2024-2026 Underfrequency Load Shedding Program Assessment

Underfrequency Load Shedding Work Group

January 27, 2026

Participating Members:

Entity Name	PC	TP	WECC UFLSWG MEMBER	Study Funding Participant
Alberta Electric System Operator	Y	Y	Y	Y
Arizona Electric Power Cooperative, Inc. (Arizona G&T)	N	Y	Y	N
Arizona Public Service Company	Y	Y	Y	Y
Avista Corporation	Y	Y	N	Y
Balancing Authority of Northern California	Y	N	Y	Y
City of Redding	N-BANC	Y	N	N
Modesto Irrigation District	N-BANC	Y	N	N
Sacramento Municipal Utility District	N-BANC	Y	Y	N
Basin Electric Power Cooperative	Y	Y	N	N
British Columbia Hydro (Power and Authority)	Y	Y	Y	Y
Black Hills Corporation	Y	Y	Y	N
Bonneville Power Administration	Y	Y	Y	Y
Cowlitz County PUD No. 1	N - BPA	Y	N	N
Eugene Water & Electric Board	N - BPA	Y	N	N
Grays Harbor County PUD	N - BPA	Y	N	N
Klickitat County PUD	N - BPA	Y	N	N
Lower Valley Energy	N - BPA	Y	N	N
Northern Wasco County People's Utility District	N - BPA	Y	N	N
Pend Oreille County Public Utility District No. 1	N - BPA	Y	N	N
Public Utility District #1 of Lewis County	N - BPA	Y	N	N
Public Utility District No. 1 of Clark County	N - BPA	Y	N	N
Public Utility District No. 1 of Snohomish County	N - BPA	Y	N	N
Public Utility District No. 1 of Whatcom County	N - BPA	Y	N	N
PUD No. 1 of Douglas County	N - BPA	Y	N	N
Umatilla Electric Cooperative Assoc.	N - BPA	Y	N	N
California Independent System Operator	Y	N	Y	Y
California Department of Water Resources	N-CAISO	Y	N	N
City of Pasadena Water and Power	N-CAISO	Y	N	N
DCR Transmission, LLC	N-CAISO	Y	N	N
DesertLink, LLC	N-CAISO	Y	N	N
Hetch Hetchy Water and Power	N-CAISO	Y	N	N
Horizon West Transmission, LLC	N-CAISO	Y	N	N
LS PowerGrid California, LLC	N-CAISO	Y	N	N
Metropolitan Water District of Southern California	N-CAISO	Y	N	N
Pacific Gas and Electric Company	N-CAISO	Y	Y	N
San Diego Gas & Electric	N-CAISO	Y	N	N
Silicon Valley Power	N-CAISO	Y	N	N
Southern California Edison Company	N-CAISO	Y	Y	N
Trans Bay Cable LLC	N-CAISO	Y	N	N
Valley Electric Association, Inc	N-CAISO	Y	N	N
Centro Nacional de Control de Energía (CENACE)	Y	Y	N	N
Colorado REA (CORE)	N	Y	N	N
City of Tacoma, Department of Public Utilities, Light Division (Tacoma Power)	Y	Y	Y	Y

Entity Name	PC	TP	WECC UFLSWG MEMBER	Study Funding Participant
Colorado Springs Utilities	Y	Y	Y	N
El Paso Electric Company	Y	Y	Y	Y
Farmington Electric Utility System	Y	Y	N	N
Fortis BC	Y	Y	N	N
Idaho Power Company	Y	Y	Y	Y
Imperial Irrigation District	Y	Y	Y	Y
Los Angeles Department of Water and Power	Y	Y	Y	Y
MATL LLP	N	Y	N	N
NorthWestern Corporation (NorthWestern Energy)	Y	Y	Y	Y
NV Energy (Nevada Power Company)	Y	Y	Y	Y
PacifiCorp	Y	Y	Y	Y
Deseret Generation & Transmission Co-operative	N-PAC	Y	N	N
Platte River Power Authority	Y	Y	Y	N
Portland General Electric Company	Y	Y	Y	Y
Public Service Company of Colorado (Xcel Energy)	Y	Y	Y	Y
Public Service Company of New Mexico	Y	Y	Y	Y
Jicarilla Apache Nation Power Authority	N-PNM	Y	N	N
Public Utility District No. 1 of Chelan County	Y	Y	Y	Y
Public Utility District No. 2 of Grant County, Washington	Y	Y	Y	Y
Puget Sound Energy, Inc.	Y	Y	Y	Y
Salt River Project Agricultural Improvement and Power District	Y	Y	Y	Y
Seattle City Light / Seattle Department of Lighting	Y	Y	Y	Y
Southwest Power Pool, Inc.	Y	N	Y	Y
Western Area Power Administration — Upper Great Plains (West) Region	N-SPP	Y	N	N
Tri-State Generation and Transmission Association, Inc.	N-Varied	Y	Y	N
Tucson Electric Power	Y	Y	Y	Y
Turlock Irrigation District	Y	Y	N	Y
Western Area Power Administration — Desert Southwest Region (Lower Colorado)	Y	Y	Y	N
Western Area Power Administration — Rocky Mountain Region (Colorado Missouri)	Y	Y	Y	Y
Western Area Power Administration - Sierra Nevada Region	Y	Y	Y	Y
Transmission Agency of Northern California	N-WASN	Y	N	N

Executive Summary

The Underfrequency Load Shedding Program Assessment Report summarizes the modeling and study methodology, including assumptions, the study cases used, and the simulation results composing the 2024-2026 assessment of the WECC Off-Nominal Frequency Load Shedding Plan (WECC Plan) in accordance with the applicable requirements in NERC Standard PRC-006-5 and WECC Criterion PRC-006-WECC-CRT-3.1. The modeling data validation and the study simulations composing the assessment were performed by PowerWorld Corporation staff under the direction and guidance of the WECC technical staff and WECC Underfrequency Load Shedding Work Group (UFLSWG) with oversight provided by the Studies Subcommittee (StS) under the Reliability Assessment Committee (RAC). PowerWorld Simulator Version 24 software platform was used for all steady-state and dynamic simulations composing this assessment.

During this assessment, performance of the WECC Plan was assessed under heavy load conditions in the 2023 HS4a1 operating case and light load conditions in the 2024 LSP2sa1 scenario case. For both operating conditions, frequency performance was evaluated in the WECC North and South islands at 10%, 20%, and 25% generation-to-load imbalance levels using the criteria in D.B.3.1 and D.B.3.2 in NERC Standard PRC-006-5. The arrest in frequency decline, the frequency nadir, and the frequency recovery performance was monitored at all buses spanning the Western Interconnection.

V/Hz performance was monitored in all 25%, 20%, and 10% imbalance levels and violations of the criteria in D.B.3.3 in NERC Standard PRC-006-5 are identified in this report. These V/Hz violations will be monitored in future assessments to establish validity.

The difference between the armed load that was available to be shed and the load shed during the 25% imbalance underfrequency simulations was used to evaluate the implemented (i.e., modeled) WECC plan's adequacy and effectiveness. The amount of load that was armed to be shed but was not actually shed, was calculated. In this report, this value is called "plan margin" and indicates the adequacy of the WECC Plan's implementation. As noted in the previous assessment, the North Island has less armed load margin than the South Island. This level of margin should be verified and compared in future UFLS assessments.

The recommendations and observations in this report are as follows:

1. The initial simulations for 2023 HS4a1 and 2024 LSP2Sa1 failed due to voltage collapse. This was resolved with modeling improvements, various supplemental actions, and application of solution techniques. The UFLSWG should determine whether these instances of voltage collapse could be remedied by modeling reactive devices that would operate in the period of the simulations, modifying the relay models for loads and generators, or by including key remedial actions that influence the UFLS simulations. It is further recommended that the UFLSWG:

   a. Continue verifying the load and branch load shedding relay data. Issues were found with the dyd files, and some of the models need to be updated to match their corresponding object in the case.
   b. Investigate the modeled armed load for the North Island. The load validation check showed that the North Island needs some corrections for the modeling to match the design armed percentage. After updating the relay models, the percentages improved, but they remained below the design plan for some entities.

2. V/Hz violations need to be addressed.
   a. It is recommended that each planning coordinator (PC) evaluate the affected generating units with violations in their control area and validate the behavior of the model. If model updates are required, these should be communicated to the necessary entities. This could include adding more dynamic models for switched shunts and disconnection of IBR capacitors when generators are opening during the simulation.
   b. It is recommended that the UFLSW investigate the issue of high system voltages in response to generation loss or imbalance and subsequent underfrequency load shedding.
3. The current UFLS methodology document, which outlines how the UFLS assessment is performed, should be reviewed by the UFLSWG to address:
   a. Methods of causing imbalance (e.g., tripping generation, setting unit PGen to zero but allowing it to stay online, dynamically opening tie lines, adding load)
   b. Selection of generators to trip, including unit location, unit type (e.g., synchronous generator, IBR, must-runs)
   c. Combination of methods of imbalance for each contingency. For example, tripping and shedding unarmed loads as part of the contingency to create the imbalance. This should be done for the purpose of making the simulation run for 60 seconds and/or to prevent the high voltage issues that were creating the V/Hz violations.
4. It is recommended that the UFLSWG coordinate with the System Review Subcommittee (SRS) to get stability, remedial action schemes (RAS), and other automatic schemes approved for use in WECC base cases, which will help better capture the scope of devices operating during these underfrequency and system imbalance simulated events.

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Purpose

The WECC Off-Nominal Frequency Load Shedding Plan (WECC Plan) was formalized and first approved in 1997 by the Western Systems Coordinating Council (WSCC), WECC's predecessor. A coordinated off-nominal frequency load shedding plan was originally developed by WSCC in the 1980s. This coordinated plan's design was updated in response to three system-wide disturbances that occurred in 1996 before its initial approval and adoption. The current WECC Plan was revised and approved in 2011 after the NERC Standard PRC-006-1 was approved in 2010. The current version of the NERC Standard PRC-006-5 was approved in 2021 and includes a WECC variance in Section D.B.

WECC has two documents associated with its Underfrequency Load Shedding (UFLS) program. The primary document is the WECC Plan, effective May 24, 2011. It is the comprehensive description of WECC's coordinated UFLS program and contains the background, design objectives, performance criteria, and the plan design details. The second document is WECC Criterion PRC-006-WECC-CRT- 3.1, effective June 18, 2019, which was created to ensure consistent use of the WECC Plan among all applicable WECC entities and to coordinate the UFLS database maintenance and update requirements among these entities.

In WECC, there are several other accepted and used UFLS plans. The Western Power Pool plan accelerates load shedding at earlier frequencies for less load shedding; the South Island Load Tripping Plan (SILTP) varies load shed obligation by participants using various criteria.

Planning coordinators (PC) in the Western Interconnection have designated the UFLS Work Group (UFLSWG) to biennially assess the performance of the WECC Plan per the UFLSWG Charter and to help WECC members meet their compliance with NERC Reliability Standard PRC-006-5. The activities and products of the UFLSWG are overseen by the Studies Subcommittee (StS), which reports to the Reliability Assessment Committee (RAC). The biennial WECC Plan assessment is reviewed and approved by both the RAC and the Reliability Risk Committee (RRC).

Responsibilities of the UFLSWG, as identified in its charter:

- Review UFLS data annually submitted by applicable WECC entities for consistency and accuracy of modeling (per requirements contained in PRC-006-WECC-CRT-3.1).
- Perform a biennial assessment of the WECC Plan to determine its effectiveness and adequacy in meeting the performance characteristics specified in PRC-006.
- Document the simulation results obtained from the biennial assessment in a report.
- Recommend improvements to the WECC Plan's design and implementation to the RRC and StS, based on findings of the biennial assessment.
- Perform other tasks as assigned by the StS or the RRC.

Within the Western Interconnection, the way electrical islands are formed results in two islands: the North Island and the South Island. As a result, the WECC Plan includes the “primary” WECC plan that could be used in either island and two sub-area plans, one for each island. The primary plan and both sub-area plans — the Western Power Pool (WPP) plan and the SILTP — are detailed in Section E, items 1a, 1b, and 1c of the WECC Plan. The WPP plan was formerly known as the Northwest Power Pool (NWPP) plan; NWPP is now doing business as WPP.

UFLS entities can adopt one plan or a combination of the three plans based on the location of their loads in the Western Interconnection. Most entities use one plan, but some UFLS entities’ loads are located in more than one sub-region, so, they use more than one plan.

This report summarizes the modeling and study methods including assumptions, the study cases used, and the simulation results comprised in the 2024–2026 assessment of the WECC Plan in accordance with the applicable requirements in NERC Standard PRC-006-5[1] and WECC Criterion PRC-006-WECC-CRT-3.1.1 The modeling data validation and the study simulations included in the assessment were performed by PowerWorld Corporation staff under the direction and guidance of the WECC UFLSWG with oversight provided by the StS under the RAC.

[1] Compliance with NERC Reliability Standard PRC-006 and WECC Regional Criteria PRC-006-WECC-CRT requirements is the responsibility of NERC registered entities. WECC does not guarantee that this report or any analysis or information contained in it is sufficient for compliance with these or any other requirements. It is the responsibility of each NERC registered entity to ensure that it meets its compliance responsibilities as applicable.

History of WECC Plan

The WECC Plan was approved and adopted in 1997 in response to three system-wide disturbances that occurred in 1996. Since then, it has been periodically updated or refined to include two subarea plans — the WPP plan and the SILTP — that are fully coordinated with the primary (original) WECC area plan. After the 2011 disturbance event, the WECC UFLS Review Group (predecessor of the WECC UFLS Work Group) evaluated the new island configurations that occurred during that disturbance (see 2013 UFLS Assessment). At the March 2014 meeting of the Planning Coordination Committee, the UFLS Review Group chair presented 14 potential BES island configurations based on the 2011 disturbance event, system studies, and RAS operation. The UFLSWG proposed, and the Planning Coordination Committee approved, that it is adequate to simulate the following planned islands in the 2015 UFLS Assessment:

- North Island
- South Island

To date, the UFLSWG has not identified any other plausible island based on application of the island formation criteria. Therefore, the study was conducted in an approach and scope similar to those of the previous the 2013[2], 2015, 2017, 2019, and 2022 UFLS assessments.

[2] 2013 UFLS Assessment: https://www.wecc.org/sites/default/files/documents/products/2024/UFLSRG_Report_2013_Final.pdf

Study Methods

Performance of the WECC Plan was assessed under 2023 heavy summer (23HS4a1) and 2024 light spring (24LSP2Sa1) operating conditions by starting with the approved versions of the WECC base cases.

Software Platform and Dynamic Models

PowerWorld Simulator Version 24 was used for all steady-state and dynamic simulations in the studies performed for this assessment.

UFLS load shed functionality was modeled in dynamic simulations by LSDT9, LSDT1, and TLIN1 models, which will automatically trip specified amounts of load at specific frequency levels. The WECC Plan also includes some automatic load restoration (reclosing) to arrest frequency overshoot, which, if actuated, would operate within the duration of the simulation run for the assessment. No frequency overshoot requiring load restoration was identified in this assessment. Generator owners with applicable relay settings also provide low-high frequency ride through (LHFRT) relays, which are also used in the simulation.

UFLS Database Review

All data requested to model the WECC Plan in dynamic simulations is contained in a UFLS database maintained by WECC staff. UFLS entities are asked to annually review this database and update it if necessary. The database is updated through a request from WECC to all UFLS entities to compile and submit their respective UFLS plan data and dynamic files using the data input form “Attachment A” of PRC-006-WECC-CRT-3.1. The Attachment A data input form is a spreadsheet that includes tabs where UFLS entities summarize their feeders and loads armed with UFLS relays, demonstrating that they provide automatic tripping of load in accordance with the UFLS program design. The database update occurs once each calendar year and is completed by June 1 for Generator Owners and July 1 for the other UFLS entities in accordance with PRC-006-WECC-CRT-3.1. The UFLSWG reviews and updates the Attachment A template before each data request to ensure that the UFLS database contains the data necessary to model the UFLS program once the Attachment A data input forms are completed by the UFLS entities.

The UFLS database submissions are reviewed by the UFLSWG to ensure the WECC master dynamics file (MDF) accurately reflects the submitted UFLS plan data. Inconsistencies are reported back to the UFLS entities with a request to correct the errors in the MDF through the company’s respective MOD- 032 processes. The MDF contains data necessary to model the UFLS program for use in event analysis and assessments. Further, it is available to all PCs within the Western Interconnection.

The process for annual maintenance of the UFLS database described above, followed by the UFLSWG on behalf of all PCs within the Western Interconnection, is in accordance with PRC-006-WECC-CRT-3.1.

Island Formation in the Western Interconnection

PCs in the Western Interconnection have regularly participated in a joint regional review to identify the portions of the interconnection's Bulk Electric System (BES) that may form islands. The criteria used to identify the formation of plausible islands in the Western Interconnection include:

a. Consideration of historical events,

b. System studies, and

c. Any portions of the BES designed to detach into islands because of Remedial Action Scheme (RAS) operation.

Based on these criteria, the consensus among PCs in the Western Interconnection is that the formation of two planned islands in the Western Interconnection — the North Island and the South Island — continues to be an adequate basis for the interconnection-wide coordinated UFLS program.

Identification of both North and South islands is based on opening tie lines in the WECC Island — the entire Western Interconnection footprint — as further described in Appendix E. The selection of islands in the Western Interconnection is therefore consistent with D.B.1 and D.B.2 in PRC-006-5.

For the UFLS assessment, dynamic simulations were run on the two specified islands in both WECC base cases identified earlier. After looking at the PRC-006-5 definition of islands and the history of WECC islands formation, it was decided that this year's assessment should be performed on the WECC North and South islands. Those islands are formed by starting with a WECC island base case and splitting the Western Interconnection into two parts by opening the tie lines between the north and south systems. The WECC-1 RAS (aka NE/SE Separation Scheme) was designed to operationally perform this function. To form the North and South islands in the base case models, some transmission elements were opened in accordance with the WECC-1 RAS (refer to Appendix E for details).

Other RAS found to be significant in analysis include:

- British Columbia-Alberta separation scheme, which will open up various ties between systems under certain conditions described here:
    - https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/suppliers/transmission-system/system_operating_orders/7T-17.pdf
- Montana-Alberta separation scheme (MATL) — this scheme has some modes that operate with the British Columbia-Alberta separation, and some modes that operate independent of the British Columbia-Alberta separation

These schemes and RAS were included in the applicable study models for the UFLS study.

Generation–Load Imbalance Creation

To simulate UFLS, a system event resulting in low frequency must be simulated; and to achieve a low frequency condition, it is necessary to simulate a case where generation in the interconnection is less than the load. In other words, there must be an imbalance between load and generation. In this assessment, the imbalance was calculated as described in D.B.3. in PRC-006-5 as:

$$\%\ Imbalance = \frac{Load - Actual\ Generation\ Output}{Load}$$

where Actual Generation Output = Total On-line Generation Output Prior to the Outage—Generation Tripped. Imbalance levels of 10%, 20%, and 25% were simulated for this assessment. These three imbalance levels were simulated in each of the two islands in both base cases for a total of 12 simulations.

Case Debug Techniques and Generation Trip Delay

One issue that arose doing this study was “spikes” in the system response due to generators going overspeed/out-of-step, as well as system frequency-related issues found during the simulations. There were issues found in certain areas’ frequencies that were a result of tripping too many generations at the same time. As part of the process to perform this year’s assessment different techniques and debug studies were done to improve the overall performance of the simulations. These techniques were part of the process to debug a case when performing simulations. A more detailed description of these techniques is available on Appendix A.

