCC and OC will compile an annual listing of the current underfrequency relays and associated armed load.

I. Review and Update

The WECC PCC and OC will maintain a UFLS database containing data within the WECC model for use in event analyses and assessments of the UFLS program at least once each calendar year, with no more than 15 months between maintenance activities.

The WECC PCC and OC will assess and document the effectiveness of the design and implementation of this Coordinated Plan at least once every five years. The WECC PCC and OC may recommend to the WECC Board of Directors changes to this Coordinated Plan as necessary to reflect system changes in the Western Interconnection.