WECC

Underfrequency Load Shedding Program Assessment

Underfrequency Load Shedding Review Group

August 14, 2020

Executive Summary

This report summarizes the modeling and study methodology including assumptions, the study cases utilized and the simulation results comprising the 2019 assessment of the WECC Off-Nominal Frequency Load Shedding Plan (aka WECC Coordinated Plan or WECC Plan) in accordance with the applicable requirements in NERC Standard PRC-006-3 and WECC Criterion PRC-006-WECC-CRT-3. The modeling data validation and the study simulations comprising the assessment were performed by WECC Technical Staff under the direction and guidance of WECC Underfrequency Load Shedding Review Group (UFLSRG) with oversight provided by the Studies Subcommittee (StS) under Reliability Assessment Committee (RAC). GE Positive Sequence Load Flow (PSLF) Version 21.0.7.1 software platform was used for all steady-state and dynamic simulations comprising this assessment.

The WECC Coordinated Plan performance was assessed for 2019 heavy summer (19HS) and 2019 light spring (19LSP) operating conditions in the Western Interconnection. Frequency recovery performance of the WECC Plan was evaluated for three islands – WECC(WI), North and South – at 10%, 20% and 25% generation-load imbalance levels by using the criteria noted in D.B.3.1 and D.B.3.2 in PRC-006-3. The arrest in frequency decline, the frequency nadir, and the frequency recovery performance was monitored at 48 representative buses spanning the WECC Region[1], equally divided among the North and South islands.

The V/Hz performance check was done for the North Island and South Island simulations but not for the WECC Island simulations. After weeding out the spurious exceedances, the six remaining V/Hz criteria exceedances were deemed non-spurious pending further review by the impacted Planning Coordinators. For these entities, this assessment of the UFLS program design does not meet the V/Hz performance characteristics noted in PRC-006-3 D.B.3.3, which may need to be addressed by implementing appropriate corrective action(s) to mitigate the criteria exceedance.

Performance sensitivity of the WECC Coordinated Plan to high DER penetration was performed using the 2019 Light Spring case for the South Island. This represents an appropriately conservative scenario for sensitivity testing because: (i) the system inertia is expected to be near-minimum for the light spring generation dispatch, and (ii) the DER penetration in California ISO footprint (which falls in South Island) is by far the highest in the WECC Region. No appreciable change in frequency nadir and/or recovery was observed in the simulation results for this high-penetration DER sensitivity case.

Comparison of maximum available armed load versus the actual load shed during the 25% imbalance underfrequency event was used as a new metric to evaluate the implemented (i.e. modeled) WECC

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[1] WECC Region is intended to imply the WECC Members footprint (which is the same as Western Interconnection footprint) – that is, the WECC Region is congruent with the Western Interconnection and includes the WECC Regional Entity (compliance monitoring) area.

Plan's adequacy and effectiveness. Computing the remaining or unused armed load – that is, available armed load margin – is an indicator of the adequacy of the WECC Plan's implementation.

The UFLSRG recommends that the significantly lower armed load margin seen for North Island be evaluated by Planning Coordinators now and verified in future UFLS assessments. Consecutively occurring low margins would be a reasonable basis for making appropriate design adjustments to the WECC primary plan and NWPP sub-area plan in order to provide additional armed load in the North Island.

Overall, the UFLSRG believes this 2019 UFLS Assessment demonstrates that the WECC Plan adopted by all Planning Coordinators and implemented by all UFLS Entities in the WECC Region conforms with all applicable requirements in NERC Standard PRC-006-3 and WECC Regional Criterion PRC-006-WECC-CRT-3.

Introduction

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

WECC has two documents associated with its UFLS program. The primary document is the ***Western Electricity Coordinating Council Off-Nominal Frequency Load Shedding Plan, May 24, 2011, ("WECC Plan")***. 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 purpose of WECC Criterion ***PRC-006-WECC-CRT-3*** effective April 2017 is to assure consistent implementation of the WECC Plan among all applicable WECC entities and to coordinate the UFLS database maintenance and update requirements among these entities.

Planning Coordinators in the Western Interconnection have designated the Underfrequency Load Shedding Review Group (UFLS Review Group) to biennially assess the performance of the WECC Plan and to help WECC Members meet their compliance with NERC Reliability Standard PRC-006-3. The activities and deliverables of the UFLS Review Group 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 Reliability Assessment Committee and the Operating Committee.

The responsibilities of the UFLS Review Group are to:

- Annually review the WECC Plan's consistency with the requirements of PRC-006-3.
- Conduct biennial simulations of the Plan to assess consistency with the performance requirements of PRC-006-3.
- Review the submitted UFLS data for consistency and accuracy of modeling.
- Collaborate with all applicable entities to develop a biennial report of the findings of the review and simulations.

The UFLSRG represents the registered Planning Coordinators, the UFLS Entities (including Transmission Owners and Distribution Providers), the Generation Owners and the Transmission Operators and Transmission Planners within the Western Interconnection who are WECC members.

The WECC Plan is coordinated across the Western Interconnection (WI), not just across the WECC Regional Entity (WECC RE) area. Therefore, what is referred to as the WECC Plan is in fact the WI Plan. *And in this context, the term WECC Region is intended to imply the WECC Members footprint (which is* *the same as Western Interconnection footprint) – that is, the WECC Region includes the WECC RE (compliance monitoring) area but is larger than it and congruent with the Western Interconnection.* To accommodate the UFLS performance differences within the WECC Region, the WECC Coordinated Plan also includes two Sub-Area plans in addition to the Primary plan. The Primary (aka WECC) plan and both Sub-Area plans (namely the NWPP and SILTP plans) are detailed in Section E, items 1a, 1b, and 1c of the WECC Off-Nominal Frequency Load Shedding Plan document. UFLS Entities can adopt one plan or a combination of the three plans based on where in the WECC Region their loads are located. Most entities have adopted a single plan, but some UFLS Entities' loads span across multiple sub-regions and hence they have appropriately implemented multiple plans.