In addition, generator delays were added to the imbalance contingency to set the opening of certain generators at a different time. In reality, not all of the generation can be tripped at the same time. This idea was supported by some issues seen on area’s frequencies, individual generators and even the composite load tripping. A more detailed explanation and analysis of the addition of generation trip delays and issues is found in Appendix G.

Frequency Performance and Monitored Buses

The frequency performance was evaluated for each of the two islands (North and South) in both the 2023 heavy summer (23HS4) and the 2024 light spring (24LSP2-S) by applying the criteria noted in D.B.3.1 and D.B.3.2 in PRC-006-5. Specifically, this was done by monitoring the arrest in frequency decline, the frequency nadir, and the frequency recovery. The frequency was monitored in all the buses in the WECC model (including BES, non-BES, and fictitious model element buses) in the respective case scenarios. As mentioned before, as part of each WECC base case area plot, there is also a plot of the underfrequency and overfrequency performance characteristic threshold curves as defined in the PRC-006-5 Attachment 1. This helps identify which buses are not following the required frequency thresholds for the study.

After the imbalance is created, the simulation must run for 60 seconds to ensure that (1) the simulation is stable, (2) the frequency recovers to the required level specified in PRC-006, and (3) additional data checks can be performed, such as V/Hz (see next section). Frequency response plots were produced for each simulation run and were separated by WECC base case areas.

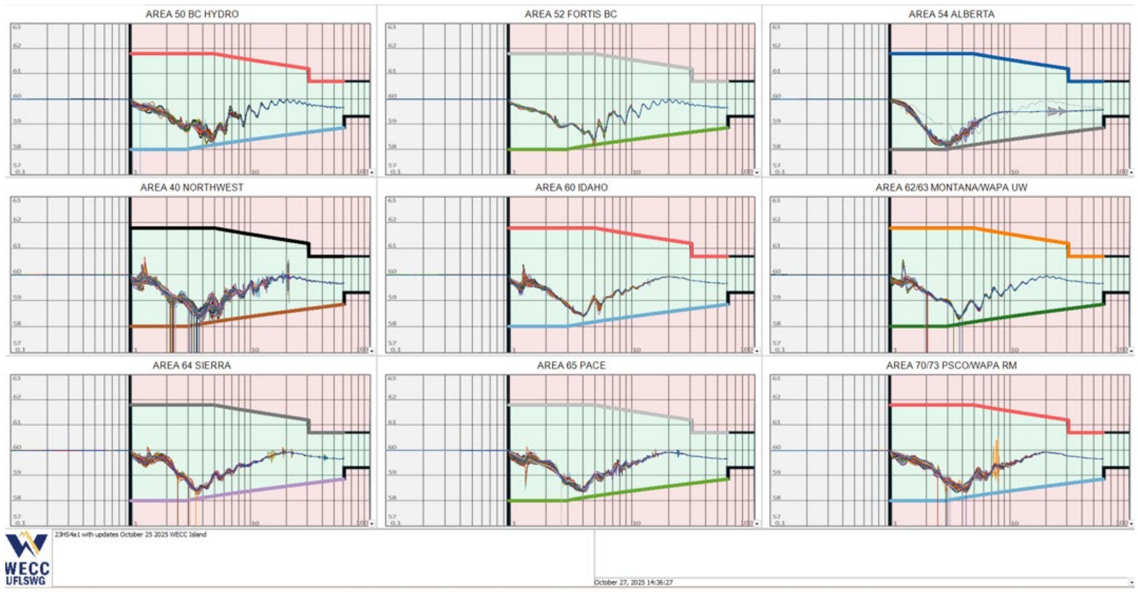


Figure 1: Sample frequency plot by WECC base case Area, shared with UFLSWG during a meeting to review simulation results, with PRC-006-5 Attachment 1 curve overlay

V/Hz Performance Check

This verification was performed at each generator bus by applying the V/Hz criteria noted in D.B.3.3 in PRC-006-5. That is, for each simulated event, V/Hz could not exceed 1.18 per unit for more than two seconds cumulatively and could also not exceed 1.10 per unit for more than 45 seconds cumulatively. A PowerWorld simulator custom transient limit monitor was used to programmatically check all generators for these exceedances, and PowerWorld Simulator V/Hz plots.

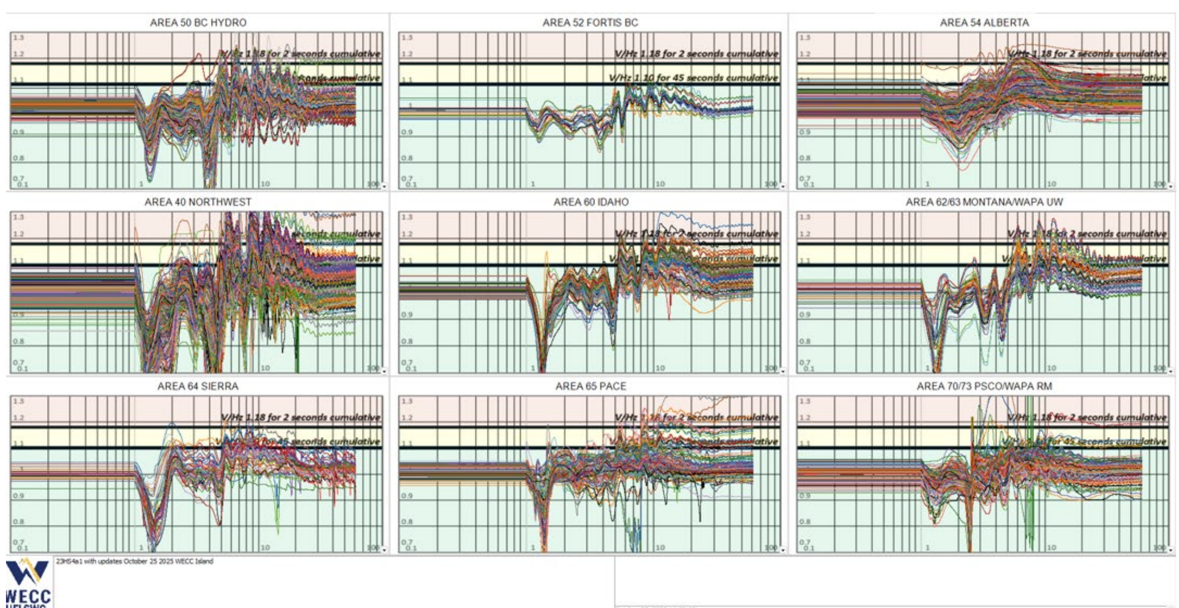


Figure 2: Sample plot to review V/Hz Performance

Coordinating UFLS Design Assessment

This coordinated UFLS design assessment was performed in accordance with D.B.4 in PRC-006-3, which states (emphasis added):

> **D.B.4.** Each Planning Coordinator shall participate in and document a coordinated UFLS design assessment with the other Planning Coordinators in the WECC Regional Entity area at least once every five years *that determines* through dynamic simulation *whether* the UFLS program design meets the performance characteristics in Requirement D.B.3 for each island identified in Requirement D.B.2.

It may be noted that the stated purpose of the coordinated UFLS assessment is to *determine whether* the WECC Plan's design meets the specified performance for each identified island. In doing so, the UFLS design assessment is intended to uncover any deficiency(ies) in the UFLS program design, which would then be addressed by developing a Corrective Action Plan.

This biennial assessment therefore identifies the specific performance characteristics that were not met (if any) by the WECC Coordinated Plan. Once validated as true indicators of design deficiencies in the WECC Plan by monitoring their occurrence in the next biennial assessment, they would qualify to be addressed with a Corrective Action Plan to improve the WECC Plan design.

North and South Island Study

The imbalance simulations were performed, and the initial raw results were tabulated in the table below:

Table 1: Study Results Summary

Case	Island	Island Load (MW)	Island Generation (MW)	Scenario	Target Gen Trip (MW)	Actual Gen Trip (MW)	Effective Imbalance (%)	Meets D.B.3.1 & D.B.3.2 Frequency	Meets D.B.3 V/Hz	Raw V/Hz Violations	Post-Utility Review Remaining V/Hz Violations
2023 HS4a1	North	79,750	86,696	10% (No Delay)	14,922	14,921	10	Y	N	63	1
				20% (No Delay)	22,897	22,898	20.002	Y	N	166	5
				25%	26,884	26,882	24.997	Y	N	219	7
2024 LSP2a1	North	59,583	61,688	10% (No Delay)	8,063	8,064	10	Y	Y	24	0
				20% (No Delay)	14,022	14,021	20	Y	N	68	1
				25%	17,001	17,465	25.78	Y	N	124	3
2023 HS4a1	South	107,056	105,974	10% (No Delay)	9,624	9,606	9.98	Y	Y	45	0
				20%	20,329	20,329	20	Y	Y	176	0
				25%	25,682	25,691	25.01	Y	Y	462	0
2024 LSP2a1	South	68,572	70,125	10% (No Delay)	8,411	8,433	10.03	Y	Y	13	0
				20%	15,268	15,268	20	Y	Y	35	0
				25%	18,697	18,688	24.99	Y	Y	79	0

The frequency response plots are included in Appendix B and C. Frequency performance results from these plots for the 10%, 20%, and 25% imbalance simulations meet requirements specified in D.B.3.1 and D.B.3.2 in PRC-006-5 for all the study scenarios.

The previous table also includes the V/Hz performance check that was done for the North Island and South Island simulations. This check is performed on generators and the high-side terminals of generator step-up transformers because of the potential for high V/Hz levels to damage this equipment through elevated magnetic saturation. V/Hz is the voltage of the element (generator terminals), in per-unit, divided by the frequency at the same location, also in per-unit. This value is then evaluated relative to PRC-006-5, D.B.3.3 and the violations shown are the total of generator buses that reported a violation regardless of unit size, and results were reviewed by utilities to exclude non-applicable units.

V/Hz Threshold	Time Limit
1.18 per- unit	2.0 sec (Cumulative)
1.1 per-unit	45.0 sec (Cumulative)

Discussion and Observations of V/Hz Results and Violations

Many of the scenarios assessed found V/Hz violations. These results do not meet requirements specified in D.B.3.3 in PRC-006-5. The amount of load shed with the combination of the generator tripped during the imbalance and simulation is creating many high voltages which are not adequately mitigated. This is causing the V/Hz ratio to be above the limits — the voltage response is the driver, and not the frequency component.

In discussions with the UFLSWG and further analysis, several cases were identified where units were excluded from these results when requested:

1. Units that were dispatched offline in the N-0 case state
2. Units that were turned off as part of the creation of the imbalance scenarios
3. Units that were motors or SVCs modeled as generator objects
4. Units that did not meet MVA and BES threshold as described in PRC-006 D.B.3.3. and subparts:

D.B.3.3.	**Volts per Hz (V/Hz) shall not exceed 1.18 per unit for longer than two seconds cumulatively per simulated event,** and shall not exceed **1.10 per unit for longer than 45 seconds cumulatively per simulated event** at each generator bus and generator step-up transformer high-side bus associated with each of the following:
D.B.3.3.1.	Individual generating units greater than 20 MVA (gross nameplate rating) directly connected to the BES
D.B.3.3.2.	Generating plants/facilities greater than 75 MVA (gross aggregate nameplate rating) directly connected to the BES
D.B.3.3.3.	Facilities consisting of one or more units connected to the BES at a common bus with total generation above 75 MVA gross nameplate rating.

In subsequent review of V/Hz issues, entities further advised issues such as bad generator step-up taps in the study models, local customer-owned generator shunt capacitors that would trip if the generator itself trips (such as during the creation of the generation-load imbalance scenario). Additionally, some participants could not adequately model their reactive control devices with WECC-approved shunt control models. These further contributed to V/Hz issues in the study cases, and the UFLSWG participants were provided an opportunity to identify these issues and test whether these modeling issues, when fixed, resulted in adequate performance for their generator units.

Generators that were open in the base case, open in the creation of the imbalance, or open due to relays as part of the system response, are not included in this reporting.

In Table 2, the distribution of the V/Hz violations is presented in both raw total numbers and remaining number after UFLSWG utility review, excluding those times where a unit was already open in the case, was open in the creation of the imbalance, opened during the simulation, did not meet the applicability criteria, or had other excluding reasons as provided by the UFLSWG participants:

Table 2: Distribution of V/Hz Violations for the 12 Cases

Imbalance Case	Raw V/HZ Violations	Post-Review V/Hz Violations
South Island 2023HS4a1 - 25%	462	0
South Island 2023HS4a1 - 20%	176	0
South Island 2023HS4a1 - 10%	45	0
North Island 2023HS4a1 - 25%	219	7
North Island 2023HS4a1 - 20%	166	5
North Island 2023HS4a1 - 10%	63	1
South Island 2024LSP2sa1 - 25%	79	0
South Island 2024LSP2sa1 - 20%	35	0
South Island 2024LSP2sa1 - 10%	13	0
North Island 2024LSP2sa1 - 25%	124	3
North Island 2024LSP2sa1 - 20%	68	1
North Island 2024LSP2sa1 - 10%	24	0

In the tables below, these generators remained in service, and there were no further utility comments to exclude these units from the violation counts. More detailed generator and ownership information can be found on the supplemental Excel spreadsheet, *V per Hz Violations Updated.xlsx*, on the secure WECC UFLSWG page.

Table 3: Distribution of V/HZ Final Violations for the Heavy Summer Case (23HS4a1)

Case Area	Case BA	V Hz HS SI 25%	V Hz HS SI 20%	V Hz HS SI 10%	V Hz HS NI 25%	V Hz HS NI 20%	V Hz HS NI 10%
South Island subtotal		0	0	0			
PACE	PacifiCorp - East				7	5	1
North Island subtotal					7	5	1
Grand Total Per Imbalance Scenario		**0**	**0**	**0**	**7**	**5**	**1**

Table 4: Distribution of V/HZ Final Violations for the Light Spring Case (24LSP2sa1)

Case Area	Case BA	V Hz LS SI 25%	V Hz LS SI 20%	V Hz LS SI 10%	V Hz LS NI 25%	V Hz LS NI 20%	V Hz LS NI 10%
South Island subtotal		0	0	0			
PACE	PacifiCorp - East				3	1	
North Island subtotal					3	1	
Grand Total Per Imbalance Scenario		**0**	**0**	**0**	**3**	**1**	**0**

Most of the generators that reported violations do not have any generator connected for most of the simulation. Not having a generator online creates the issue of not having enough generation to provide voltage support for the voltages to return to the original value. Also, the addition of more reactors and capacitors in the system will benefit the simulation to reduce those voltages to normal levels. There are many reactors in the system, but they lack dynamic models to control them. For example, in the North Island there are about 249 of the 1,714 switched shunts that have some dynamic model with them. In contrast, the South Island only has 10 of the 1,964 switched shunts with a dynamic model. This helps explain why there are more raw counts of V/Hz violations in the South Island than in the North Island. Also, it is pointing out the need to add more dynamic models to these reactive support devices to control the voltages better during the simulation. This issue needs to be investigated further.

The list of V/Hz violations was shared among the WECC entities, and some violations were found to not be real violations for reasons mentioned earlier. In addition, many entities reported that some inverter-based resource (IBR) capacitors needed to be disconnected when the associated generator was opened, either because the generator was part of the imbalance contingency or because, during the simulation, the generator opened because of relay actions. This is another contributing factor to high voltages in the system.

The PRC-006-5, D.B.3.3 also has the following requirements to report a violation regarding the size of the units:

- Individual generating units greater than 20 MVA (gross nameplate rating) directly connected to the BES
- Generating plants/facilities greater than 75 MVA (gross aggregate nameplate rating) directly connected to the BES
- Facilities consisting of one or more units connected to the BES at a common bus with total generation above 75 MVA gross nameplate rating.

In addition, Table 2 shows the generators with valid observed violations after 60 seconds (last column of Table 2) after removing generators from the original list that were found to not be real violations. Those valid violations are for generators that remain closed and have the minimum unit MVA size and BES connectivity type per PRC-006 associated with the V/Hz requirement.

Armed Load Data Validation

As part of the validation check of UFLS data submittals received from the UFLS entities, the amount of load armed for each Load Shed Block of the WECC Plan was tabulated for both the 2023 heavy summer (23HS4a1) and the 2024 light spring (24LSP2Sa1) cases. This benchmarks the consistency between actual implementation of the WECC Plan by UFLS entities compared to its design. The values in the Plan Design columns reflect the WECC primary plan, WPP sub-plan, and SILTP sub-plan descriptions in the WECC Plan and are tabulated here for easy comparison. The percentages of the Plan Design SITLP column can vary, but, for reference, the same values as those in the previous assessments were used. The percentages in these columns are minimum requirements. The values in the "Modeled" columns of Tables 5 and 6 represent the amount of load armed for underfrequency shedding within the North and South islands — these percentages are the ratio of armed load shed data submitted by UFLS entities to the connected bus load in the case, computed for each load shed block.

Table 5: Armed Load Shed Data Validation for the 2023 Heavy Summer Case 25% North — South Island Separated — Original UFLS Dynamics File

	Modeled Armed Load Validation 2023 Heavy Summer Case 25% North — South Island Separated									
Load Shed	North Island (WPP & WECC plans)						South Island (SILTP)			
Stage	Plan Design				Modeled		Plan Design		Modeled	
	WPP		WECC				SILTP			
1	5.60%	(59.3 Hz)	5.30%	(59.1 Hz)	**7.42%**	(≥ 59.1 Hz)	% varies	(59.1 Hz)	5.94%	(59.1 Hz)
2	5.60%	(59.2 Hz)	5.90%	(58.9 Hz)	**4.45%**	(≥ 58.9, < 59.1 Hz)	% varies	(58.9 Hz)	5.95%	(58.9 Hz)
3	5.60%	(59.0 Hz)	6.50%	(58.7 Hz)	**4.83%**	(≥ 58.7, <58.9 Hz)	% varies	(58.7 Hz)	6.36%	(58.7 Hz)
4	5.60%	(58.8 Hz)	6.70%	(58.5 Hz)	**4.94%**	(≥ 58.5, < 58.7 Hz)	% varies	(58.5 Hz)	6.61%	(58.5 Hz)
5	5.60%	(58.6 Hz)	6.70%	(58.3 Hz)	**3.25%**	(≥58.3, < 58.5 Hz)	% varies	(58.3 Hz)	6.27%	(58.3 Hz)
< 58.3 Hz					1.77%				17.31%	
TOTAL	28.00%		31.10%		26.66%		35.10%		48.45%	
UF Stalling	6.00%		6.00%		4.58%		6.00%		6.22%	

Table 6: Armed Load Shed Data Validation for the 2024 Light Spring Case 25% North — South Island Separated — Original UFLS Dynamics File

	Modeled Armed Load Validation 2024 Light Spring Case North — South Island Separated									
Load Shed	North Island (WPP & WECC plans)						South Island (SILTP)			
Stage	Plan Design				Modeled		Plan Design		Modeled	
	WPP		WECC				SILTP			
1	5.60%	(59.3 Hz)	5.30%	(59.1 Hz)	**6.63%**	(≥ 59.1 Hz)	% varies	(59.1 Hz)	5.44%	(59.1 Hz)
2	5.60%	(59.2 Hz)	5.90%	(58.9 Hz)	**3.78%**	(≥ 58.9, < 59.1 Hz)	% varies	(58.9 Hz)	5.91%	(58.9 Hz)
3	5.60%	(59.0 Hz)	6.50%	(58.7 Hz)	**4.65%**	(≥ 58.7, <58.9 Hz)	% varies	(58.7 Hz)	5.85%	(58.7 Hz)
4	5.60%	(58.8 Hz)	6.70%	(58.5 Hz)	**4.03%**	(≥ 58.5, < 58.7 Hz)	% varies	(58.5 Hz)	6.17%	(58.5 Hz)
5	5.60%	(58.6 Hz)	6.70%	(58.3 Hz)	**2.67%**	(≥58.3, < 58.5 Hz)	% varies	(58.3 Hz)	5.85%	(58.3 Hz)
< 58.3 Hz					1.48%				15.69%	
TOTAL	28.00%		31.10%		23.24%		35.10%		44.91%	
UF Stalling	6.00%		6.00%		4.03%		6.00%		5.26%	

North Island — Note that, in Table 5 and Table 6 the total armed load modeled in the North Island falls short of what is required by plan design for both the 2023 heavy summer and 2024 light spring cases. Assuming the connected load in the North Island is almost equally distributed between the WPP plan and WECC plan, the total armed load, per plan design, would be 29.55% (average of 28.0% and 31.1%). In the 2023 heavy summer WECC Island, the modeled total armed load percentage is 26.66% and, in the 2024 light spring, it is 23.24%. This results in armed load **deficits of 2.89%** and **6.31%,** respectively.