This report summarizes the modeling and study methodology including assumptions, the study cases utilized and the simulation results comprising the 2019 assessment of the WECC Off-Nominal Frequency Load Shedding Plan in accordance with the applicable requirements in NERC Standard PRC-006-3 and WECC Criterion PRC-006-WECC-CRT-3[2]. The modeling data validation and the study simulations comprising the assessment were performed by WECC Technical Staff under the direction and guidance of the WECC UFLS Review Group with oversight provided by the Studies Subcommittee (StS) under Reliability Assessment Committee (RAC).

[2] 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 therein is sufficient for compliance with these or any other requirements. It is the responsibility of each NERC Registered Entity to ensure that this report and the analysis and information contained therein sufficiently meet their compliance responsibilities as applicable.

Assessment Studies Methodology

The WECC Coordinated (UFLS) Plan performance was assessed for 2019 heavy summer (19HS) and 2019 light spring (19LSP) operating conditions in the Western Interconnection by starting with the WECC base cases 19HS2a.sav case and 19LSP1a.sav respectively.

Software Platform and Dynamic Models

GE Positive Sequence Load Flow (PSLF) Version 21.0.7.1 was used for all steady-state and dynamic simulations comprising the studies performed for this assessment.

The salient dynamic models utilized in the simulations comprising the UFLS assessment are:

- Composite Load model CMPLDW – to represent all loads > 5 MW
- Distributed Energy Resource model DER_A – to represent all DER's by using the augmented CMPLDW model (with DER_A integrated) for all loads > 5 MW
- Volts-per-Hz Monitoring model VFMGEN – to monitor V/Hz performance criteria violations.
- Load Shed Monitoring model LSMON – to monitor load shed by under-frequency tripping.
- Load Tripping model LSDT9 – load relay for underfrequency load block trips
- Transmission Line Tripping model TLIN1 – line relay for underfrequency load block trips
- Relay model LHFRT – generator frequency ride through capability

UFLS dynamic simulations used lsdt9 and tlin1 models to automatically trip specified amount of load at specific frequency decline thresholds that are consistent with the applicable primary plan or the sub-area plans comprising the WECC Coordinated UFLS Plan. The Coordinated 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.

UFLS Database Review

UFLS Entities within WECC maintain and annually update a UFLS database to ensure that sufficient information is available to model the UFLS program for use in event analysis and assessments of the UFLS program. UFLS Entities provide updates to the UFLS database annually in accordance with *PRC-006-WECC-CRT-3*. 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*. The "Attachment A" data input form is a spreadsheet that includes tabs where UFLS Entities summarize their feeders and loads armed with UFLS relays, thereby 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 1st for Generator Owners and July 1st for the other UFLS Entities in accordance with *PRC-006-WECC-CRT-3*. The UFLS Review Group reviews and updates the Attachment A template prior to 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 UFLS Review Group 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 Planning Coordinators within the WECC Region.

The above described process for annual maintenance of the UFLS database followed by UFLS Review Group on behalf of all Planning Coordinators within the WECC Region is in accordance with *PRC-006-WECC-CRT-3* and, in turn, effectively fulfills the requirements R6, R7, R8 in PRC-006-3.

Islands Formation in WECC Region (Western Interconnection)

Planning Coordinators in the WECC Region (which includes the WECC Regional Entity area) have regularly participated in a joint regional review to identify the portions of the WECC Region's Bulk Electric System (BES) that may form islands. The criteria used to identify the formation of plausible islands in the Western Interconnection includes:

a) consideration of historical events,
b) system studies, and
c) any portions of the BES designed to detach into islands as a result of Remedial Action Scheme (RAS) operation.

Based on these criteria, the consensus among Planning Coordinators in the WECC Region is that the formation of two planned islands in the Western Interconnection – North Island and South Island – continues to be an adequate basis for the WECC Region-wide (i.e. Interconnection-wide) coordinated UFLS program. Identification of both North and South planned islands is based on all three criteria as further described below. The selection of islands in WECC Region is therefore consistent with D.B.1 and D.B.2 in PRC-006-3.

As noted earlier, the WECC Off-Nominal Frequency Load Shedding Plan (WECC Coordinated Plan) was initially approved and adopted in 1997 in response to three system-wide disturbances that occurred in 1996. Since then, it has been periodically updated and/or refined to include two sub-area plans (namely NWPP and SILTP plans) that are fully coordinated with the primary (original) WECC area plan. After the 2011 disturbance event, the WECC UFLS Review Group evaluated the new island configurations that occurred during that disturbance (see 2013 UFLS Assessment). At the March 2014 Planning Coordination Committee meeting, the UFLS Review Group Chair presented 14 potential Bulk Electric System island configurations based on the 2011 disturbance event, system studies and RAS operation. The UFLS Review Group proposed, and the Planning Coordination Committee approved, that it's adequate to simulate the following planned islands in the 2015 UFLS Assessment:

WECC Island; **North Island; and** **South Island**

To-date, the UFLS Review Group has not identified any additional plausible island based on applying the island formation criteria. Therefore, like the 2015 and 2017 UFLS Assessments, the studies for this 2019 UFLS Assessment are also performed for the three planned islands noted above.

The WECC Region was separated into North and South Islands by opening the following transmission elements in accordance with WECC-1 RAS (refer to Appendix F for details):

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

Starting with the WECC Island steady-state case, flows across the north/south cut-plane were reduced to almost zero by generation redispatch to create the North Island and South Island steady-state cases.

Generation-Load Imbalance

All prior WECC UFLS Assessment studies were performed by calculating the imbalance using:

$$\%\ \text{Imbalance}_{\text{prior}} = \text{Generation Lost (Tripped) / Total (On-line) Generation Output}$$

In this assessment, the imbalance was calculated consistent with D.B.3. in PRC-006-3 as follows:

$$\%\ \text{Imbalance}_{\text{now}} = [\text{Load} - \text{Actual Generation Output}]\ /\ \text{Load}$$

where Actual Generation Output = Total (On-line) Generation Output – Generation Lost (Tripped)

It must be noted that:

Imbalances calculated consistent with D.B.3 are equivalent to 2.5 – 3% increase in the prior imbalances. That is, 10% imbalance in this assessment is equivalent to ~13% imbalance in any of the prior assessments. Similarly, 25% imbalance in this assessment is equivalent to ~27.5% imbalance in any prior assessment.