South Island—The total armed load modeled in the South Island is much higher than what is required by plan design for both the 2023 heavy summer and the 2024 light spring cases—a **surplus of 13.35%** in the 2023 heavy summer and **9.81%** in the 2024 light spring using the WECC Island case as an example.

Many LSDT9 and TLNI1 relays included in the original dynamic data file were not read because the corresponding load or branch could not be found or the data was outdated. A request to the different WECC entities was presented to correct issues with the LSDT9 and the TLIN1 relays. After some of the entities provided input, the tables were updated. Also, some corrections were made when loads models were found to not been read because the id of the load was changed. The new percentages are presented in Tables 7 and 8.

Example chart used to check amount of load shed with respect to WPP and WECC thresholds

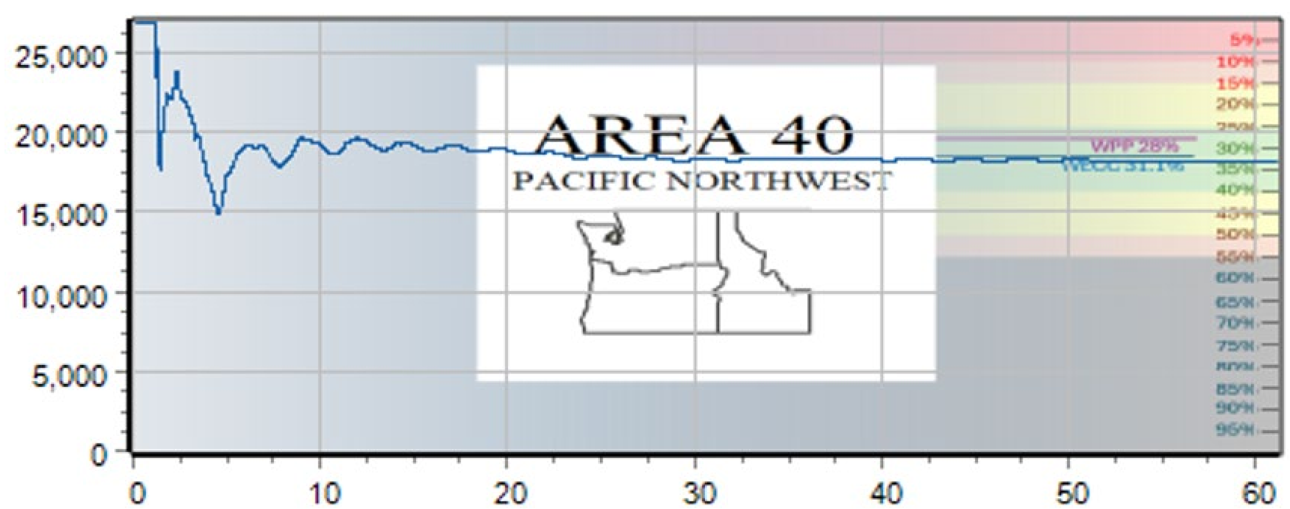


Table 7: Armed Load Shed Data Validation for the 2023 Heavy Summer Case 25% North — South Island Separated

	Modeled Armed Load Validation 2023 Heavy Summer Case 25% North — South Island Separated									
Load Shed	North Island (WPP & WECC plans)						South Island (SILTP)			
Stage	Plan Design WPP		WECC		Modeled		Plan Design SILTP		Modeled	
1	5.60%	(59.3 Hz)	5.30%	(59.1 Hz)	**7.33%**	(≥ 59.1 Hz)	% varies	(59.1 Hz)	5.98%	(59.1 Hz)
2	5.60%	(59.2 Hz)	5.90%	(58.9 Hz)	**4.77%**	(≥ 58.9, < 59.1 Hz)	% varies	(58.9 Hz)	5.95%	(58.9 Hz)
3	5.60%	(59.0 Hz)	6.50%	(58.7 Hz)	**4.87%**	(≥ 58.7, <58.9 Hz)	% varies	(58.7 Hz)	6.36%	(58.7 Hz)
4	5.60%	(58.8 Hz)	6.70%	(58.5 Hz)	**5.12%**	(≥ 58.5, < 58.7 Hz)	% varies	(58.5 Hz)	6.66%	(58.5 Hz)
5	5.60%	(58.6 Hz)	6.70%	(58.3 Hz)	**3.33%**	(≥58.3, < 58.5 Hz)	% varies	(58.3 Hz)	6.26%	(58.3 Hz)
< 58.3 Hz					1.80%				17.35%	
TOTAL	28.00%		31.10%		27.21%		35.10%		48.57%	
UF Stalling	6.00%		6.00%		4.91%		6.00%		6.22%	

Table 8: Armed Load Shed Data Validation for the 2024 Light Spring Case 25% North — South Island Separated

	Modeled Armed Load Validation 2024 Light Spring Case North — South Island Separated									
Load Shed	North Island (WPP & WECC plans)						South Island (SILTP)			
Stage	Plan Design WPP		WECC		Modeled		Plan Design SILTP		Modeled	
1	5.60%	(59.3 Hz)	5.30%	(59.1 Hz)	**6.87%**	(≥ 59.1 Hz)	% varies	(59.1 Hz)	5.40%	(59.1 Hz)
2	5.60%	(59.2 Hz)	5.90%	(58.9 Hz)	**4.32%**	(≥ 58.9, < 59.1 Hz)	% varies	(58.9 Hz)	5.83%	(58.9 Hz)
3	5.60%	(59.0 Hz)	6.50%	(58.7 Hz)	**4.74%**	(≥ 58.7, <58.9 Hz)	% varies	(58.7 Hz)	6.07%	(58.7 Hz)
4	5.60%	(58.8 Hz)	6.70%	(58.5 Hz)	**4.47%**	(≥ 58.5, < 58.7 Hz)	% varies	(58.5 Hz)	6.29%	(58.5 Hz)
5	5.60%	(58.6 Hz)	6.70%	(58.3 Hz)	**2.87%**	(≥58.3, < 58.5 Hz)	% varies	(58.3 Hz)	5.77%	(58.3 Hz)
< 58.3 Hz					1.84%				15.57%	
TOTAL	28.00%		31.10%		25.11%		35.10%		44.93%	
UF Stalling	6.00%		6.00%		4.59%		6.00%		5.19%	

As can be seen, the percentages in the North Island did improve close to 2%, and in the South Island, the percentages changed by less than half of a percentage point. Now, the North Island for the heavy summer case is closer to the plan design. Note the simulation results shown in the appendices are with the updated data and armed load percentages shown in Tables 7 and 8.

The armed load data validation also serves as the prerequisite step for performing the armed load adequacy check for the WECC Plan (see next section).

Armed Load Adequacy Check

This check provides another metric for evaluating the adequacy and effectiveness of the implemented (i.e., modeled) WECC Plan. Comparing the amount of actual load shed during the underfrequency event simulation with the amount of total armed load (i.e., maximum available load for shedding) in the model allows computing the remaining or unused armed load—available armed load margin—as an indicator of the adequacy of the WECC Plan's implementation. The difference between this section and the previous section is that this section shows how much load is armed and is still available to be shed in the specified simulations (unused armed load), while the previous section shows how much load is armed compared to what is required in the WECC Plan.

As shown in Table 9 and Table 10 below, the total armed load in the North Island has significantly lower margin compared to the others. Tables 11 and 12 are taken from the previous assessment report and are included only for the purpose of comparison. As in the current assessment, the North Island has lower margin compared to the others, but slightly higher when compared to the previous assessment report. This should be monitored and verified in future UFLS assessments since validated low margin would be a reasonable basis for making appropriate design adjustments to the WECC primary plan and WPP sub-area plan to provide additional armed load in the North Island.

Table 9: Armed Load Adequacy for the 2023HS4a1 Case

Island				25% Imbalance		
	Total (MW)	Armed (MW)	Armed (% of Total)	Shed (MW)	Shed (% of Armed)	Plan Margin %
North	79,977	25,688	32.12%	16,715	65.07%	34.93%
South	106,829	58,527	54.79%	20,237	34.58%	65.42%

Table 10: Armed Load Adequacy for the 2024LSP2a1 Case

Island				25% Imbalance		
	Total (MW)	Armed (MW)	Armed (% of Total)	Shed (MW)	Shed (% of Armed)	Plan Margin %
North	59,704	17,733	29.70%	12,167	68.61%	31.39%
South	68,451	34,303	50.11%	17,004	49.57%	50.43%

Table 11: Armed Load Adequacy for the 2021LSP-1S Case (Previous Assessment)

Island				25% Imbalance		
	Total (MW)	Armed (MW)	Armed (% of Total)	Shed (MW)	Shed (% of Armed)	Plan Margin %
North	78,283	25,625	32.70%	Simulations Incomplete[4]		7.90%
South	97,696	54,980	56.30%	26,106	47.50%	52.50%

Table 12: Armed Load Adequacy for the 2024LSP-1S Case (Previous Assessment)

Island				25% Imbalance		
	Total (MW)	Armed (MW)	Armed (% of Total)	Shed (MW)	Shed (% of Armed)	Plan Margin %
North	48,696	14,355	29.50%	10,529	73.30%	26.70%
South	43,358	19,898	45.90%	10,335	51.90%	48.10%

Findings and Conclusions

This assessment of the WECC UFLS Plan was able to demonstrate that it meets the performance characteristics defined in PRC-006-5, with the exception of the V/Hz violations shown in Table 2 for one entity. Specifically, PRC-006-5, D.B.3.1-2. requires it to maintain a steady-state frequency condition between 59.3 and 60.7 Hz under generation-to-load imbalance conditions of up to 25% within identified islands for 60 seconds. Also, the simulation needs to be above 58 Hz and under 61.8 HZ for the entire simulation and follow the Underfrequency and Overfrequency Performance Characteristic curve in PRC-006-5 - Attachment 1. The assessment was successful in achieving the required frequency performance within the Characteristic Curve for 60 seconds. To complete some of the simulations for the required 60 seconds, a delay needed to be implemented for certain areas. The underlying cause cannot be attributed to any specific issue in any particular area, and it seems it is related to the base case configuration in the initial solution and numeric solution needs for the model. A different case could be run without delays in any area but for this study this delay method was the best alternative found to the failed numeric solution situation. Also, the delay provided a more realistic imbalance scenario because it is not realistic to trip this magnitude of generation across multiple Bas, RCs, and system areas at the same exact time.

As shown in the Armed Load Adequacy Check section of this report, the North Island has a lower armed load margin than the South Island in the 25% imbalance simulations, particularly under heavy load conditions. None of the imbalance simulations resulted in 100% of the armed load being shed, but as this level of load shed is approached, the addition of more armed load or WECC Plan design adjustments should be considered as well as a review of the data for the North islands areas. Data submitting entities and owners need to ensure the North Island footprint’s load and line frequency relays are an adequate and acceptable representation of their respective implementation of the UFLS plan.

V/Hz results were tabulated for all the imbalance simulations. For these scenarios, many initial V/Hz violations were observed. Although the underfrequency response is doing its job in driving the frequency back within the desired range, it seems that the amount of load shed with the combination of the generator tripped during the imbalance and simulation is creating many high voltages, thus potentially causing the V/Hz performance to be above the required PRC-006-5 D.B.3.3 criteria. More investigation regarding this issue should be carried out to understand if any mitigation needs to be done to prevent these violations and if mitigation is required, entities should coordinate Corrective Action Plans through the UFLSWG.

Recommendations/Observations

Due to findings and results in WECC UFLS assessment, the following recommendations are made:

1. The initial simulations for 2023 HS4a1 and 2024 LSP2Sa1 failed due to voltage collapse. This was resolved with modeling improvements, various supplemental actions, and application of solution techniques. The UFLSWG should determine whether these instances of voltage collapse could be remedied by modeling reactive devices that would operate in the period of the simulations, modifying the relay models for loads and generators, or by including key remedial actions that influence the UFLS simulations. It is recommended that the UFLSWG:
    a. Continue verifying the load and branch load shedding relay data. Issues were found with the dyd files, and some of the models need to be updated to match their corresponding object in the case.
    b. Investigate the modeled armed load for the North Island. The load validation check showed that the North Island needs some corrections for the modeling to match the design armed percentage. After updating the relay models, the percentages improved but they remained below the design plan for some entities.
2. V/Hz violations need to be addressed.
    a. It is recommended that each PC evaluate the affected generating units with violations in their control area and validate the behavior of the model. If model updates are required, these should be communicated to the necessary entities. This could include adding more dynamic models for switched shunts and disconnection of IBR capacitors when generators are opening during the simulation.
    b. It is recommended that the UFLSW investigate the issue of high system voltages in response to generation loss/imbalance and subsequent underfrequency load shedding.
3. The current UFLS Methodology Document, which outlines how the UFLS assessment is performed, should be reviewed by the UFLSWG to address:
    a. Methods of causing imbalance (e.g., tripping generation, setting unit PGen to zero but allowing it to stay online, dynamically opening tie lines, adding load); and
    b. Selection of generators to trip, including unit location, unit type (e.g., synchronous generator, IBR, must-runs).

c. Combination of methods of imbalance for each contingency. For example, tripping and shedding Unarmed loads as part of the contingency to create the imbalance. This should be done for the purpose of making the simulation run for 60 seconds and/or to prevent the high voltage issues that was creating the V/Hz violations.

UFLSWG should work with the System Review Subcommittee (SRS) to get RAS and other automatic schemes modeled in dynamics. Below is a graphic derived from a discussion at the 12/16/2025 UFLSWG meeting:

UFLS-analysis oriented relay modeling concerns

MODELS USED WELL:

TLIN1 – UFLS load shed via transmission lines
LSDT1 – UFLS load shed
LSDT9 – UFLS load shed
LHFRT – Gen frequency
LHVRT – Gen voltage

MODELS APPROVED, NOT WIDESPREAD USE:

Reactive device control
- MSC1
- MSR1
- SWSHNT

Generator Protection GP1/2/3
TS simulation-oriented RAS
SCMOV – Series cap MOV/ bypass
OEL and UEL*

*OEL and UEL available for some, but not all, exciter models

MODELS AVAILABLE BUT NOT WECC APPROVED:

Shunt Line reactor control (MSLR1)
Transformer tap controllers (LTC1)
Generator out-of-step (GENOOS)
Generator overspeed (LHSRT)
Generator V/Hz (GVPHZFT, GFPHZIT, VPERHZ1)
Line Overvoltage tripping (TLIN1O)
Overfrequency load restoration (LRDT9)
Related reactive device tripping if gen trips (no model yet)
Shunt device overvoltage protection (no model yet)

Appendix A — Case Debug Techniques

As part of the study, many simulations were performed. In the 20% and 25% generation imbalance contingencies, a consistent issue was the simulation failing to converge. In this section, an explanation of the techniques and tools used in PowerWorld to debug those cases will be presented. The techniques and tools are not applied in a linear approach, meaning using one or a combination of them typically requires multiple iterations and re-simulation to resolve the convergence issues.

a. Case Solution Details

In PowerWorld Simulator, one of the first software logs to review after the solution fails is the Solution Details table. This table provides solution details about the simulation solution at each time step. It has a table that describes mismatches, the bus of the mismatch, as well as some information about the Jacobian factorization and simulation details. Looking at the mismatches and the bus of the mismatch could point to one of the generators or object that is causing problems, as well as the time step where the solution failed:

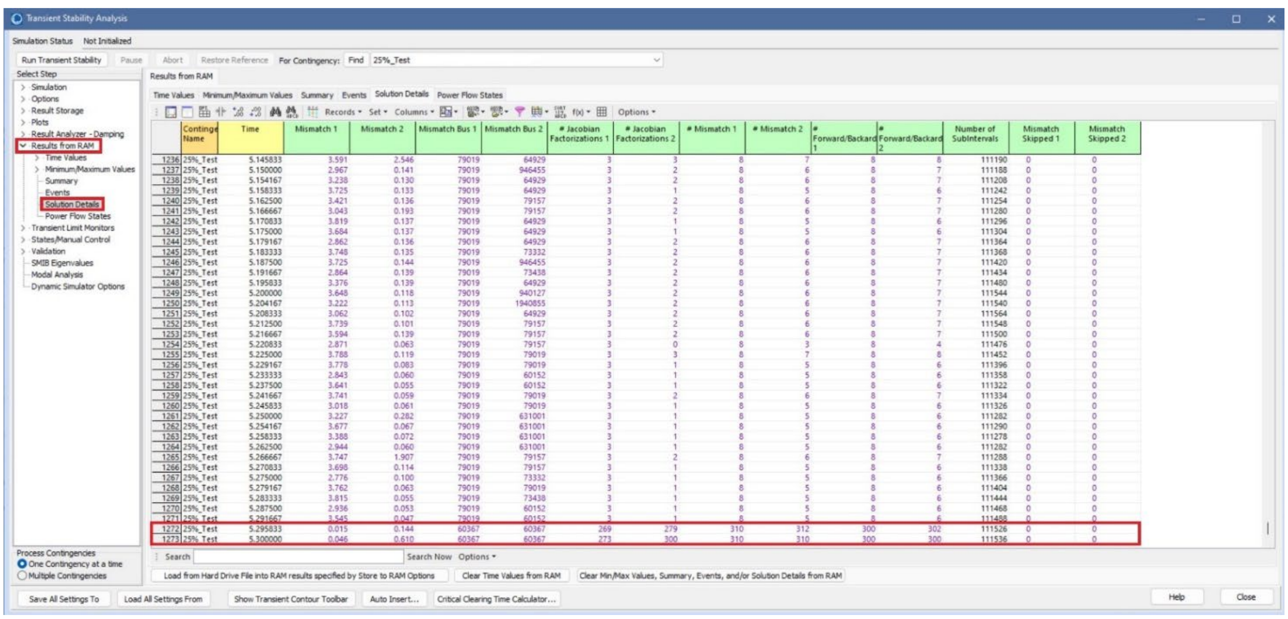


Figure A.1: Solution Details in PowerWorld Simulator

In the example in Figure A.1, the solution failed during the 23HS4a1 case when running a 25% unbalanced contingency. In the time steps before collapsing, the mismatches and the corresponding bus gives information about where an object might be causing problems in the case. Opening a bus view of that bus can show which object might be causing the mismatch that never solves. In this example, it was a generator on that bus. The next step would be to de-activate the machine model of that generator and see if the solution improves by re-running the simulation.

b. Plotting Voltage and Frequency

Plotting voltages and frequency is another important tool when debugging a case solution. Instead of just plotting the value of the voltages and frequencies, it is better to additionally plot the deviation from the original value at time step zero. When creating plots of voltage and frequency, PowerWorld Plot Designer tool lets select the Actual Deviation as one of the options in the Plot Series List table:

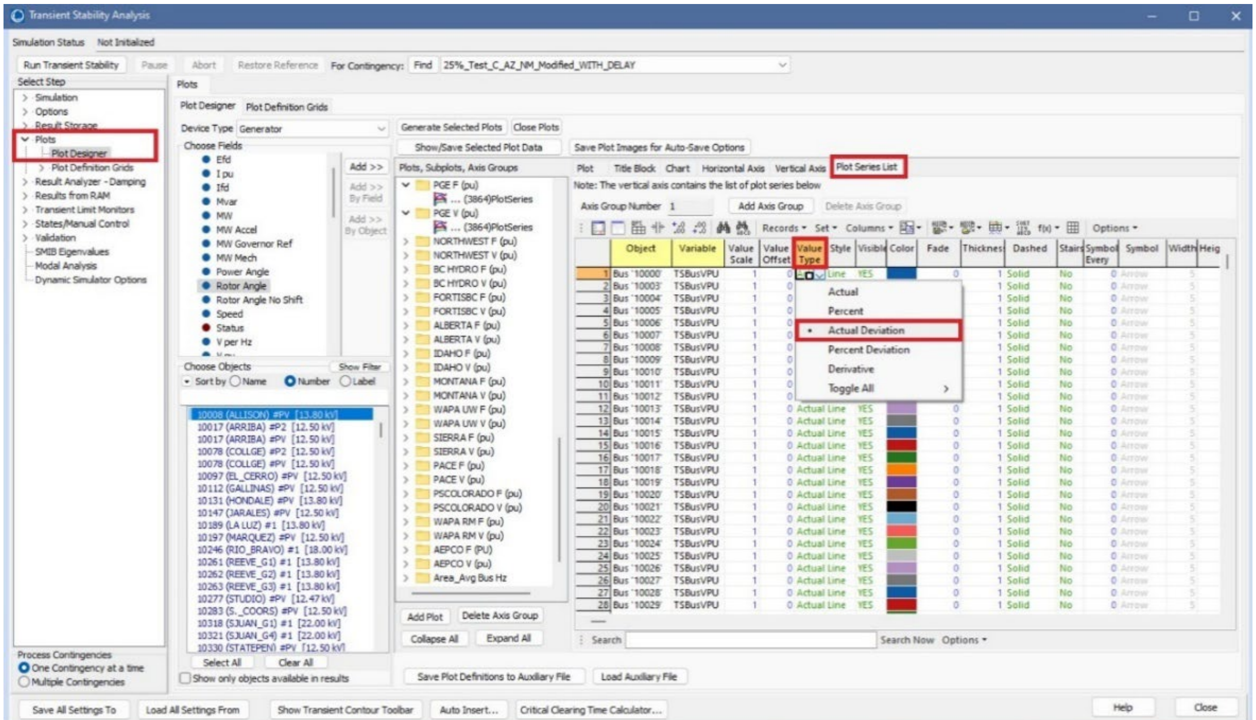


Figure A.2: Plot Designer in PowerWorld

After selecting all the V pu and Frequency (pu) in the Plot Series List by pressing right click in the Value Type and selecting Toggle All, set Actual Deviation as the value Type. This plot is an excellent tool to see how the values are changing from their steady state values. Most importantly, it might show particular buses that might be diverging from the rest of the buses. These buses can then be viewed in a Bus View to determine which object might be causing problems. De-Activating that object model and re-running the simulation might show if the simulation improves or not.

c. States/Manual Control

The States/Manual Control tool in PowerWorld Simulator is another useful tool to look at particular states in a model and determine if the model is behaving improperly. At time zero, the derivatives should be zero or close to zero. If they are not, that could point to a problem with that particular model that will need to be corrected either by modifying some parameters or removing the model from the analysis (de-active model). During the simulation, when a system fails sometimes the derivatives on models go very high and could point to a problem with that model. The best way to determine this is by looking at the time steps before failing and seeing if the model derivatives and states were going high and see if they match the Solution Detail mismatches in the Case Solution Detail page.

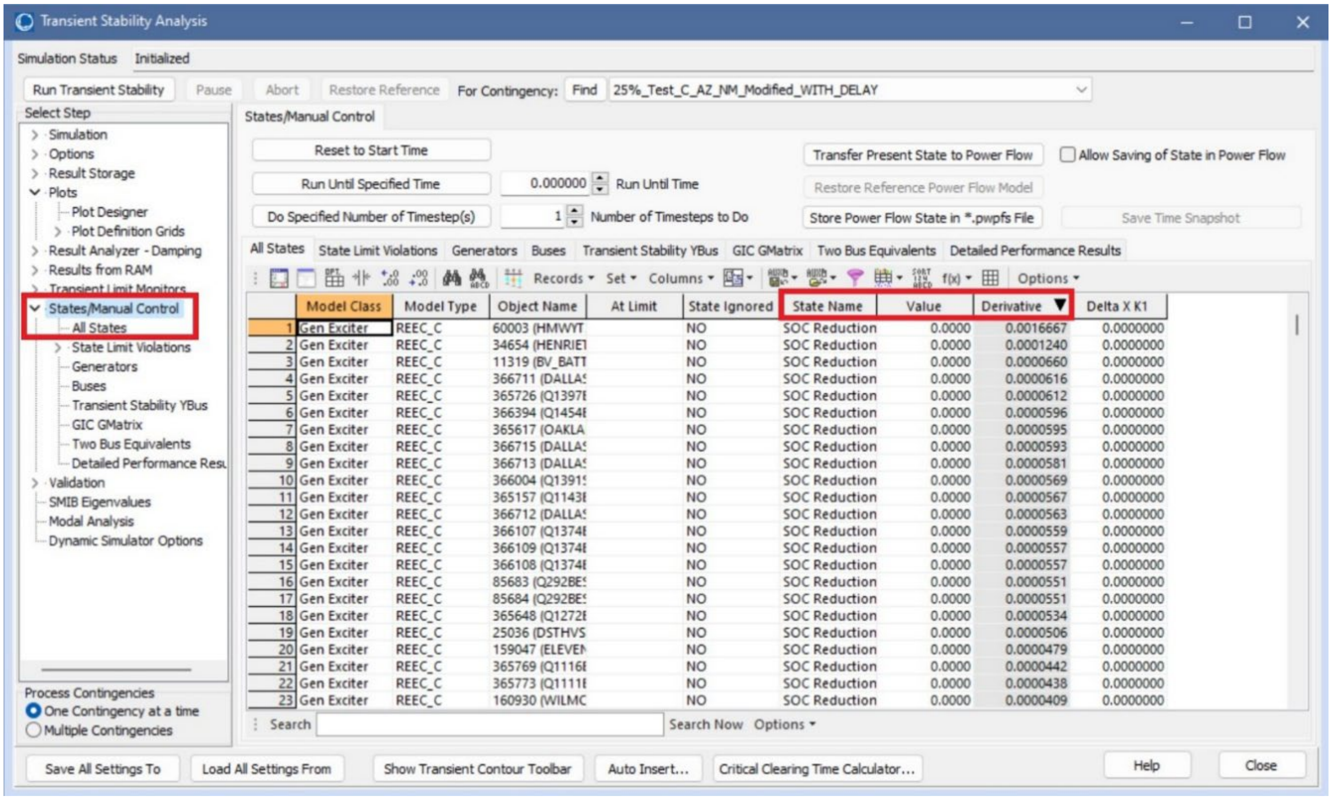


Figure A.3: State manual Control in PowerWorld

d. Setting certain models to Not Active

As part of the process of running simulations, there are situations in which the contingency runs for the entire 60 seconds, but when looking at the frequency and voltage plots, some generators or buses do not have ideal plots. Typically, those generators buses are easy to identify because they are oscillating or are behaving differently from the rest of the plots. In certain cases, certain generators, load or branch models were set to "Not Active" because doing so improves the overall performance and behavior of the simulation. The list of models set to "Not Active" for the different cases are presented in Appendix F. These models should be checked for possible parameters errors or other issues with the models that need some correction.

e. Setting the transient simulation to not model island of less than seven buses

During the simulations, small islands (six buses or less) were formed as part of the contingency solution. These small islands were causing the simulation to not solve because islands were not converging. PowerWorld has an option to only simulate islands above a certain bus or generator count. In the cases for this study, the minimum bus count to simulate an island was set to seven. Using this option helped many of the cases to run without any issues for 60 seconds.

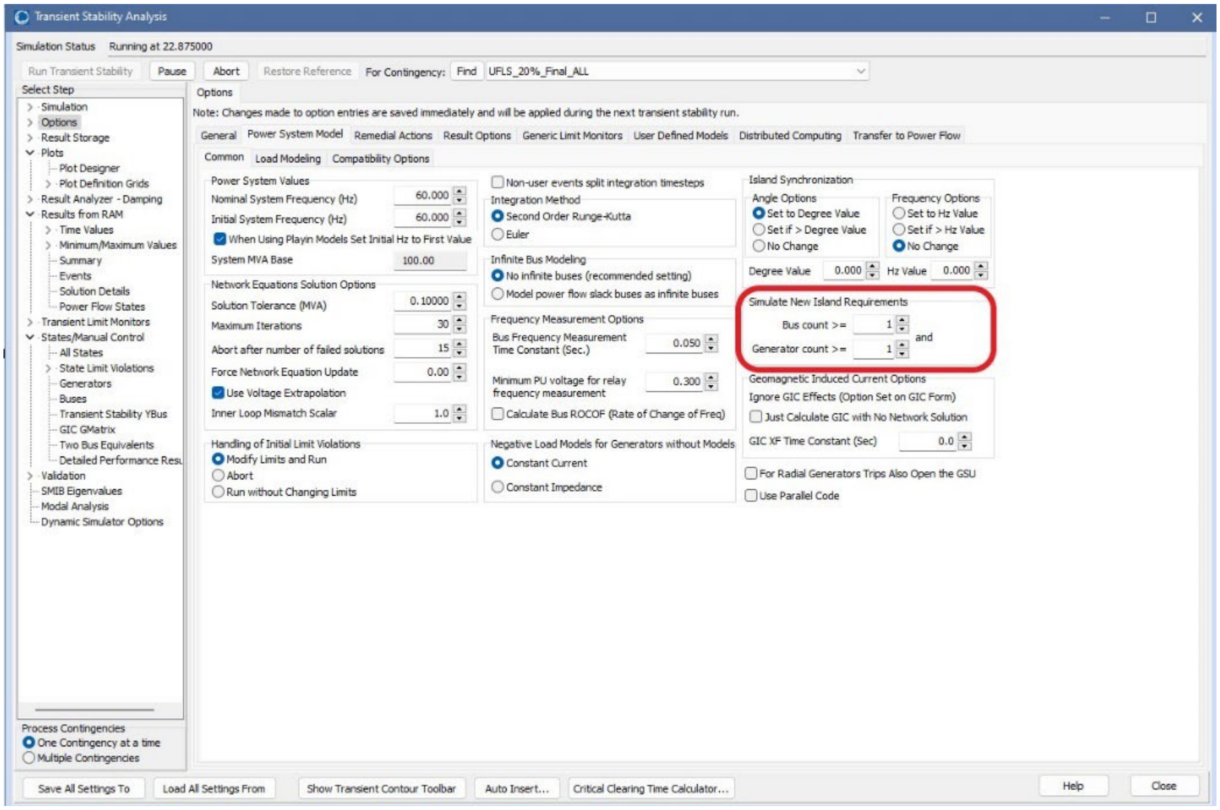


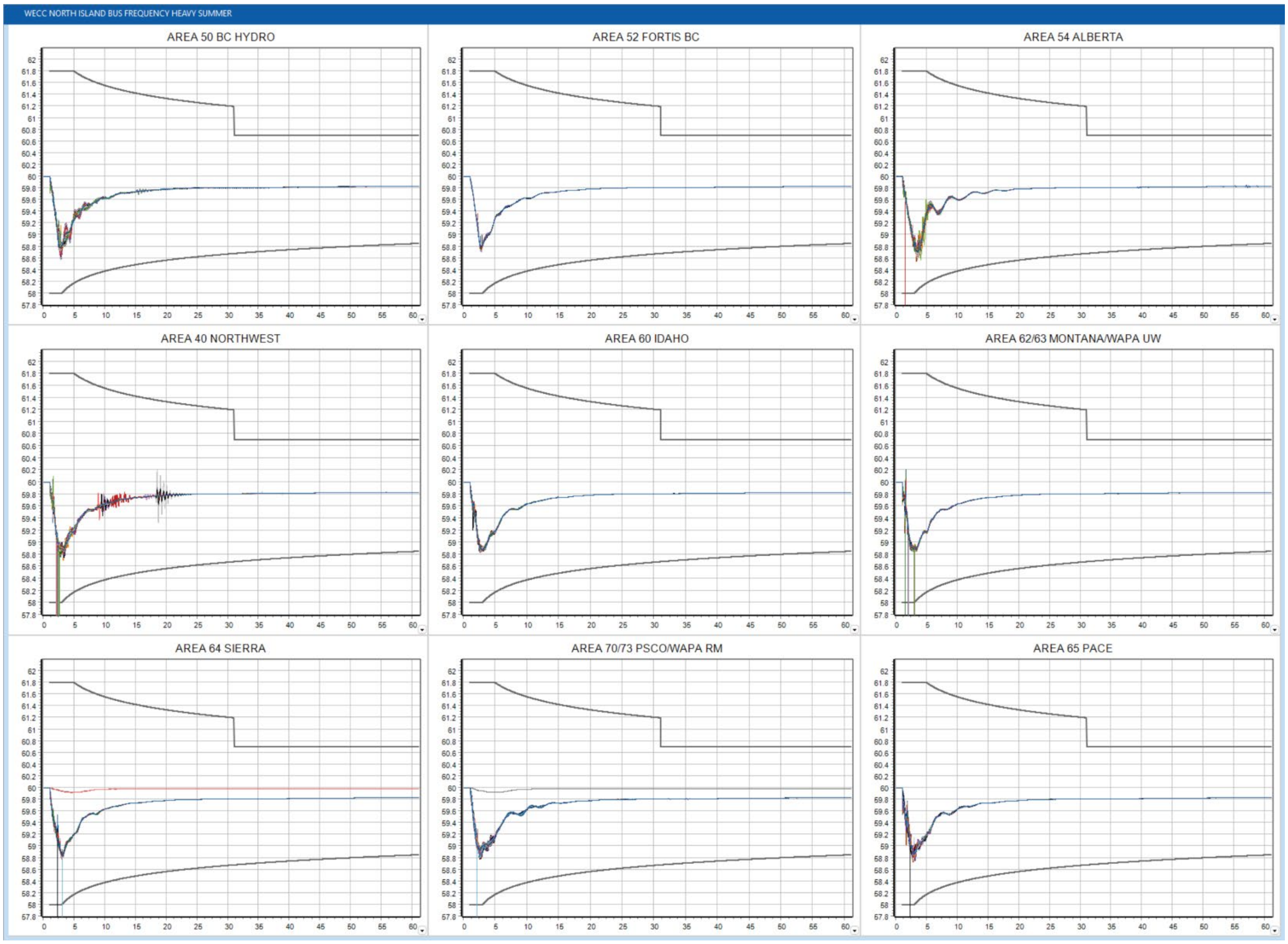
Figure A.4: State manual Control in PowerWorld

These islands are usually small and are created as part of different devices opening branches as part of their relay settings. Ignoring those islands should not have an impact on the overall study and is recommended because those small islands are already separated from the bigger island in which the frequency is studied, and the frequency of those small islands does not follow the overall frequency of the system.

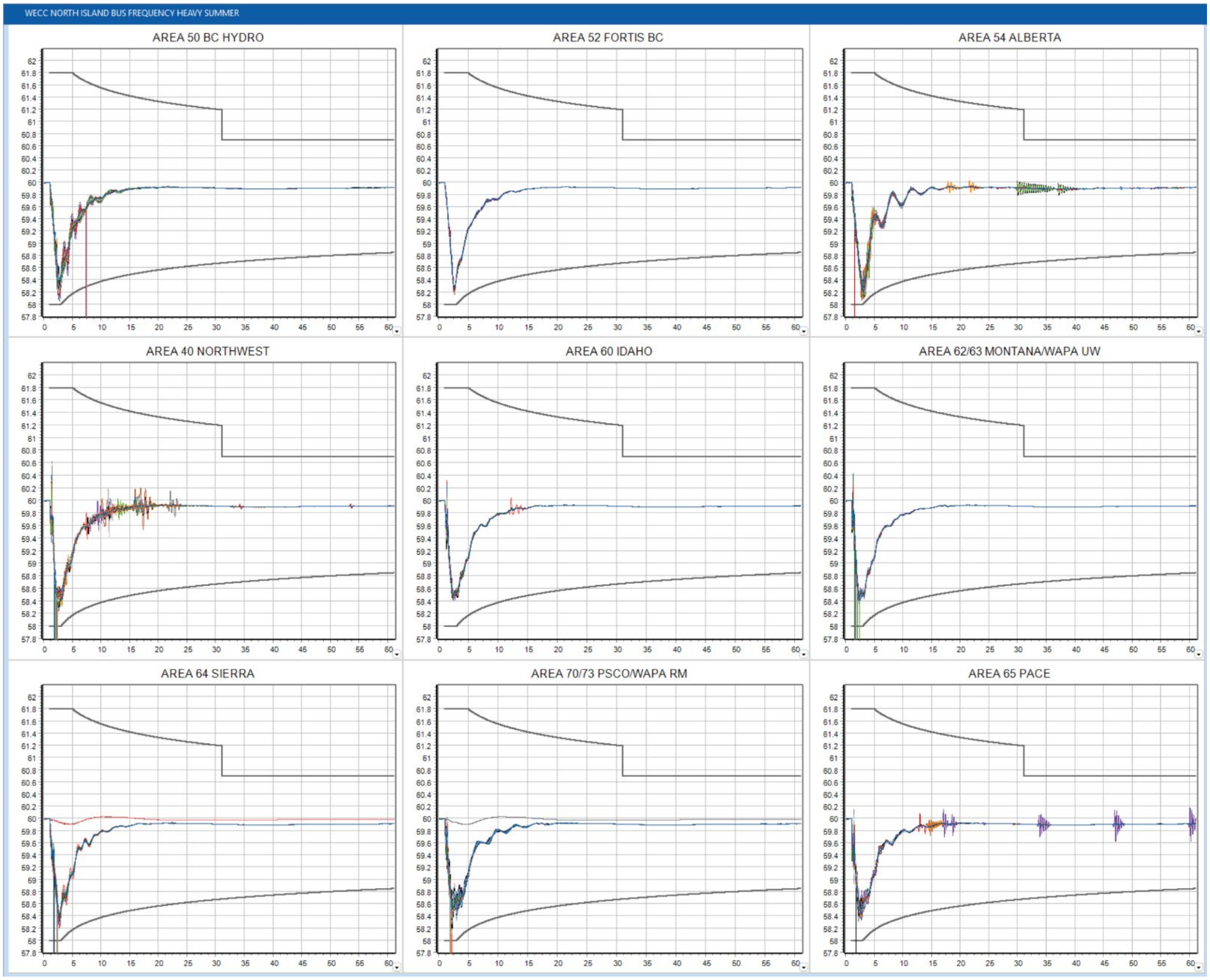
Appendix B — Frequency Performance — North Island

Note: In some plots, there are down spikes that appear to be violations. In reality, these spikes show that the frequency at that bus dropped to zero because the bus was disconnected as part of the simulations.

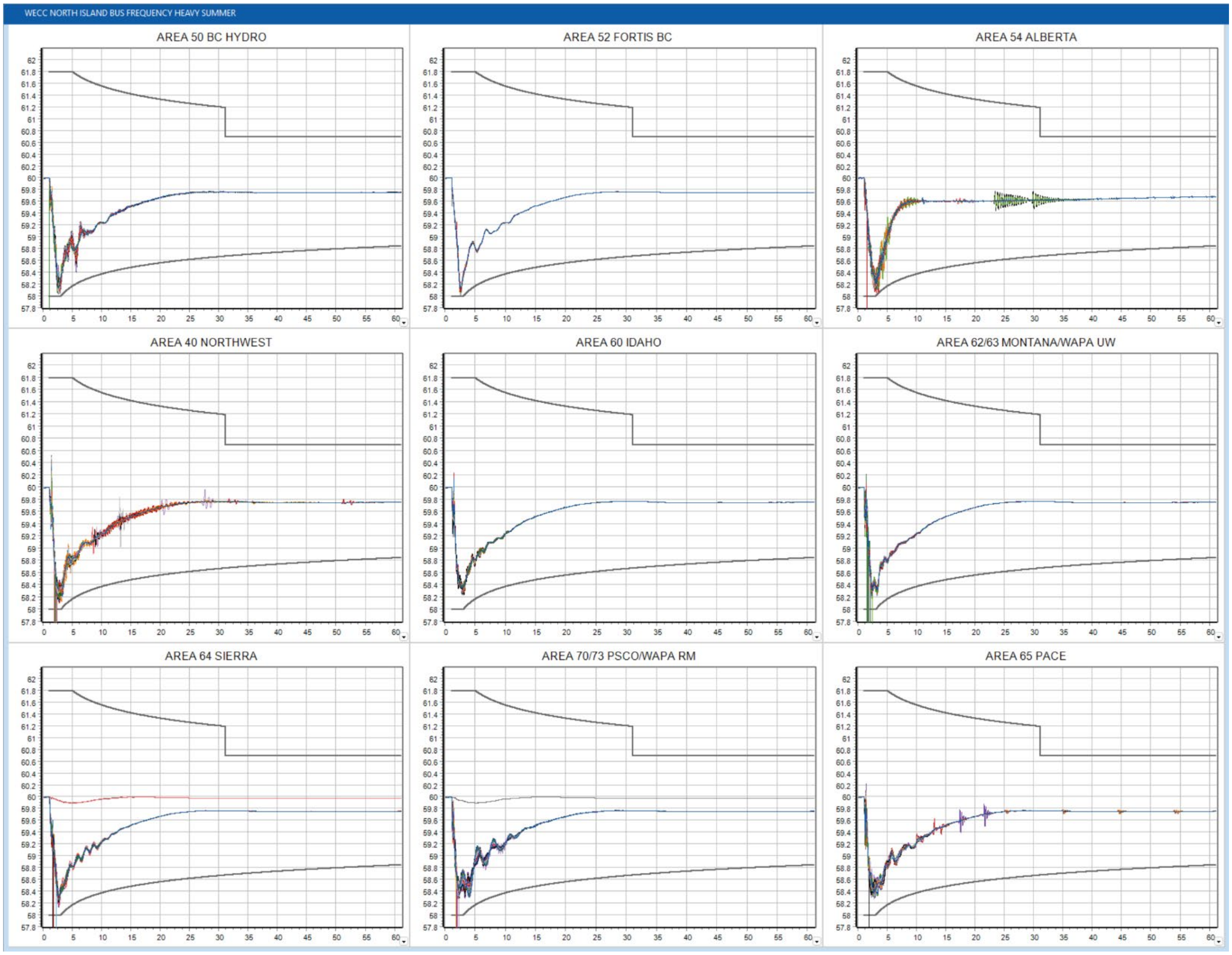
23HS4a1 — 10% Without Delay — North Island Frequency



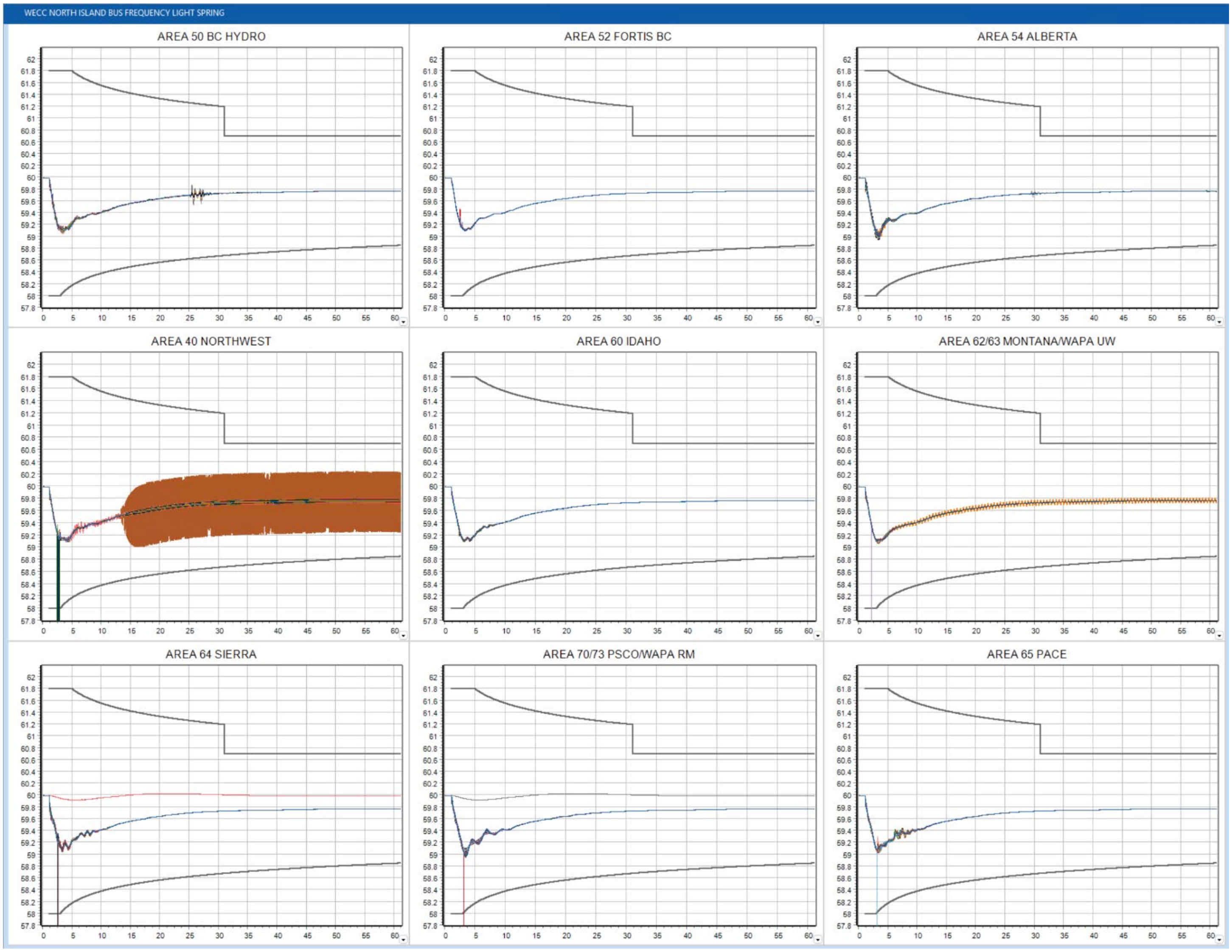
23HS4a1 — 20% With Delay — North Island Frequency



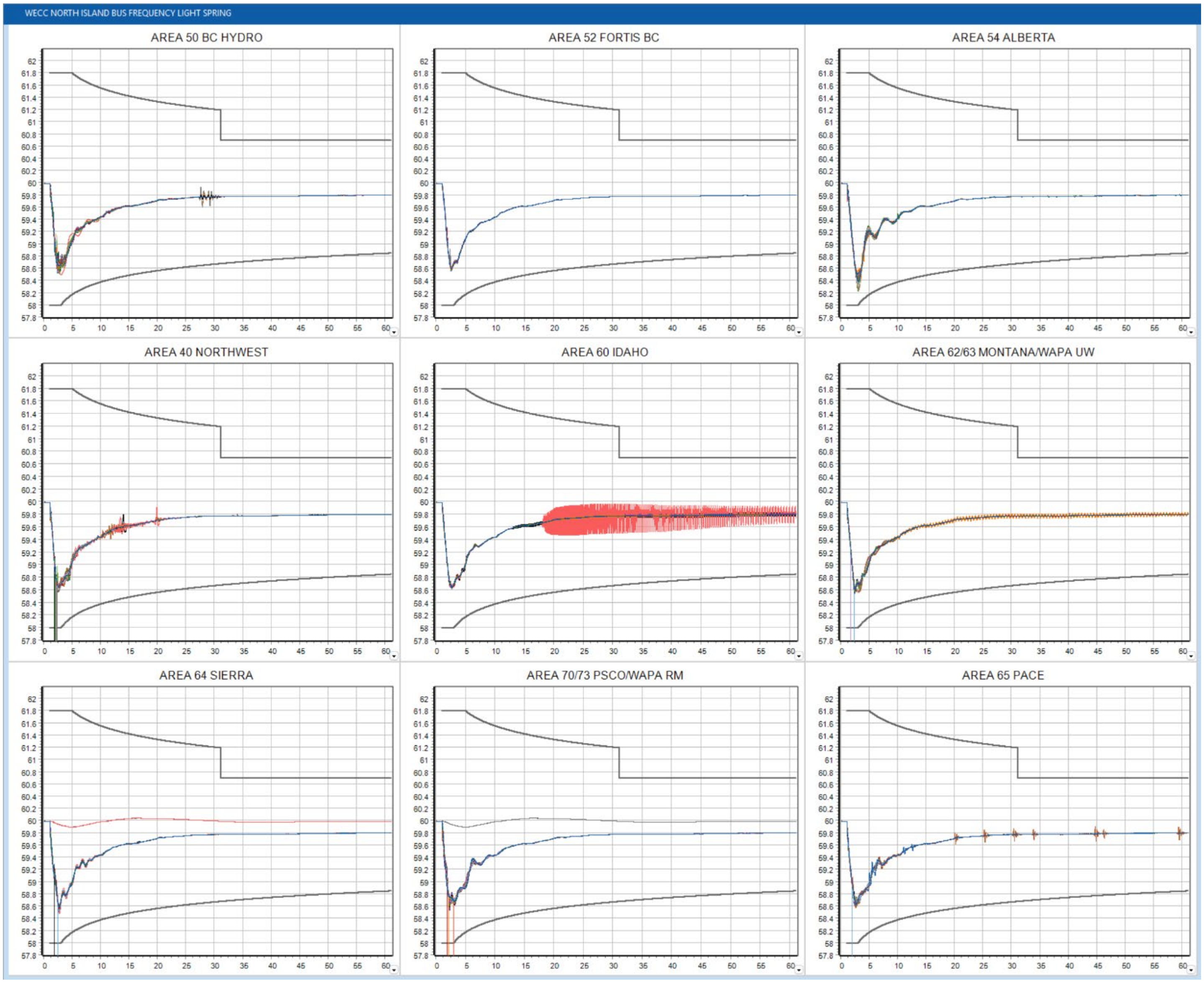
23HS4a1 — 25% With Delay — North Island Frequency



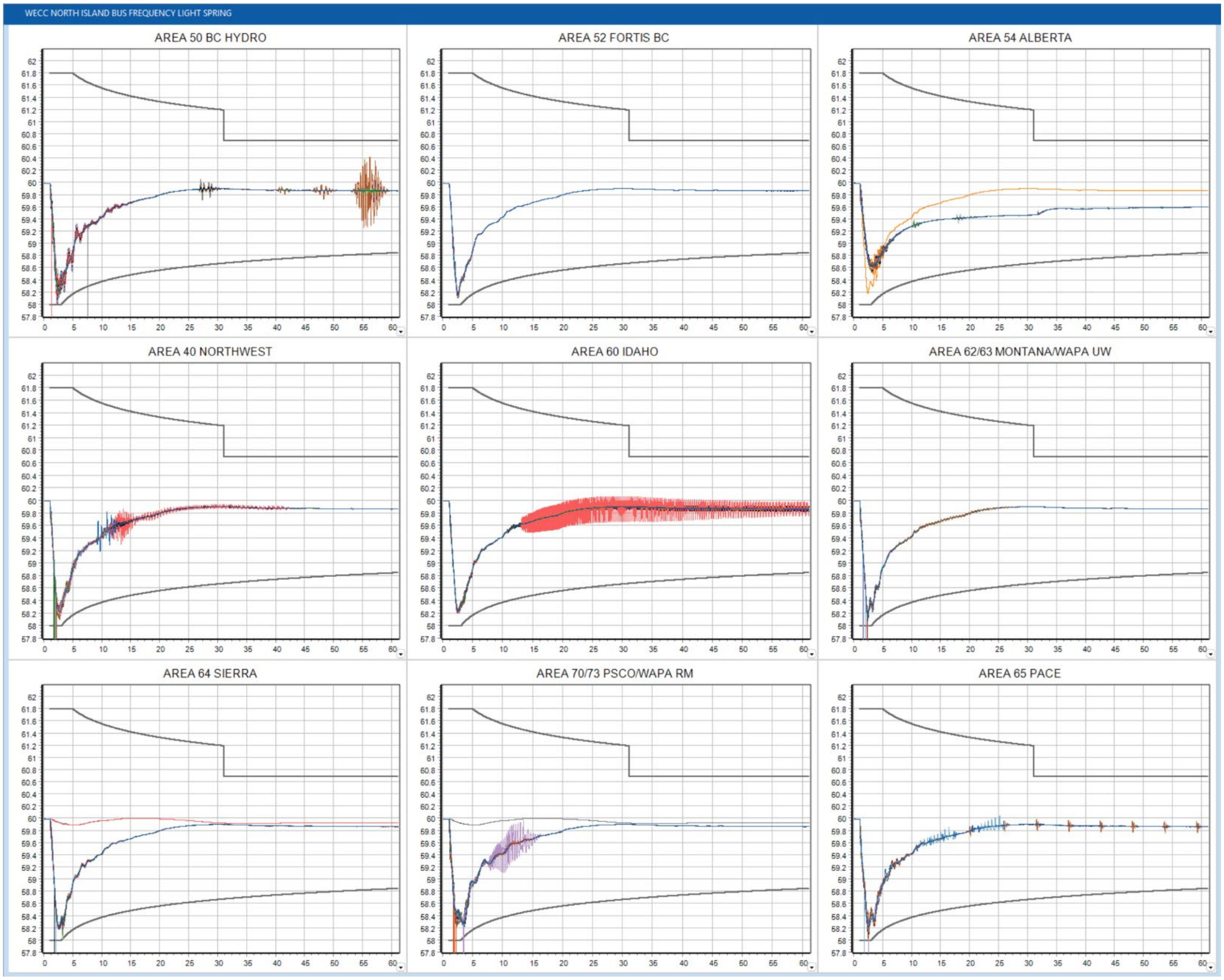
24LSP2 — 10% Without Delay — North Island Frequency



24LSP2 — 20% Without Delay — North Island Frequency



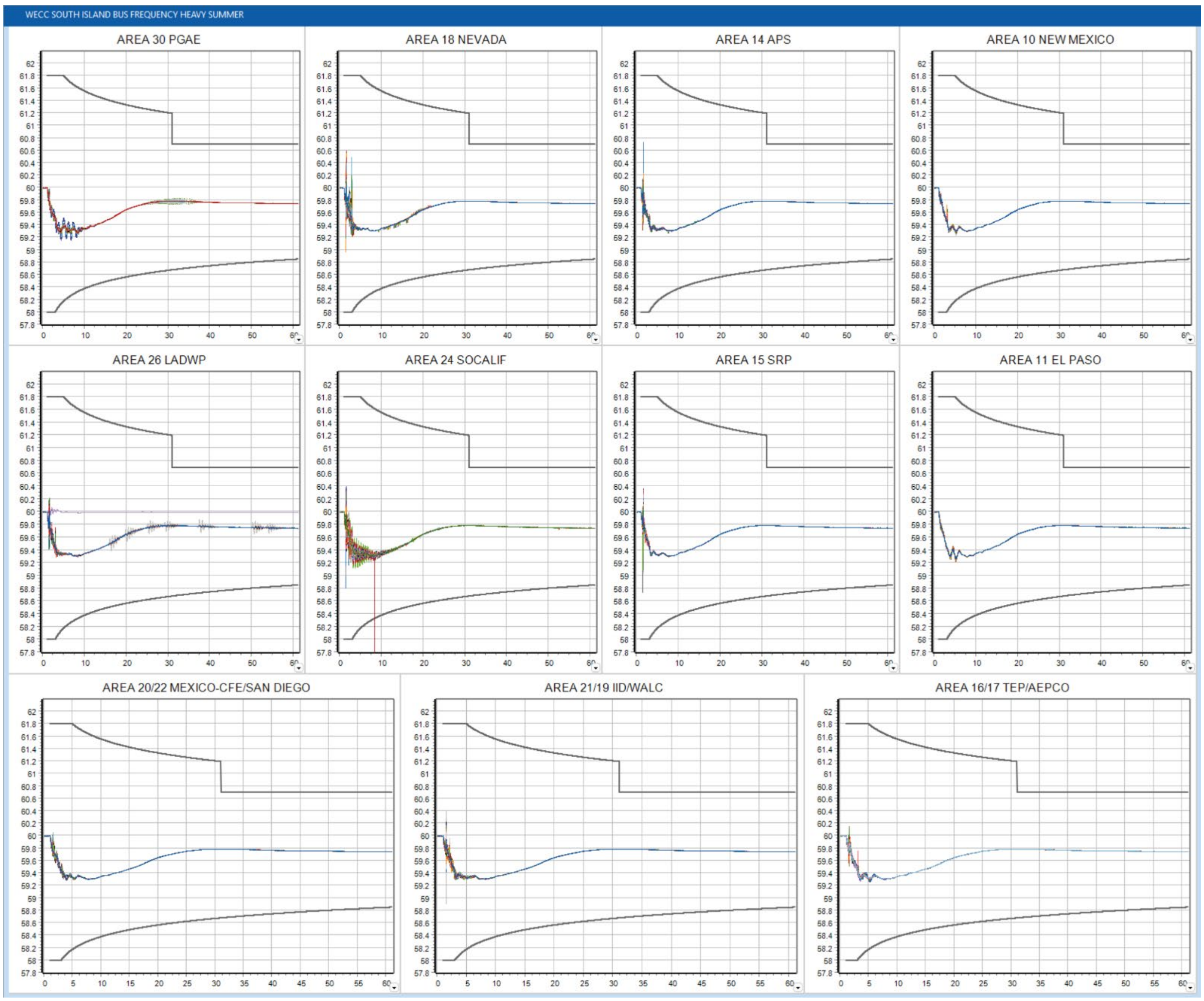
24LSP2 — 25% Without Delay — North Island Frequency