Frequency Performance & Monitored Buses

The frequency performance was evaluated for each of the three islands (WECC, North and South) at three generation-load imbalance levels (10%, 20% and 25%) by applying the criteria noted in D.B.3.1 and D.B.3.2 in PRC-006-3. The frequency performance was evaluated for 2019 heavy summer (19HS) and 2019 light spring (19LSP) operating conditions by monitoring the arrest in frequency decline, the frequency nadir, and the frequency recovery (including overshoot). The frequency was monitored at 48 representative buses spanning the WECC Region, equally divided among the North and South islands. Within each island the 24 monitored buses were equally divided among four sub-regions of the island. The six buses in each sub-region were selected to achieve both geographic and voltage level diversity across the sub-region. The 48 monitored buses where acceptable frequency performance of the WECC Plan was verified are tabulated below.

Table 1 - North Island Monitored Buses

Canada	MT/ID/WY	WA/OR	CO/UT/NV
Williston 500 kV	Garrison 500 kV	Coulee 500 kV	Valmy 345 kV
Nicola 500 kV	Midpoint 500 kV	John Day 500 kV	Terminal 345 kV
Langdon 240 kV	Bridger 345 kV	Bethel 230 kV	Daniels Park 230 kV
Kelly Lake 230 kV	Wyodak 230 kV	Boundary 115 kV	Sigurd 230 kV
Clover Bar 240 kV	Crossover 230 kV	Talbot Hill 115 kV	Hayden 230 kV
Muskeg River 72 kV	DRAM 138 kV	Port Angeles 69 kV	North 115 kV

Table 2 - South Island Monitored Buses

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

Dynamic simulations for evaluating the frequency performance were run for 60 seconds and the target generation-load imbalance (10%, 20% and 25%) was initiated at 1 second by tripping of generators. Frequency response plots were produced for each simulation run – at 48 buses for WECC Island, and at 24 buses for North Island and South Island each.

V/Hz Performance Check

This verification was performed at each generator bus and generator step-up transformer high-side bus by applying the V/Hz criteria noted in D.B.3.3 in PRC-006-3. That is, **for each simulated event, V/Hz not exceed 1.18 per unit for longer than two seconds cumulatively, and not exceed 1.10 per unit for longer than 45 seconds cumulatively**. The violation check was performed by using the VFMGEN model implemented in PSLF.

Coordinated 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 and its implementation schedule in accordance with R15 in PRC-006-3.

This biennial assessment therefore identifies the specific performance characteristic 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.

WECC Island (Western Interconnection) Study

WECC 2019HS Case

Load = 172,836 MW   Generation Output = 178,780 MW

W19HS Imbalance

Imbalance	Generation Tripped, MW		Imbalance
Target	Target	Actual	Actual
10%	23228	24187	10.6%
20%	40512	41962	20.8%
25%	49153	49367	25.1%

W19HS Frequency Performance

The frequency response plots are included in Appendix A. It is evident from the plots that the WECC Plan meets the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3).

WECC 2019LSP Case

Load = 95,080 MW   Generation Output = 98,422 MW

W19LSP Imbalance

Imbalance	Generation Tripped, MW		Imbalance
Target	Target	Actual	Actual
10%	12850	13326	10.5%
20%	22358	22666	20.3%
25%	27112	27613	25.5%

W19LSP Frequency Performance

The frequency response plots are included in Appendix A. It is evident from the plots that the WECC Plan meets the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3).

North Island Study

North 2019HS Case

Load = 75,640 MW Generation Output = 78,272 MW

N19HS Imbalance

Imbalance	Generation Tripped, MW		Imbalance
Target	Target	Actual	Actual
10%	10196	10305	10.1%
20%	17760	17890	20.2%
25%	21542	21634	25.1%

N19HS Frequency Performance

The frequency response plots are included in Appendix B. It is evident from the plots that the WECC Plan meets the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3).

North 2019LSP Case

Load = 50,432 MW Generation Output = 52,146 MW

N19LSP Imbalance

Imbalance	Generation Tripped, MW		Imbalance
Target	Target	Actual	Actual
10%	6757	6803	10.1%
20%	11801	11884	20.2%
25%	14322	14502	25.4%

N19LSP Frequency Performance

The frequency response plots are included in Appendix B. It is evident from the plots that the WECC Plan meets the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3).

South Island Study

South 2019HS Case

Load = 92,567 MW Generation Output = 94,922 MW

S19HS Imbalance

Imbalance	Generation Tripped, MW		Imbalance
Target	Target	Actual	Actual
10%	11612	11911	10.3%
20%	20868	21150	20.3%
25%	25497	25804	25.3%

S19HS Frequency Performance

The frequency response plots are included in Appendix C. It is evident from the plots that the WECC Plan meets the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3).

South 2019LSP Case

Load = 44,519 MW Generation Output = 45,801 MW

S19LSP Imbalance

Imbalance	Generation Tripped, MW		Imbalance
Target	Target	Actual	Actual
10%	5734	5744	10.05%
20%	10186	10312	20.3%
25%	12412	12642	25.5%

S19LSP Frequency Performance

The frequency response plots are included in Appendix C. It is evident from the plots that the WECC Plan meets the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3).

V/Hz Performance Check

V/Hz performance check was done for the North Island and South Island simulations but not for the WECC Island simulation. Since a major disturbance in WECC Region is expected to result in controlled separation of WECC island into the North and South islands – only the V/Hz performance verification for these two planned islands for 25% imbalance is germane to the assessment of UFLS program's performance characteristics specified in PRC-006-3, D.B.3.3.

V/Hz criteria exceedance check was performed using the VFMGEN model available in PSLF, which monitors both components of the criteria as follows:

Volts-per-Hz threshold	Time limit
Vhtol1 = 1.18 p.u	Tlim1 = 2.00 sec.
Vhtol2 = 1.10 p.u	Tlim2 = 45.0 sec.

The V/Hz criteria exceedances detected by the VFMGEN model are recorded in the simulation log file – one or both exceedances may be seen at a generator bus or generator step-up transformer bus. The V/Hz criteria exceedances flagged by the model were manually post-processed to weed out the spurious ones. The remaining V/Hz criteria exceedances have been communicated to the appropriate Planning Coordinators for review. This is because:
(a) further detailed inspection of each simulation is needed to confirm that the observed exceedance is not a manifestation of unrealistic dynamic model response and/or unrealistic reactive power output(s) at start or end of the dynamic simulation;
(b) recurrence of V/Hz exceedances in consecutive biennial assessments increases confidence in their validity.