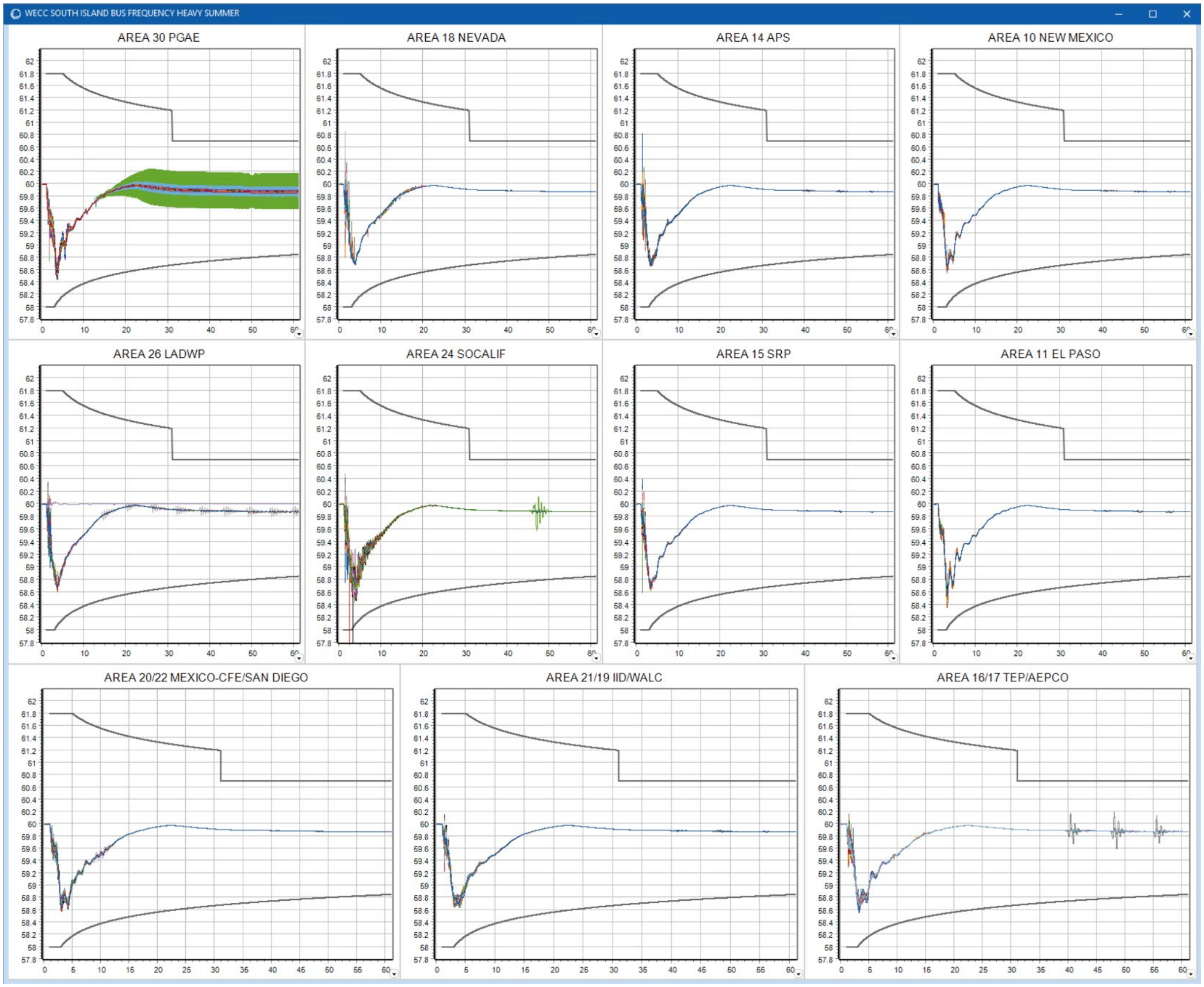
Appendix C — Frequency Performance — South Island

Note: In some plots, there are down “spikes” that appear to be violations. In reality, these spikes show that the frequency at that bus dropped to zero because the bus was disconnected as part of the simulations.

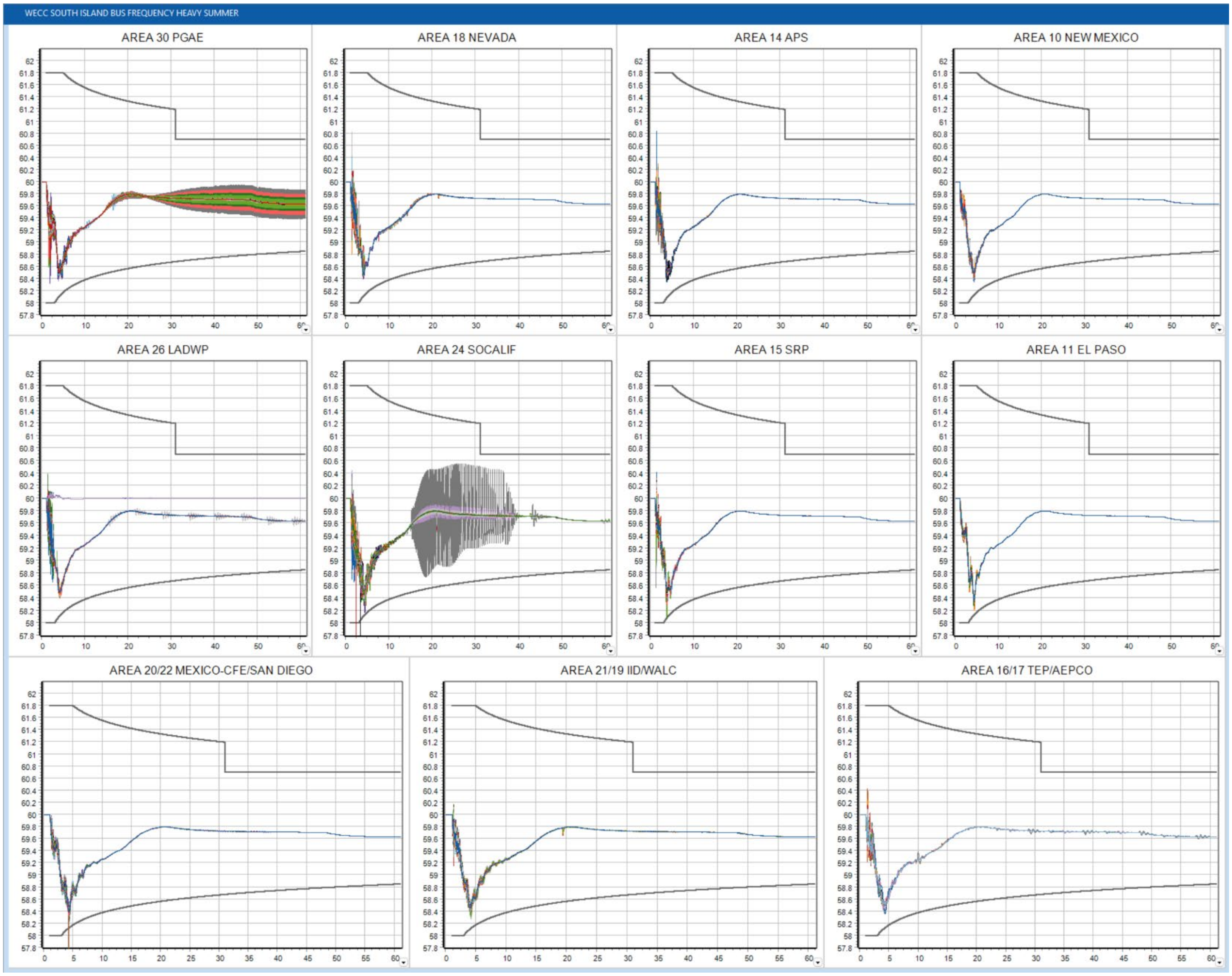
23HS4a1 — 10% Without Delay — South Island Frequency



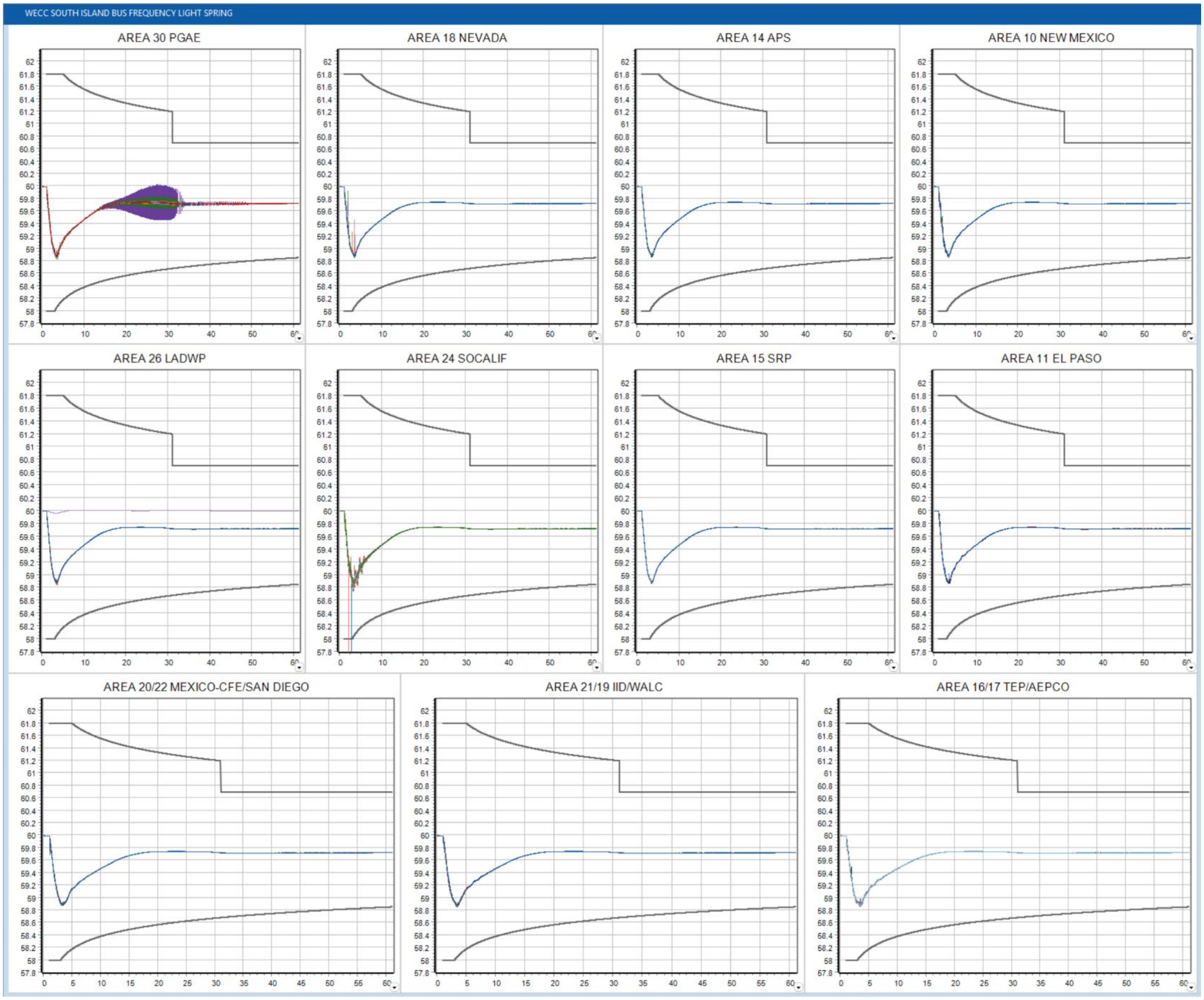
23HS4a1 — 20% With Delay — South Island Frequency



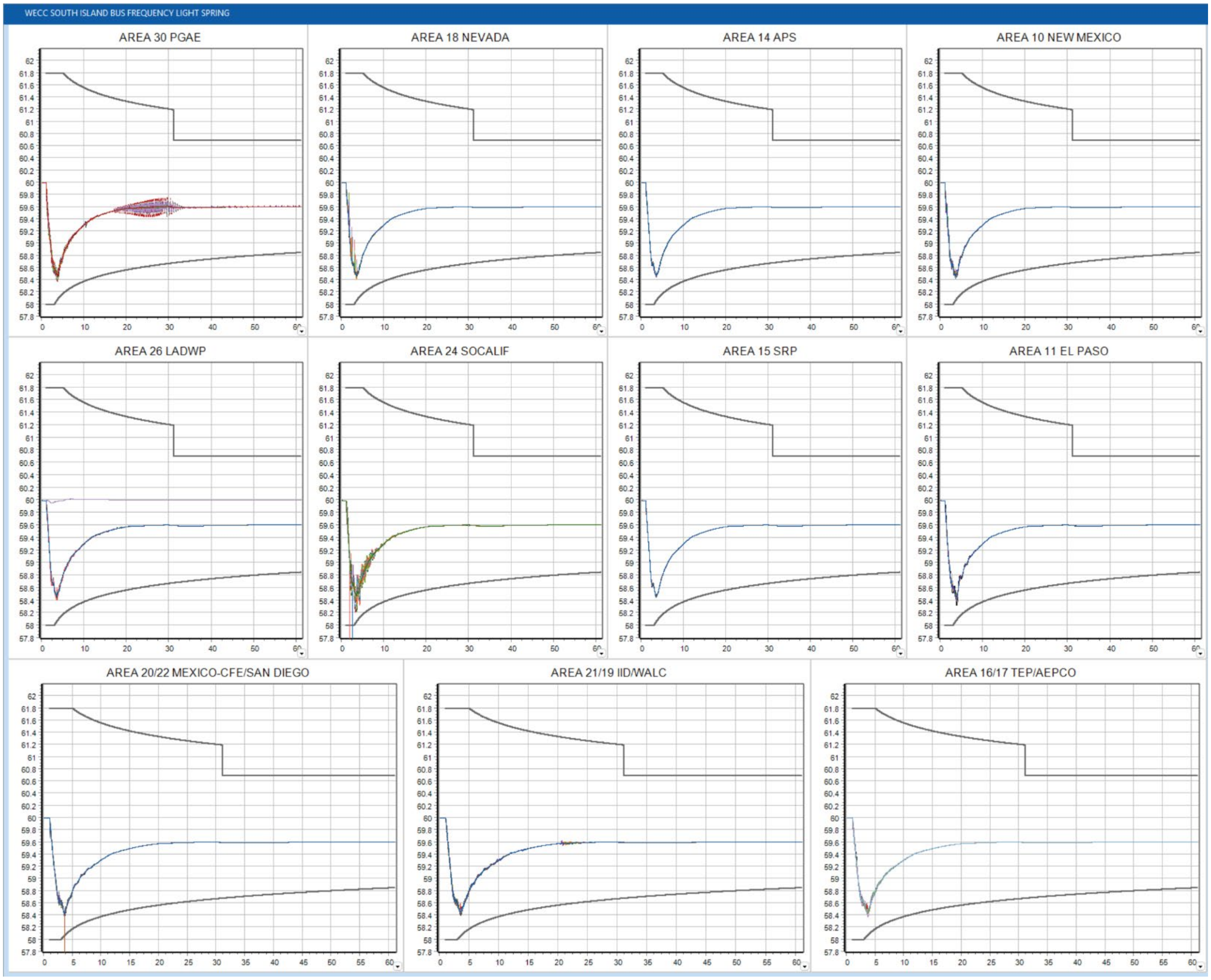
23HS4a1 — 25% With Delay — South Island Frequency



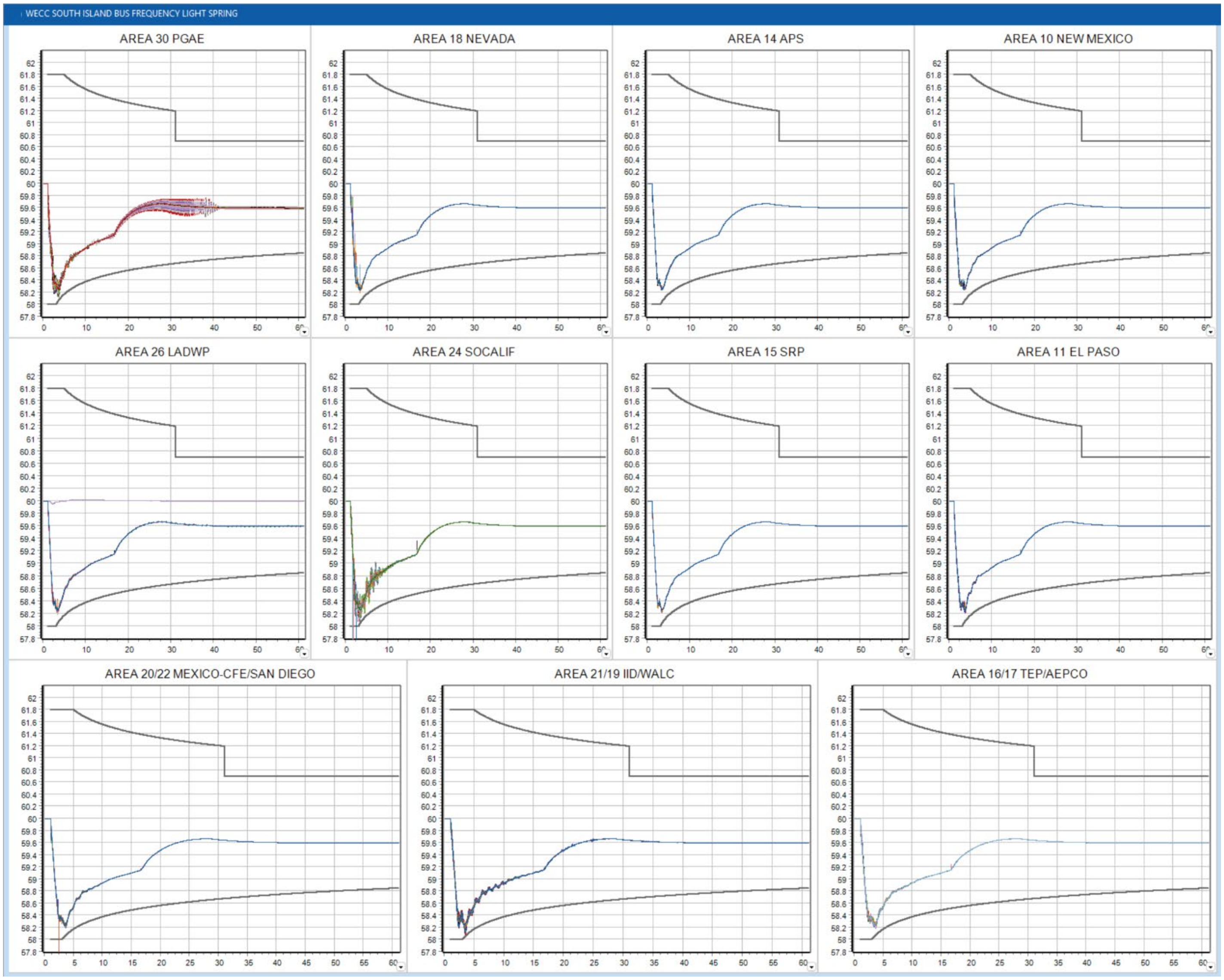
24LSP2 — 10% Without Delay — South Island Frequency



24LSP2 — 20% With Delay — South Island Frequency



24LSP2 — 25% With Delay — South Island Frequency



Appendix D — WECC Power Flow Areas

Area #	Area Name
South Island	
10	New Mexico
11	El Paso
14	APS
15	SRP
16	TEP
17	AEPCO
18	Nevada
19	WAPA L.C.
20	Mexico- CFE
21	IID
22	SDGE
24	So. Ca. Edison
26	LADWP
30	PG&E
North Island	
40	Northwest
50	B.C. Hydro
52	Fortis BC
54	Alberta
60	Idaho
62	Montana
63	WAPA U.W.
64	Sierra
65	PACE
70	PSCO
73	WAPA R.M.

Appendix E — WECC NE/SE Separation Scheme

The Western Interconnection is designed to detach into North and South AC islands as a result of the WECC-1 Remedial Action Scheme (RAS), which is triggered by loss of major tie lines between the two systems. RAS switching includes several sub-system schemes across multiple WECC regions. The DC lines across the RAS separation boundary were not expected to be tripped as part of this RAS action, so the created islands are AC islands joined by DC tie lines. RAS simulation actions were compiled from the WECC RASRS documentation, RC West files and documentation, and WECC base case RAS file definitions. Expected RAS actions include:

- Tripping of the remaining AC tie lines
- Generation dropping in the Pacific Northwest
- Generation dropping in British Columbia
- Chief Joseph dynamic brake insertion
- Fast switching of reactive devices along the AC Intertie for voltage support
- Drop pump loads in the Southwest RAS footprint
- Other minor switching

These actions are documented in case materials stored on the secure portion of the WECC UFLSWG team site.

Approximate WECC-1 RAS separation boundary.

Source: https://www.westernenergyboard.org/wp-content/uploads/2017/10/2017-09-29-WIRAB-RAS-Presentation-FINAL.pdf

Appendix F — Models Set to Not Active in Cases to Improve Results

AREA	BA	Owner	Generating Unit		Model Type	North Island Cases						South Island Cases					
						23 HS 10%	23 HS 20%	23 HS 25%	23 LSP2 10%	23 LSP2 20%	23 LSP2 25%	23 HS 10%	23 HS 20%	23 HS 25%	23 LSP2 10%	23 LSP2 20%	23 LSP2 25%
ALBERTA	AESO	AIES	554968 #G1	URS_LV1	GENTPJ				x	x	x						
			555968 #G2	URS_LV2	GENTPJ						x						
B.C.HYDRO	BCH	BCH IPP	80440 #1	CRW 13G1	GENROU				x	x	x						
			80752 #1	FGE 13	GENTPJ				x	x	x						
			80760 #1	MIG 13	GENTPJ	x	x	x	x	x	x						
			81089 #1	SWF .5W	REGC_A									x			
		BCH Ind. Load/Gen Customer	51140 #1	SEE 13G1	GENTPJ				x	x							
MEXICO-CFE	CENACE	CFE - Mexico	20912 #1	GEN-PID	GENROU										x	x	x
NORTHWEST	BPA	USACE-Walla Walla	44105 #5	MCNARY_05	GENTPJ	x	x	x									
			44108 #8	MCNARY_08	GENTPJ	x	x	x									
			44109 #9	MCNARY_09	GENTPJ	x	x	x									
			44110 #10	MCNARY_10	GENTPJ	x	x	x									
	PACW	PACW	45176 #1	FALL CRK	GENTPJ				x	x							
	GCPD	GCPD	46180 #1	WANAPM01	GENTPJ				x	x	x						
			46181 #2	WANAPM02	GENTPJ				x	x	x						
			46182 #3	WANAPM03	GENTPJ				x	x	x						
			46183 #4	WANAPM04	GENTPJ				x	x	x						
			46185 #6	WANAPM06	GENTPJ				x	x	x						
			46186 #7	WANAPM07	GENTPJ				x	x	x						
			46187 #8	WANAPM08	GENTPJ				x	x	x						
			46188 #9	WANAPM09	GENTPJ				x	x	x						
			46189 #A	WANAPM10	GENTPJ				x	x	x						
PG AND E	CAISO	PG&E customer	35050 #1	SLR-TANN	GENTPF							x	x		x	x	x
PSCOLORADO	PSCO	TSGT	70493 #ST	JMSHAFR2	GENTPJ	x	x	x									
SIERRA	NVE	SPP	64106 #1	STILLWTR-GEO	GENTPF	x	x	x									
SOCALIF	CAISO	MWD	25422 #1	ETI MWDG	GENTPJ							x	x				
		Non SCE Owned	29003 #1	HIDEDCT1	GENROU										x	x	x
WAPA U.W.	WAUW	USACE	631001 #1	FTPK-G1	GENTPJ	x	x	x	x	x	x						
			631002 #2	FTPK-G2	GENTPJ	x	x	x	x	x	x						
			631003 #3	FTPK-G3	GENTPJ	x	x	x	x	x	x						

South Island 23HS — 10%, 20%, 25% Cases:

DC Line	Rect Balancing Authority	Inv Balancing Authority	Rect Area	Inv Area	Model Type
DCTransmissionLine '41311' '26097' '1'	BPA	LADWP	NORTHWEST	LADWP	CHVDC2
DCTransmissionLine '41312' '26099' '1'	BPA	LADWP	NORTHWEST	LADWP	CHVDC2

Appendix G — Generation Trip Delays

G.1) South Island Delay

On first pass, voltage and frequency issues were observed in the South Island imbalance simulations. These issues were most pronounced in the results of the South Island 20% and 25% generation imbalance contingencies. When these contingencies were simulated for 60 seconds, voltage instability was apparent when plotting voltage deviation.

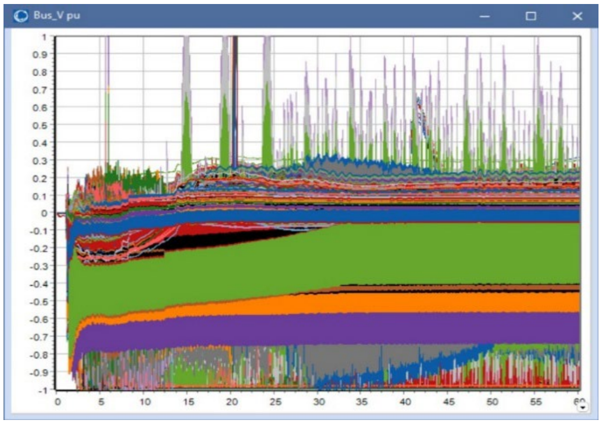


Figure G.1: Voltage Deviation from South Island 25% Imbalanced Generation

While plotting the average frequency of all the areas in the case, the PG&E area frequency appeared to deviate significantly compared to the rest of the South Island areas:

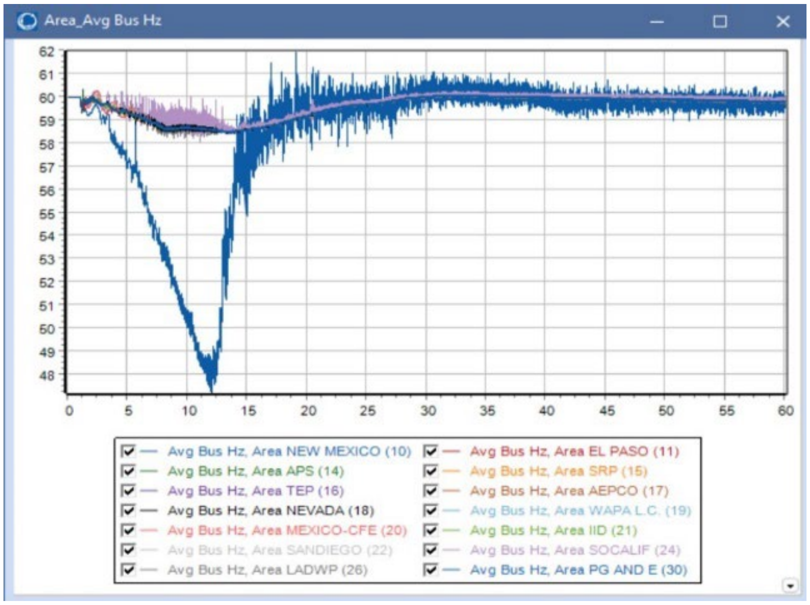


Figure G.2: Solution Details in PowerWorld

This prompted an exploration of what could be done within the contingency definitions to resolve the issues. Rather than opening all generators in the contingency simultaneously, adding short delays to a portion of the generators being opened in the imbalance definition represented a more realistic scenario.

This frequency issues occurred the moment the contingency was applied at one second. A rerun of the contingency was performed by adding a delay for the opening of the generators used for the imbalance in area PG&E. The results were greatly improved and all the simulations that were previously not running 60 seconds finished their simulations:

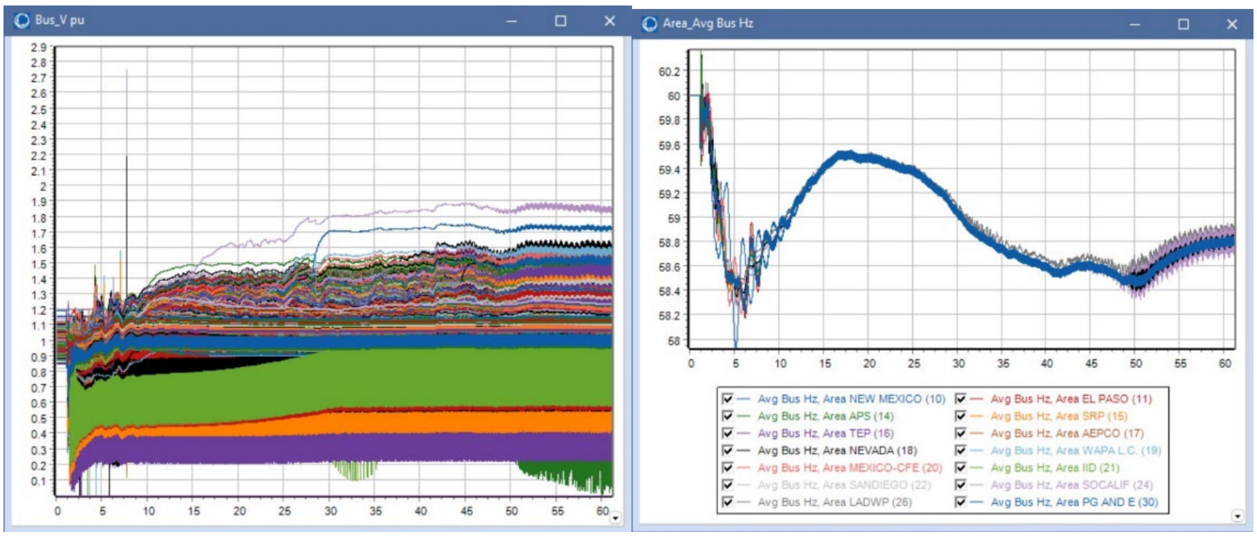


Figure G.3: Voltages and Average frequency after PG&E Delays

G.2) Plotting All frequencies to Identify Area Problems

In certain areas, there were issues during the initial transient period. The frequencies were dipping below the desired thresholds. The best way to see those issues was by plotting all the bus frequencies in the areas. As part of each individual area plots, there is also a plot of the underfrequency and overfrequency performance characteristic threshold curves as defined in the PRC-006-5 Attachment 1. This helps identify which buses are not following the required frequency thresholds for the study.

As an example, below is a plot of the frequencies from the North Island for the first seven seconds of the 25% Heavy Summer (2023 HS4a1) North Island scenario:

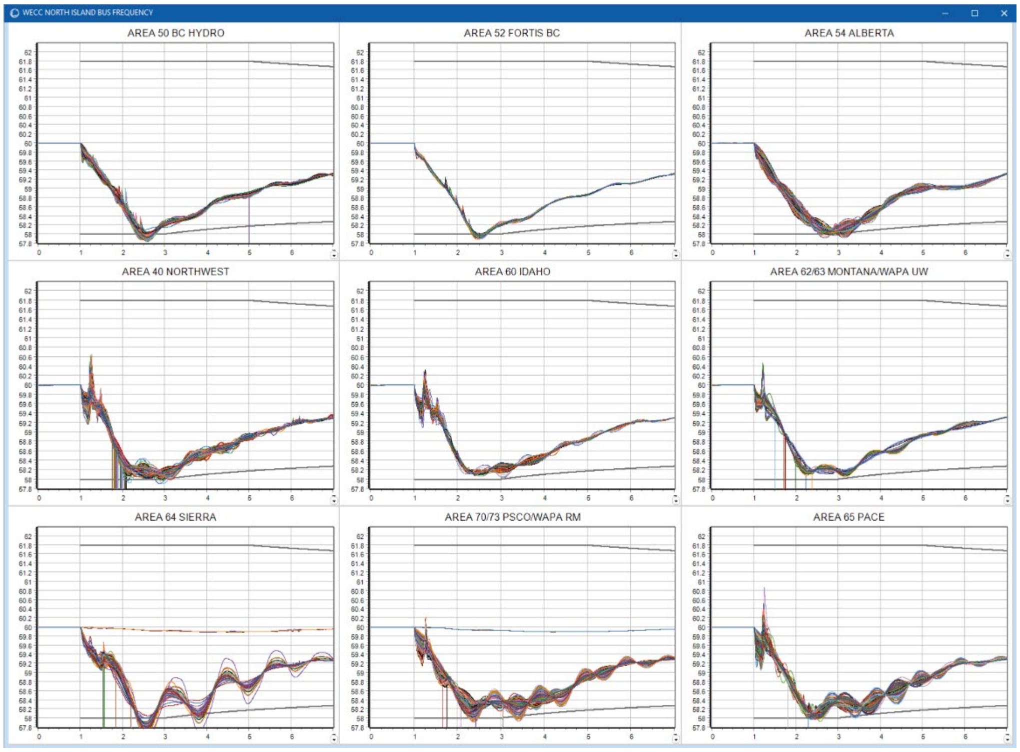


Figure G.4: Frequency response for North Island 25% Heavy Summer Simulation

In Figure G.4, as can be seen, certain areas dip below the thresholds for underfrequency. A rerun of the contingency was performed by implementing delays in certain generators that were part of the imbalance for those areas. The process requires some trial and error, but it was found that delaying the opening of certain generators improved the simulation. This process was repeated for each of the areas with frequency problems until a successful simulation was found.

G.3) Look at Undervoltage Reconnections for Composite Loads

As part of the debugging process to fix the underfrequency issues seen in the scenarios, the load voltage tripping was investigated. Since most of the under frequencies occurred during the initial transient period, the tripping of devices was looked at during that time. Analyzing the results showed that certain motors that were part of the composite load (CMPLDW) models were tripping because of under voltages but also reconnecting during that same period once the voltage recovered to acceptable levels for the under voltages relays.

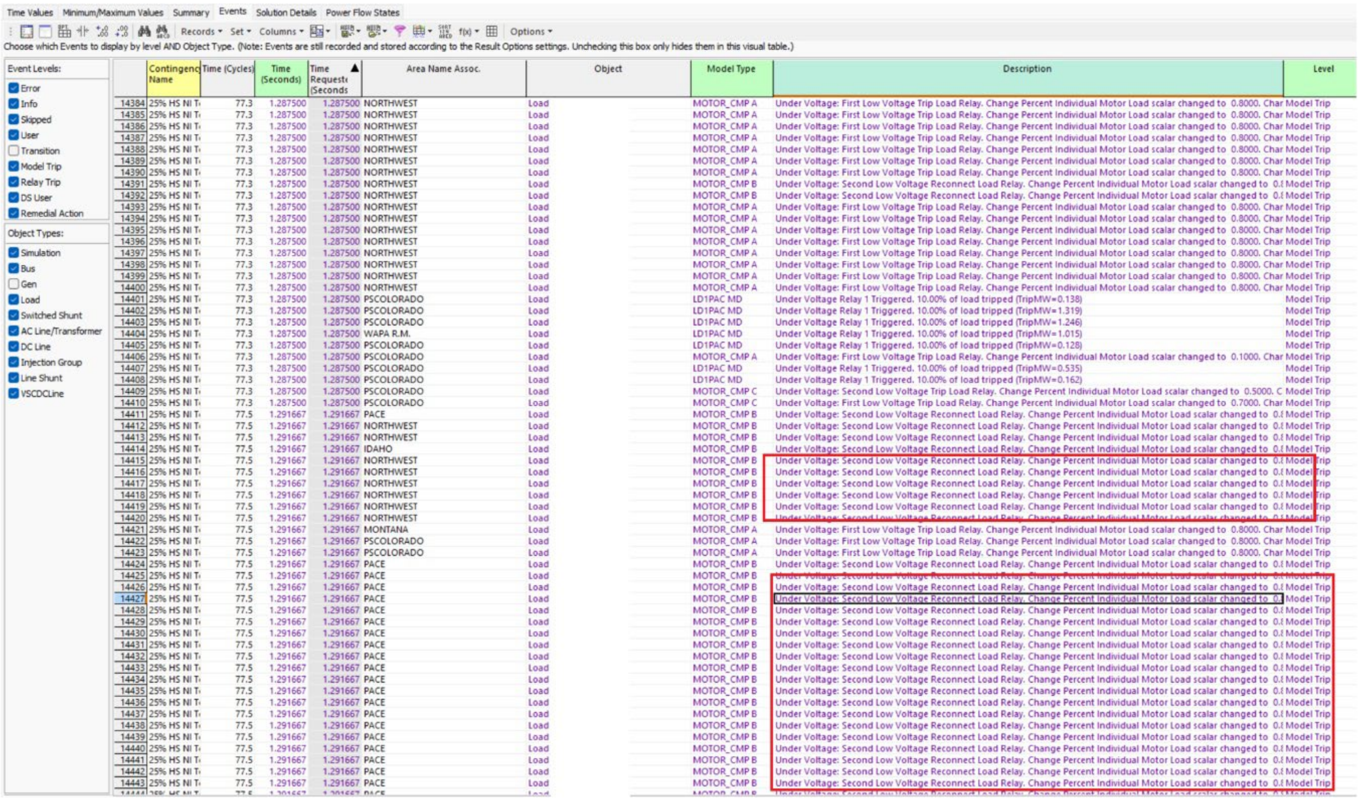


Figure G.5: Load Event messages during the North Island 25% Heavy Summer (2023 HS4a1) Simulation

As shown in Figure G.5, the motors were reconnecting load during the transient period. During that period it is important to trip load to fix the underfrequency of the system, but the composite load models were doing the opposite. This undermines the underfrequency response needed to achieve the desired frequency levels for the study. In Figure G.6, the frequency response for the North Island 25% heavy summer imbalance is shown, and there are multiple areas with underfrequency responses.

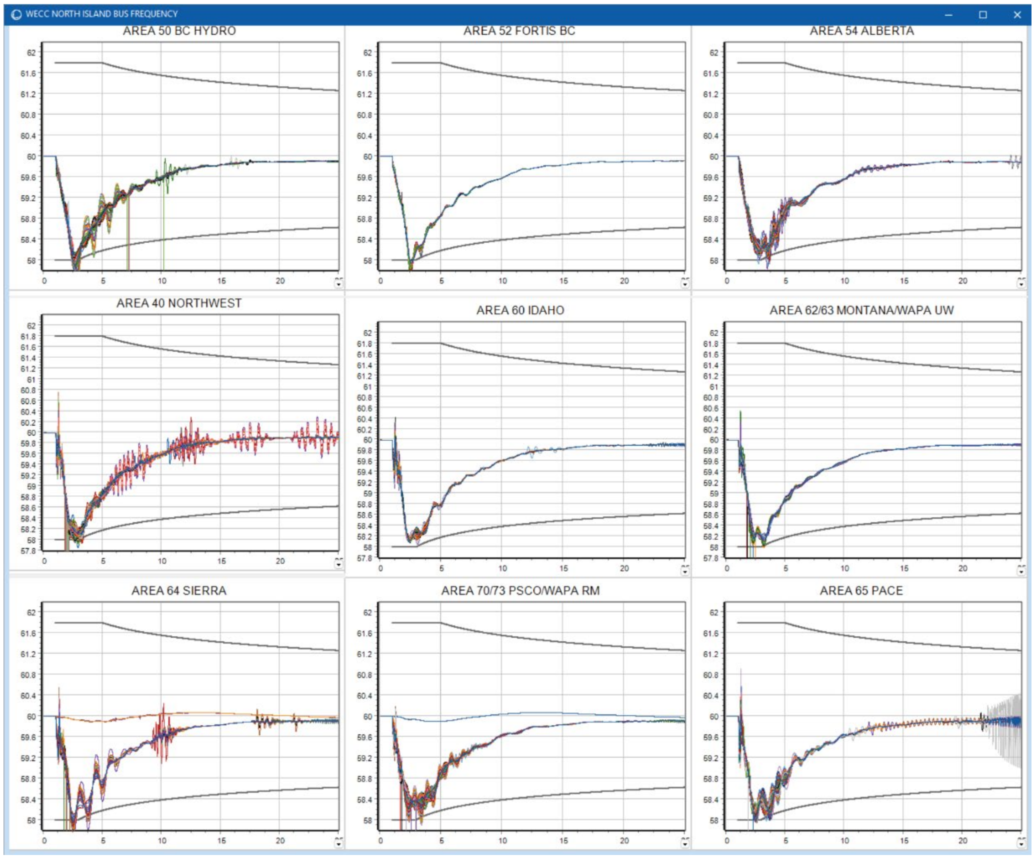


Figure G.6: Frequency response for North Island 25% Heavy Summer Simulation 25 Seconds

A simple test was done by identifying the areas with most of the reconnections and modifying the reconnect timers of some of the composite load models associated with those areas. For example, below is a table of changes done on the load reconnection timers during the test. The format of the parameters is change/original value.