South Island 25% Imbalance

2019HS case: 10 criteria exceedances were flagged in the simulation log file. On closer scrutiny, all 10 of them were determined to be spurious exceedances -- see tabular listing in Appendix D for details.

2019LSP case: 4 criteria exceedances were flagged in the simulation log file. On closer scrutiny, 3 of them were determined to be spurious exceedances -- see tabular listing in Appendix D for details. The plot for the remaining non spurious exceedance (tabulated below) is included in Appendix D.

Area	Generator Bus	Exceedance
30 PG&E	35860 OLS-AGNE	1.10pu 45 sec

North Island 25% Imbalance

2019HS case: 22 criteria exceedances were flagged in the simulation log file. On closer scrutiny, 21 of them were determined to be spurious exceedances -- see tabular listing in Appendix D for details. The plot for the remaining non spuriousexceedance (tabulated below) is included in Appendix D.

Table 3 - V/Hz Criteria Exceedances - 2019HS North Island

Area	Generator Bus	Exceedance
40 NW	40199 CENTRALA	1.10pu 45 sec

2019LSP case: 20 criteria exceedances were flagged in the simulation log file. On closer scrutiny, 16 of them were determined to be spurious exceedances -- see tabular listing in Appendix D for details. The remaining 4 non spurious exceedances (tabulated below) and their plots are included in Appendix D.

Table 4 - V/Hz Criteria Exceedances - 2019LSP North Island

Area	Generator Bus	Exceedance
54 AB	55781 ED1002-2	1.18pu 2 sec
	55782 ED1003-2	"
40 NW	47596 GRYHB G1	"
	47597 GRYHB G2	"

Performance Sensitivity to High-penetration DER

The UFLS Review Group determined that useful insights would be gained by performing a sensitivity evaluation of the WECC Plan performance to high penetration of Distributed Energy Resources (DERs). This sensitivity analysis was only performed using the 2019 Light Spring case for the South Island. This represents an appropriately conservative scenario for sensitivity testing because: (i) the system inertia is expected to be near-minimum for the light spring generation dispatch, and (ii) the DER penetration in California ISO footprint (which falls in South Island) is by far the highest in the WECC Region, higher by an order of magnitude compared to DER penetration levels in all other areas of the Western Interconnection.

The DER sensitivity case was developed in consultation with California ISO and the modeling details for it are noted below:

DER Penetration Level in California ISO footprint = ~6200 MW
Based on ~75% dispatch of ~8300 MW installed DERs[3]

~6200 MW DER modeled at Loads > 5 MW within Areas 22 (SDGE), 24 (SOCAL) and 30 (PG&E)

Generation-Load balance after DER integration achieved by turning off ~6200 MW generation in 19LSP-25 South case

~6200 MW generation reduction allocated to Areas 22, 24 and 30 using two methods:
a) reduction is proportional to Area Generation dispatch ratios (Area Pgen ratios)
b) reduction is proportional to Area Load ratios (Area Pload ratios)

DER_A model parameters used as per the following DER type assumption:
70% - IEEE 1547-2018 compliant; 30% - IEEE 1547-2003 compliant

No appreciable change in frequency nadir and/or recovery was observed in the simulation results for this high-penetration DER sensitivity case. This is evident from the simulation plots included in Appendix E. Therefore, it may be concluded that the South Island Sub-area plan (SILTP) of the WECC Plan continues to meet the required frequency performance (specified by D.B.3.1 and D.B.3.2 in PRC-006-3) for the studied DER penetration.

[3] Based on California ISO's DER modeling practice consistent with California DER statistics available at: https://www.californiadgstats.ca.gov/

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 calculated for both 2019 Heavy Summer and 2019 Light Spring cases. This benchmarks the consistency between actual implementation of the WECC Plan by UFLS Entities in comparison to its design. The values in Modeled column of Table 5 and Table 6 represent the amount of load armed for underfrequency shedding within North and South Islands – these percent values 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. The Plan Design values reflect the primary WECC plan, NWPP sub-plan and SILTP sub-plan descriptions in the *WECC Off-Nominal Frequency Load Shedding Plan*, and are tabulated here for easy comparison.

Table 5 - Armed Load Shed Data Validation for 2019 Heavy Summer Case

	Modeled Armed Load Validation 2019 Heavy Summer Case				
Load Shed	North Island (NWPP & WECC plans)			South Island (SILTP plan)	
	Plan Design NWPP	Plan Design WECC	Modeled	Plan Design SILTP	Modeled
0	n/a	n/a	n/a	~4.0% (DLT)	~0%
1	5.6% (59.3)	5.3% (59.1)	7.3% (≥ 59.1)	5.3% (59.1)	5.7% (59.1)
2	5.6% (59.2)	5.9% (58.9)	4.1% (≥ 58.9, < 59.1)	5.9% (58.9)	5.6% (58.9)
3	5.6% (59.0)	6.5% (58.7)	4.7% (≥ 58.7, <58.5)	6.5% (58.7)	6.2% (58.7)
4	5.6% (58.8)	6.7% (58.5)	4.9% (≥ 58.5, < 58.3)	6.7% (58.5)	6.1% (58.5)
5	5.6% (58.6)	6.7% (58.3)	3.3% (≥58.3, < 58.5)	6.7% (58.3)	6.3% (58.3)
< 58.3			1.6%		17.7%
TOTAL	28.0%	31.1%	25.9%	35.1%	47.6%
UF Stalling	6.0%	6.0%	4.3%	6.0%	4.2%