<table>
<tr><th></th><th>Element Type</th><th>ID</th><th>Type</th><th>Trc2a_Tth</th><th>Vrc1b_Vtr2b</th><th>Trc1b_Ttr2b</th><th>Vrc2b_Vc2onb</th><th>Trc2b_Tthb</th><th>Trc2c_Tthc</th></tr>
<tr><td>1</td><td>LoadModelGroup</td><td>DSW_MIX</td><td>CMPLDWNF</td><td>2|0.1</td><td></td><td>999|0.05</td><td></td><td>2|0.05</td><td>2|0.1</td></tr>
<tr><td>2</td><td>LoadModelGroup</td><td>HID_COM</td><td>CMPLDWNF</td><td>2|0.1</td><td>1|0.75</td><td>999|0.05</td><td>0.8|0.65</td><td>2|0.05</td><td>2|0.1</td></tr>
<tr><td>3</td><td>LoadModelGroup</td><td>HID_MIX</td><td>CMPLDWNF</td><td>2|0.1</td><td>1|0.75</td><td>999|0.05</td><td>0.8|0.65</td><td>2|0.05</td><td>2|0.1</td></tr>
<tr><td>4</td><td>LoadModelGroup</td><td>HID_RAG</td><td>CMPLDWNF</td><td>2|0.1</td><td>1|0.75</td><td>999|0.05</td><td>0.8|0.65</td><td>2|0.05</td><td>2|0.1</td></tr>
<tr><td>5</td><td>LoadModelGroup</td><td>HID_RES</td><td>CMPLDWNF</td><td>2|0.1</td><td>1|0.75</td><td>999|0.05</td><td>0.8|0.65</td><td>2|0.05</td><td>2|0.1</td></tr>
<tr><td>6</td><td>LoadModelGroup</td><td>NWC_COM</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>7</td><td>LoadModelGroup</td><td>NWC_MIX</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>8</td><td>LoadModelGroup</td><td>NWC_RAG</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>9</td><td>LoadModelGroup</td><td>NWC_RES</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>10</td><td>LoadModelGroup</td><td>NWI_COM</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>11</td><td>LoadModelGroup</td><td>NWI_MIX</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>12</td><td>LoadModelGroup</td><td>NWI_RAG</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>13</td><td>LoadModelGroup</td><td>NWI_RES</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>14</td><td>LoadModelGroup</td><td>NWV_COM</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>15</td><td>LoadModelGroup</td><td>NWV_MIX</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>16</td><td>LoadModelGroup</td><td>NWV_RAG</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>17</td><td>LoadModelGroup</td><td>NWV_RES</td><td>CMPLDWNF</td><td>0.75|0.1</td><td></td><td>0.75|0.05</td><td></td><td>0.75|0.05</td><td>0.75|0.1</td></tr>
<tr><td>18</td><td>LoadModelGroup</td><td>RMN_COM</td><td>CMPLDWNF</td><td>1|0.1</td><td></td><td>1|0.05</td><td></td><td>0.75|0.05</td><td>1|0.1</td></tr>
<tr><td>19</td><td>LoadModelGroup</td><td>RMN_MIX</td><td>CMPLDWNF</td><td>1|0.1</td><td></td><td>1|0.05</td><td></td><td>1|0.05</td><td>1|0.1</td></tr>
<tr><td>20</td><td>LoadModelGroup</td><td>RMN_RAG</td><td>CMPLDWNF</td><td>1|0.1</td><td></td><td>1|0.05</td><td></td><td>1|0.05</td><td>1|0.1</td></tr>
<tr><td>21</td><td>LoadModelGroup</td><td>RMN_RES</td><td>CMPLDWNF</td><td>1|0.1</td><td></td><td>1|0.05</td><td></td><td>1|0.05</td><td>1|0.1</td></tr>
</table>

Figure G.7: Reconnection times changes in some composite load models groups.

The new plots, after the composite load models were modified, are shown in Figure G.8, and the areas are now above the underfrequency threshold.

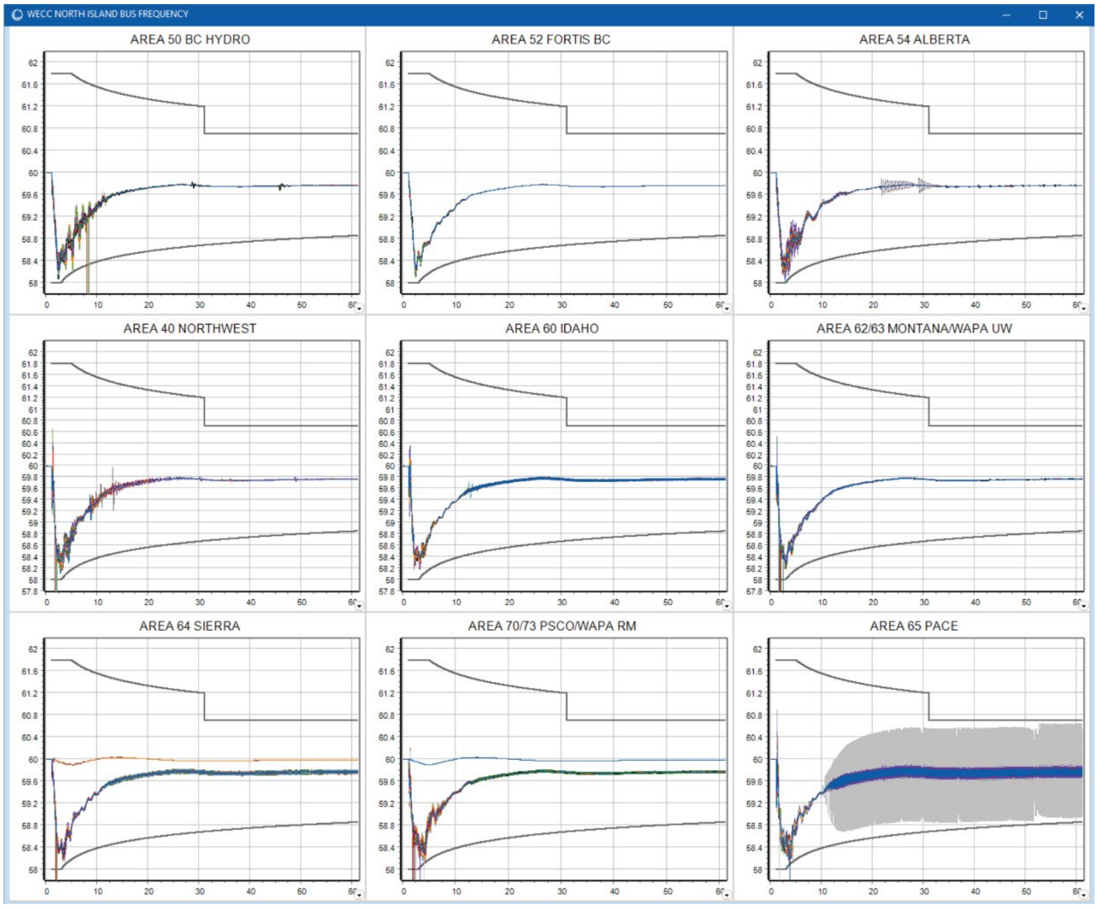


Figure G.8: Frequency response for North Island 25% Heavy Summer After Comp Load modifications, 60 Seconds

With the composite load test study, we can identify areas that might cause problems for the frequency response. In the scenarios studied for this assessment, the composite loads reconnection timers were not modified but the information provided by the reconnection events was used in conjunction with the results shown in topic G.1 and G.2 of this section. After assessing all the information obtained from these results the following delays were found to be useful and were applied to some of the scenarios. The areas that read “Some Gens,” mean the imbalance delay was not applied to all the gens in the area, only to some of the gens that were part of the imbalance for that area. The list of those “Some Gens” generators can be found in Table G.2.

The delays are shown in Table G.1:

Table G.1: Cases with Delay

Case with Delay	Area	Delay Time (Seconds)
North Island 2023HS4a1 - 25%	NORTHWEST (Some Gens)	3
	PSCOLORADO (Some Gens)	2.25
	PACE (Some Gens)	1.25
	IDAHO (Some Gens)	0.75
	ALBERTA (Some Gens)	0.5
North Island 2023HS4a1 - 20%	ALBERTA (Some Gens)	0.5
South Island 2023HS4a1 - 25%	SOCALIF	2
	EL PASO (Some Gens)	2
	SOCALIF (Some Gens)	2.25
	PG & E (Some Gens)	3
South Island 2023HS4a1 - 20%	SOCALIF	1.75
	SOCALIF (Some Gens)	0
North Island 2024LSP2sa1 - 25%	SIERRA	2
South Island 2024LSP2sa1 - 25%	SOCALIF	1.75
	SOCALIF (Some Gens)	0
South Island 2024LSP2sa1 - 20%	SOCALIF	1.75

Table G.2: Some Gens with Delay in addition to the Areas shown in Table G.1

AREA	BA	Owner	Generating Unit		North Island 23HS 20%	North Island 23HS 25%	South Island 23HS 20%	South Island 23HS 25%	South Island 24LSP2 25%
ALBERTA	AESO	AIES	54712 #3	CMH 3R 9	x	x			
			55035 #4	RBW 4		x			
			55171 #1	VALLEYG1	x	x			
			557709 #17	CMH17_2					
			560894 #G1	CLARESHOLM1	x				
			567031 #G1	WINDRISE1					
			56990 #G1	SHAMROC5		x			
			57516 #G3	CB_GTG3	x				
			58290 #2	BALZ 1&2	x	x			
			58831 #G1	SEDALIA6		x			
			58832 #G2	SEDALIA7		x			
			59223 #G4	TAR-GN-2		x			
			59290 #1	BALZ 3		x			
			59746 #1	BSR_4		x			
			59935 #G2	HALKIRK6		x			
NORTHWEST	AVA	Wheelabrator Spokane Inc.	48407 #1	SPKWASTE		x			
	BPA	AVRN	47389 #Z1	JNPER_CAN_W1		x			
			47391 #1	BRICKOVEN					
			47489 #Z1	GOLDH W1		x			
			47799 #Z1	BIGHORN_W3		x			
			47974 #Z1	HCAYN W1		x			
		BPA	402010 #1	CHANDLER		x			
			40277 #C1	COSMOPLS					
			40277 #S1	COSMOPLS		x			
		Caithness	47455 #Z1	N_HRLBRT_W2		x			
		Cannon Power	47937 #Z1	WNDY_FLT_W1		x			
		Condon Wind	47989 #Z1	CONDN W1		x			
		Cowlitz PUD	474412 #1	CHEM#2		x			
		Energy Northwest	47948 #Z1	9CANY W1		x			
			47952 #Z1	9CANY W2		x			
			47956 #Z1	9CANY W3		x			
		EWEB	46268 #1	WEYCO 4		x			
		Eurus Energy Amer.	47805 #Z1	CMBNE_HIL_W2		x			
		Flathead Elec.	47359 #1	LION_MTN+		x			
		Harvest Wind LLC	47981 #Z1	HARVEST_W1		x			
		NewSun Energy	412681 #1	TYGH_VALLEY					
			412681 #2	TYGH_VALLEY					
		NextEra Energy	47607 #2	BLUERDG2_G2					
			47944 #Z1	VANSY W1		x			
		Nippon Dynawave Packaging (NDP)	474415 #1	CHEM#5		x			
		N. Pacific Paper	474414 #1	CHEM#4		x			
		PSE	47879 #Z1	HOPKR W2		x			
		SCPA	47384 #Z1	LINDEN W		x			
		TID	47939 #Z1	TUOLUMNE_W1		x			
			47940 #Z2	TUOLUMNE_W2		x			
		USACE-Portland	40484 #1	GREEN PT		x			
			41213 #2	HILLS CR		x			
			41304 #2	COUGAR PH		x			
			41306 #1	LOST CRK		x			
			44009 #F2	BONVILE_1718		x			
			44052 #F1	T_DALES_F1F3		x			
			44271 #1	LOKOUT_PT_01		x			
			44272 #2	LOKOUT_PT_02		x			
			44273 #3	LOKOUT_PT_03		x			
		USACE-Seattle	40030 #2	ALBENI F2		x			
		WestRock CP, LLC	47446 #7	LVF89		x			
			47447 #4	LVF23		x			

AREA	BA	Owner	Generating Unit		North Island 23HS 20%	North Island 23HS 25%	South Island 23HS 20%	South Island 23HS 25%	South Island 24LSP2 25%
			47448 #6	LVF22		x			
		White Creek Wind I	47907 #Z2	WHTCK W2		x			
	PACW	PACW	44585 #1	MILCN SLR L		x			
			45022 #1	BEND GEN		x			
			45138 #1	CULVER					
			45340 #1	MERWIN 1		x			
			45342 #1	MERWIN 2		x			
	PGE	PGE	43017 #1	BEAVER		x			
			43017 #2	BEAVER		x			
			43022 #3	BEAVER2		x			
			43022 #4	BEAVER2		x			
			43023 #5	BEAVER3		x			
			43023 #6	BEAVER3		x			
			43189 #1	FARADAY		x			
			43359 #1	NORTH FK		x			
			43359 #2	NORTH FK		x			
			43368 #1	OAKGROVE1		x			
			43369 #2	OAKGROVE		x			
			43378 #1	COVANGEN		x			
			43425 #1	PTLBRUN1		x			
			43465 #3	RIVRMILL		x			
			43466 #4	RIVRMILL2		x			
			43466 #5	RIVRMILL2		x			
			43910 #1	PORTW2A		x			
			43910 #2	PORTW2A		x			
			43910 #3	PORTW2A		x			
			43911 #4	PORTW2B		x			
			43911 #5	PORTW2B		x			
			43911 #6	PORTW2B		x			
			43913 #7	PORTW2C		x			
			43913 #8	PORTW2C		x			
			43913 #9	PORTW2C		x			
			43914 #10	PORTW2D		x			
			43914 #11	PORTW2D		x			
			43914 #12	PORTW2D		x			
	PSE	PSE	42022 #L	SUMAS L		x			
			42114 #3	FREDONA3		x			
			42115 #4	FREDONA4		x			
			42128 #1	KOMO K		x			
			42336 #7	SNOQPWR2		x			
			42341 #2	TWINFALL		x			
	TPWR	TPWR	46617 #2	N_FORK		x			
			46624 #2	MAYFILD2		x			
			46624 #3	MAYFILD2		x			
			46672 #1	ALDER2		x			
			46789 #1	CUSHMN11		x			
			46790 #2	CUSHMN12		x			
			46792 #1	WYNOOCHE		x			
			46911 #1	CUSHMN31		x			
			46912 #2	CUSHMN32		x			
IDAHO	**IPCO**	Exelon Wind	60417 #1	HIGHMESA		x			
		IPC	60025 #2	AMFLS		x			
			60036 #1	BLISS 1		x			
			60041 #1	BOBN-34.5		x			
			60065 #1	BOMT_138					
			60116 #1	SHSNFALS		x			
			60120 #NT	DALE					
			602451 #1	MLNR-34.5_1		x			
			602452 #2	MLNR-34.5_2		x			

AREA	BA	Owner	Generating Unit		North Island 23HS 20%	North Island 23HS 25%	South Island 23HS 20%	South Island 23HS 25%	South Island 24LSP2 25%
			602453 #3	MLNR-34.5_3		x			
			60246 #1	MILNER		x			
			60246 #2	MILNER		x			
			60261 #1	ONTO-12.5		x			
			60276 #1	OXBOW1-2		x			
			60276 #2	OXBOW1-2		x			
			602841 #1	HZNA-4.16		x			
			60345 #1	TWINFALL					
			60345 #NT	TWINFALL					
			60352 #1	TWINFALS		x			
			60361 #1	U SAMN 1		x			
			60392 #C2	DNPR CT2		x			
			60431 #1	BCSR_GEN		x			
			610341 #1	HOPE-12.5		x			
			610811 #1	LIME-12.5		x			
			612131 #1	CDWL-12.5		x			
			612151 #1	CACK-34.5		x			
			612291 #2	ELMORE-34.5					
			61296 #1	STWP_GEN		x			
			614201 #1	BYPS-4.16		x			
			617121 #1	KUNA-12.5		x			
			617411 #1	ADRN-12.5		x			
			61938 #12	CAWP_12_GEN		x			
		Idaho Wind Partners	60032 #1	TUANAGEN		x			
		Ridgeline Energy	60995 #1	RKWP_GEN		x			
		SCL	61817 #2	LUCKYPK2		x			
		TERNA Energy	60410 #1	MTNAIRW1		x			
		USBR	60804 #1	BCANY1-2		x			
			61801 #1	ANDERSN1		x			
			61811 #6	MINIDOKA		x			
			61811 #7	MINIDOKA		x			
PACE	**PACE**	Duke Energy, Inc.	69092 #1	3BUTTES_WG		x			
		PACE	65778 #1	HINSHAW		x			
			66801 #1	WEST VAL GT1		x			
			66802 #1	WEST VAL GT2		x			
			66803 #1	WEST VAL GT3		x			
			66804 #1	WEST VAL GT4		x			
			67565 #1	WOLVCK 1		x			
			69102 #1	RAWHD G1		x			
			69773 #1	BASELINE_SG		x			
			69778 #1	CHAUT_SG		x			
		USBR	66160 #1	PALISADES_G1		x			
PSCOLORADO	**PSCO**	PRPA	78012 #GA	RAWHIDEA		x			
		PSCO	70314 #G1	MANCHEF1		x			
			70736 #W2	CHEYRGE_W2		x			
			70770 #W2	RUSHCK1_W2		x			
		Tri-State G&T	70493 #ST	JMSHAFR2		x			
			70565 #G1	KNUTSON1		x			
EL PASO	**EPE**	EPE	11268 #1	NEWMAN_6GT5				x	
PG AND E	**CAISO**	Customer Owned	35050 #1	SLR-TANN				x	
SOCALIF	**CAISO**	NON SCE Owned	25250 #1	ALMASOL_G4					x
			29290 #1	CABAZON_G			x		
		SCE	24308 #1	B CRK2-1					x
			24308 #2	B CRK2-1					x
			24315 #81	B CRK 8			x	x	x
			24315 #82	B CRK 8			x	x	x
		Terra-Gen Dixie Valley	24747 #1	OXBOW G1					x

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