Table 6 - Armed Load Shed Data Validation for 2019 Light Spring Case

	Modeled Armed Load Validation 2019 Light Spring Case				
Load Shed	North Island (NWPP & WECC plans)			South Island (SILTP plan)	
	Plan Design NWPP	Plan Design WECC	Modeled	Plan Design	Modeled
0	n/a	n/a	n/a	~4.0% (DLT)	~0%
1 (59.1 Hz)	5.6% (59.3)	5.3% (59.1)	7.8% (≥ 59.1)	5.3% (59.1)	5.5% (59.1)
2 (58.9 Hz)	5.6% (59.2)	5.9% (58.9)	4.2% (≥ 58.9, < 59.1)	5.9% (58.9)	5.3% (58.9)
3 (58.7 Hz)	5.6% (59.0)	6.5% (58.7)	4.5% (≥ 58.7, <58.5)	6.5% (58.7)	6.1% (58.7)
4 (58.5 Hz)	5.6% (58.8)	6.7% (58.5)	4.6% (≥ 58.5, < 58.3)	6.7% (58.5)	5.8% (58.5)
5 (58.3 Hz)	5.6% (58.6)	6.7% (58.3)	2.8% (≥58.3, < 58.5)	6.7% (58.3)	5.6% (58.3)
< 58.3 Hz			1.4%		17.4%
TOTAL	28.0%	31.1%	25.3%	35.1%	45.7%
UF Stalling		6.0%	4.0%	6.0%	3.6%

North Island – It may be noted from Tables 5 and 6 that the Total Armed Load modeled in the North Island falls short of what is required by plan design for both 2019 Heavy Summer and 2019 Light Spring Cases. Assuming the connected load in North Island is almost equally distributed between the NWPP plan and WECC plan, the Total Armed Load as per Plan Design would be 29.55% (average of 28.0% and 31.1%). Whereas the Total Armed Load modeled in 2019 Heavy Summer and 2019 Light Spring Cases is 25.9% and 25.3% respectively – an **average deficit of approximately 13.5%**.

South Island – Similarly, it may be noted from Tables 5 and 6 that the Total Armed Load modeled in the South Island is much higher than what is required by plan design for both 2019 Heavy Summer and 2019 Light Spring Cases – an **average surplus of approximately 11.5%**.

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 implemented (i.e. modeled) WECC Plan's adequacy and effectiveness. 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 – that is, available armed load margin – is an indicator of the adequacy of the WECC Plan's implementation.

As evident from the tabulated statistics for 2019HS and 2019LSP cases in Table 7 and Table 8 below, the total armed load in North Island has significantly lower margin compared to the others. This would need to 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 NWPP sub-area plan in order to provide additional armed load in the North Island.

Table 7 Armed Load Adequacy for 2019HS Case

				25% Imbalance		
Island	**Total (MW)**	**Armed (MW)**	**Armed (% of Total)**	**Shed (MW)**	**Shed (% of Armed)**	**Plan Margin %**
WECC	172836	73044	42.3%	49925	68.35%	31.65%
North	75712	22863	30.2%	21604	94.5%	5.5%
South	97124	50181	51.7%	30353	60.5%	39.5%

Table 8 Armed Load Adequacy for 2019LSP Case

				25% Imbalance		
Island	**Total (MW)**	**Armed (MW)**	**Armed (% of Total)**	**Shed (MW)**	**Shed (% of Armed)**	**Plan Margin %**
WECC	95071	36765	38.7%	29014	78.9%	21.1%
North	50442	14743	29.2%	13147	89.2%	10.8%
South	44629	22021	49.3%	30353	68.0%	32.0%

Conclusions

The WECC Plan continues to be effective in arresting frequency decline for a 25% load and generation imbalance scenario for each of the identified islands – WECC (WI) Island, North Island, South Island. The WECC Plan's performance was verified for two system operating conditions – 2019 Heavy Summer and 2019 Light Spring.

The WECC Plan's performance was also evaluated for a high DER penetration scenario – this sensitivity evaluation was done for 25% imbalance in South Island for 2019 Light Spring case. The WECC Plan continues to meet the required frequency performance for the studied DER penetration.

Several V/Hz criteria exceedances were identified in both South and North Island. Based on review and feedback received from the impacted Planning Coordinators, a large majority of these exceedances (13 of 14 in the South Island and 37 of 42 in the North Island) were determined to be spurious exceedances. The remaining six (6) exceedances are deemed non-spurious pending further review by the impacted Planning Coordinators. For these entities, this assessment of the UFLS program design does not meet the V/Hz performance characteristics noted in PRC-006-3 D.B.3.3, which may need to be addressed by implementing appropriate corrective action(s) to mitigate the criteria exceedance.

Comparison of maximum available armed load versus the actual load shed during the 25% imbalance underfrequency event was used as a new metric to evaluate the implemented (i.e. modeled) WECC Plan's adequacy and effectiveness. Computing the remaining or unused armed load – that is, available armed load margin – is an indicator of the adequacy of the WECC Plan's implementation.

The UFLSRG recommends that the significantly lower armed load margin seen for North Island be evaluated by Planning Coordinators now and verified in future UFLS assessments. Consecutively occurring low margins would be a reasonable basis for making appropriate design adjustments to the WECC primary plan and NWPP sub-area plan in order to provide additional armed load in the North Island.

Overall, the UFLSRG believes this 2019 UFLS Assessment demonstrates that the WECC Plan adopted by all Planning Coordinators and implemented by all UFLS Entities in the WECC Region conforms with all applicable requirements in NERC Standard PRC-006-3 and WECC Regional Criterion PRC-006-WECC-CRT-3.

Appendix A – Frequency Performance – WECC (WI) Island

Appendix B – Frequency Performance – North Island

Appendix C – Frequency Performance – South Island

Appendix D – V/Hz Check for 25% Imbalance in North and South Islands

Spurious V/Hz Exceedances – South Island				
	Generator Bus No.	Name	Exceedance	Comment
19HS	25422	ETI MWDG	1.18pu 2 sec	Oscillatory Dynamic Model Response
19HS	29305	ETWPKGEN	"	"
19HS	14938	YCACT1	1.10pu 45 sec	Invalid Dynamic Model Response*
19HS	22704	SAMPSON	"	"
19HS	24071	INLAND	Both	Invalid Dynamic Model Response*
19HS	24118	PITCHGEN	"	"
19HS	24026	CIMGEN	"	"
19HS	33460	SMATO2SC	"	"
19HS	160923	SUNDT_GEN1	"	"
19HS	160924	SUNDT_GEN2	"	"
19LSP	33460	SMATO2SC	Both	Invalid Dynamic Model Response*
19LSP	33806	TH.E.DV.	"	"
19LSP	36222	DUKMOSS2	"	"

* Qgen > Rated MVA

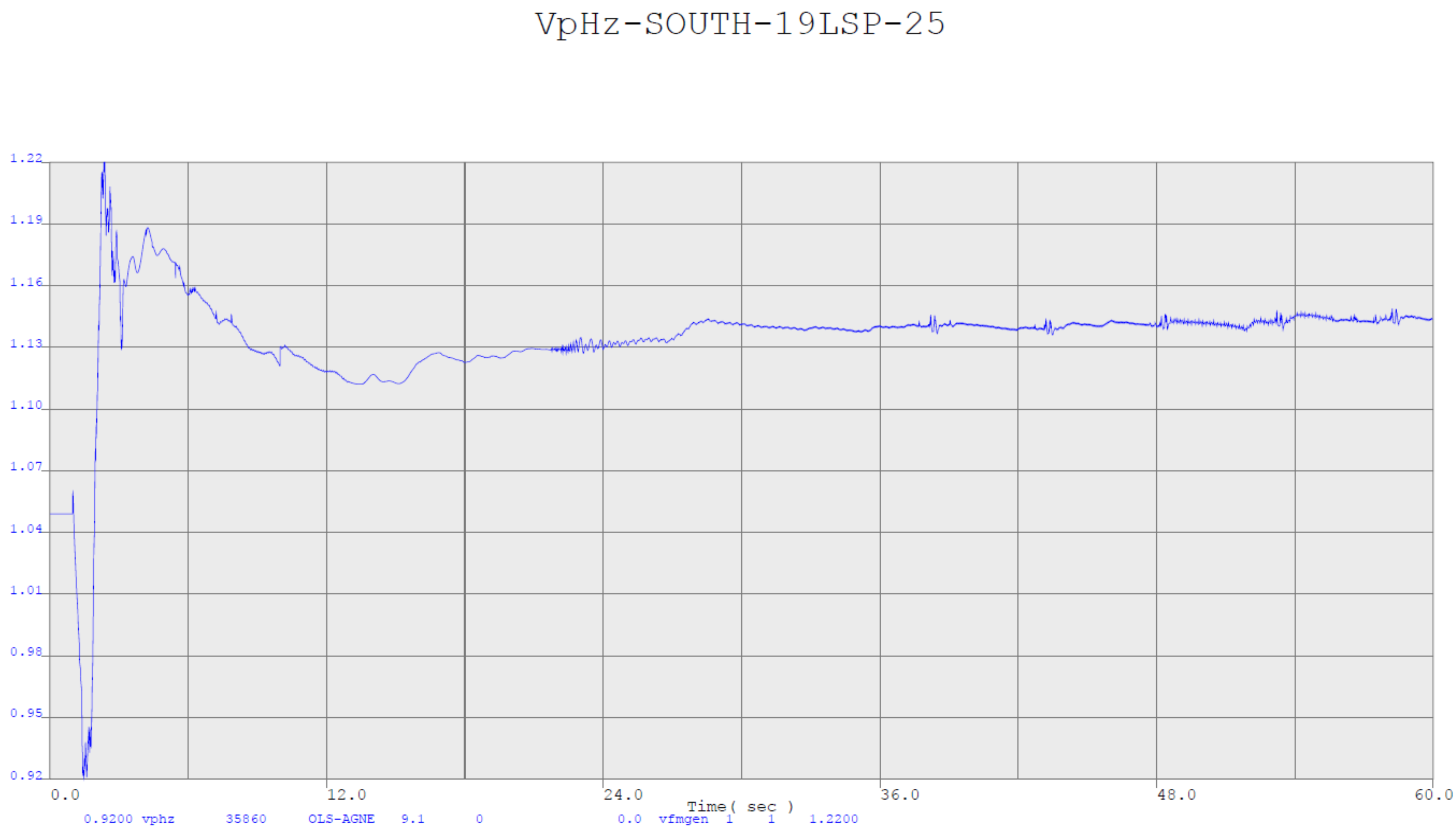
Spurious V/Hz Exceedances– North Island 19HS			
Generator Bus No.	Name	Exceedance	Comment
47577	FREDST G	1.18pu 2 sec	Oscillatory Dynamic Model Response
51395	PGP 13G5	"	"
56941	LONGLK17	"	Not a Generating Unit (Motor)
59941	LONGLK15	"	Not a Generating Unit (Motor)
80760	MIG G1	"	Implementation of existing high voltage mitigation operating plans eliminates the exceedance
43556	SULIVAN	1.10pu 45 sec	Not a BES generator – connected to PGE's 57 kV bus
81109	CKY_ROR 13	"	Implementation of existing high voltage mitigation operating plans eliminates the exceedance
40307	COWFALLS	Both	Invalid Dynamic Model Response*
44980	CAMASSW	"	"
47047	GLENOMA	Both	Invalid Dynamic Model Response*
50295	VIT 12C2	"	"
50296	VIT 12C3	"	"
50297	VIT 12C4	"	"
51697	NWP 13	"	"
60050	BOBNS011	"	"
60051	BOBNS012	"	"
60188	KINPORT	"	"
80586	HMC 13T2	"	"
474415	CHEM#5	"	"
51627	ICP 13G2	"	Implementation of existing high voltage mitigation operating plans eliminates the exceedance
81130	CFT 13C	"	"

* Qgen > Rated MVA

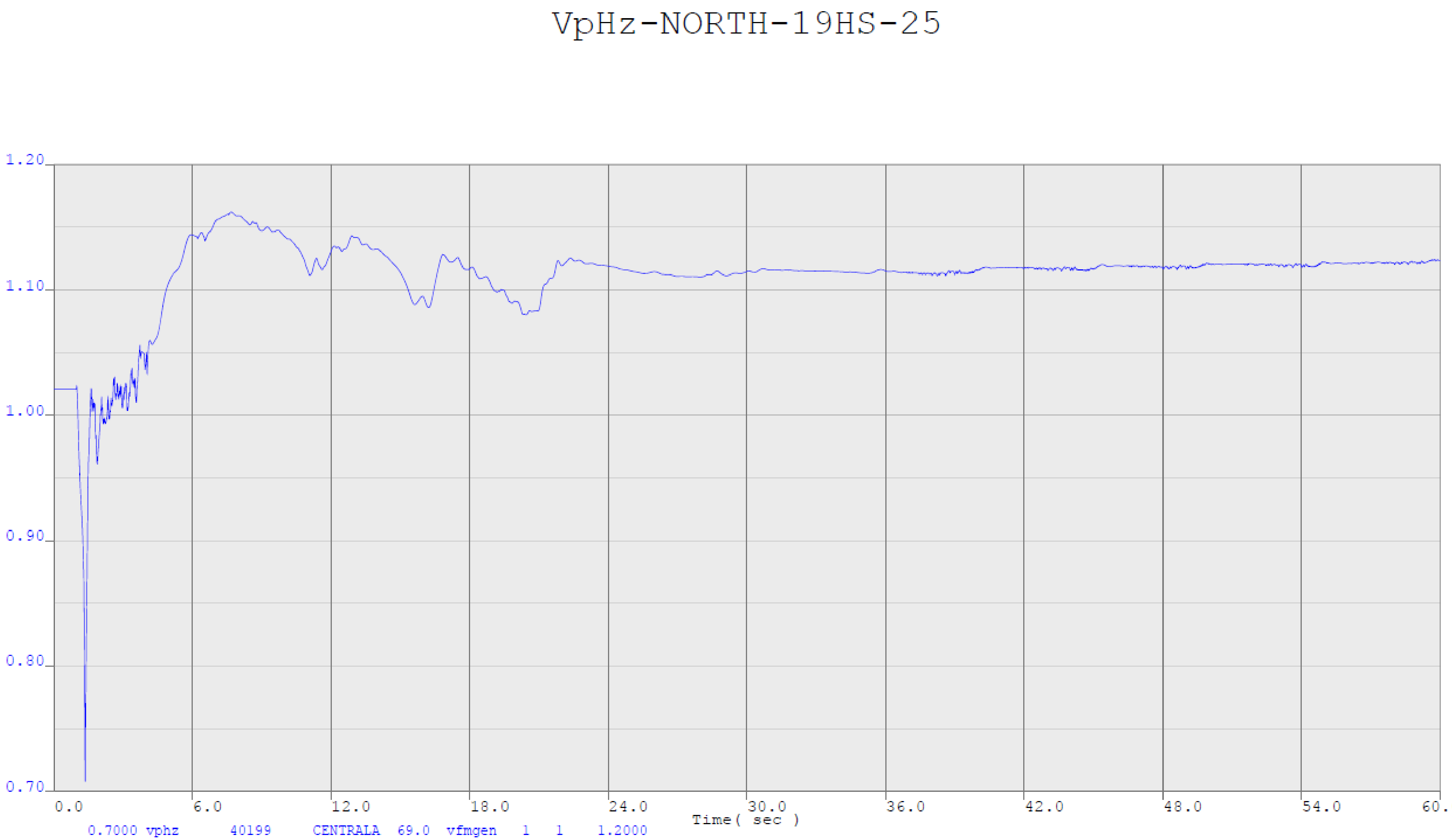
Spurious V/Hz Exceedances– North Island 19LSP			
Generator Bus No.	Name	Exceedance	Comment
56941	LONGLK17	1.18pu 2 sec	Not a Generating Unit (Motor)
59941	LONGLK15	"	Not a Generating Unit (Motor)
65391	CURRNTC1	"	Invalid Dynamic Model Response*
60050	BOBNS011	1.10pu 45 sec	"
60051	BOBNS012	"	"
51686	BMW .4W1	"	Invalid Dynamic Model for WTG Exceedance does not occur after using updated WTG dynamic models available in 2020 MDF
51687	BMW .4W2	"	"
51689	BMW .4W4	"	"
81109	CKY_ROR 13	"	Implementation of existing high voltage mitigation operating plans eliminates the exceedance
50295	VIT 12C2	Both	"
50296	VIT 12C3	"	"
50297	VIT 12C4	"	"
60188	KINPORT	"	"
67906	LAKSDCT3	"	"
67908	LAKSDST2	"	"
81130	CFT 13C	"	Implementation of existing high voltage mitigation operating plans eliminates the exceedance

* Qgen > Rated MVA

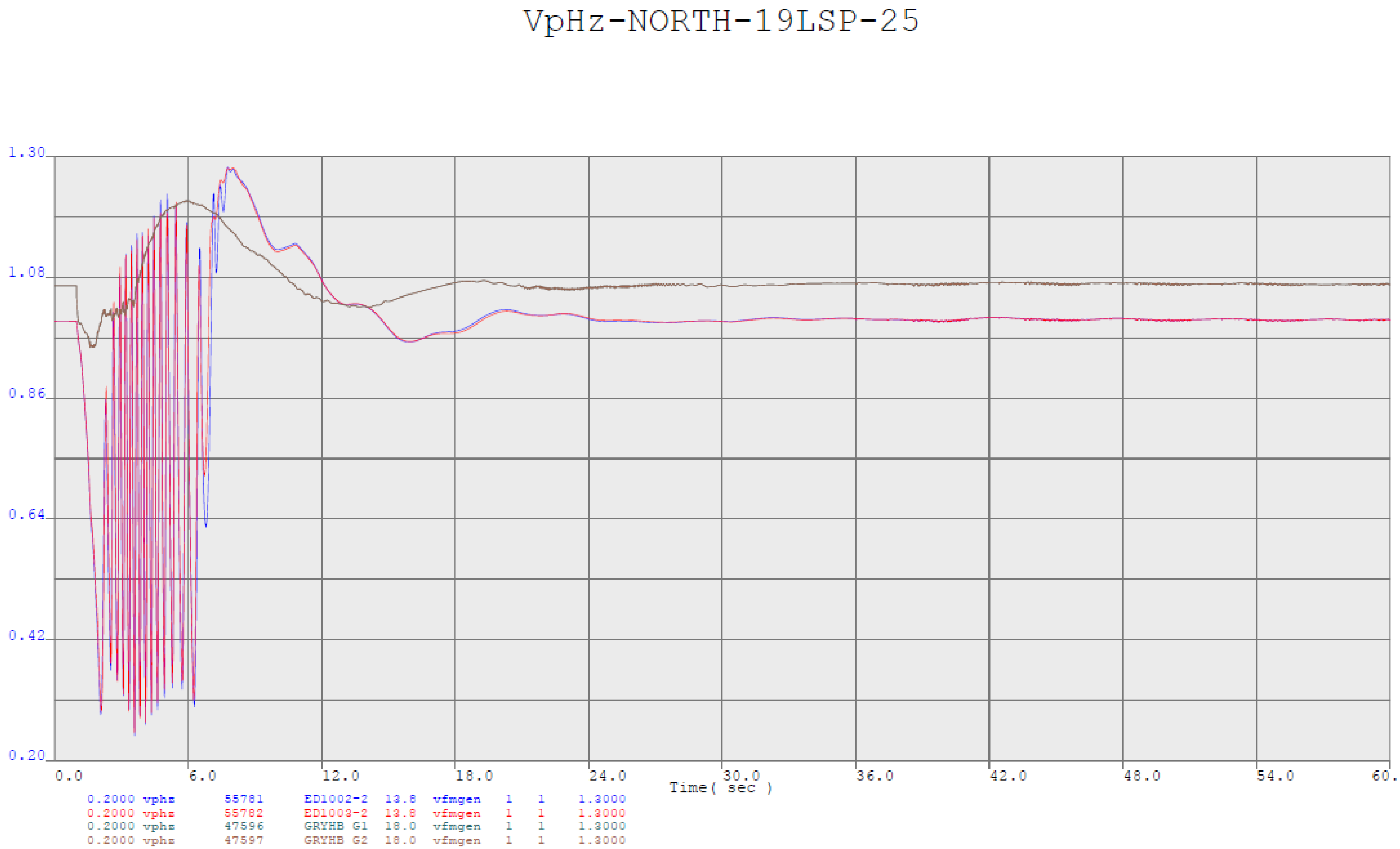
V/Hz Exceedance – South Island 25% **19HS-25: None** **19LSP-25: 35860 OLS-AGNE (1.11pu 45 sec)**



V/Hz Exceedances – North Island 25% **19HS-25**

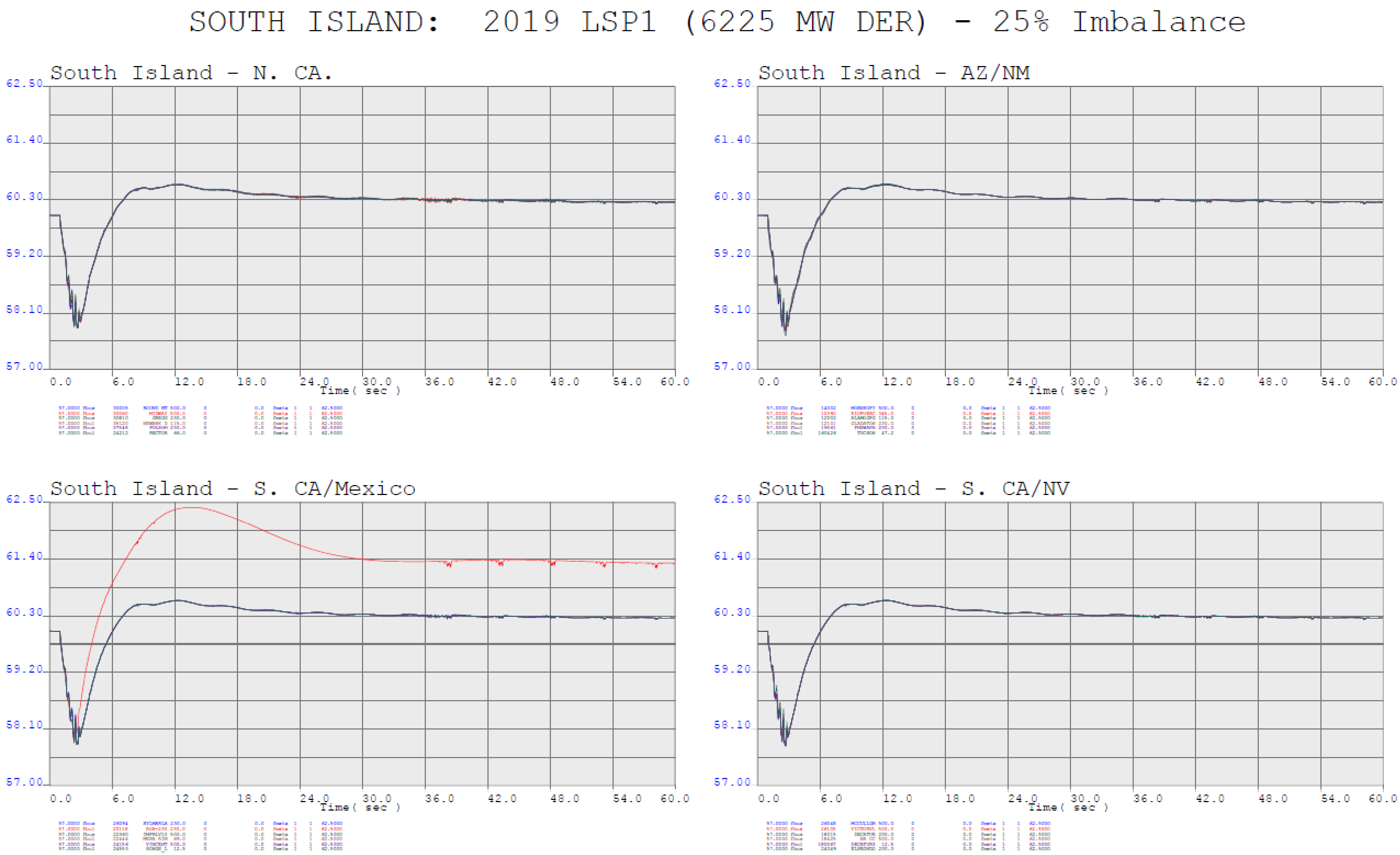


V/Hz Exceedances – North Island 25% 19LSP-25



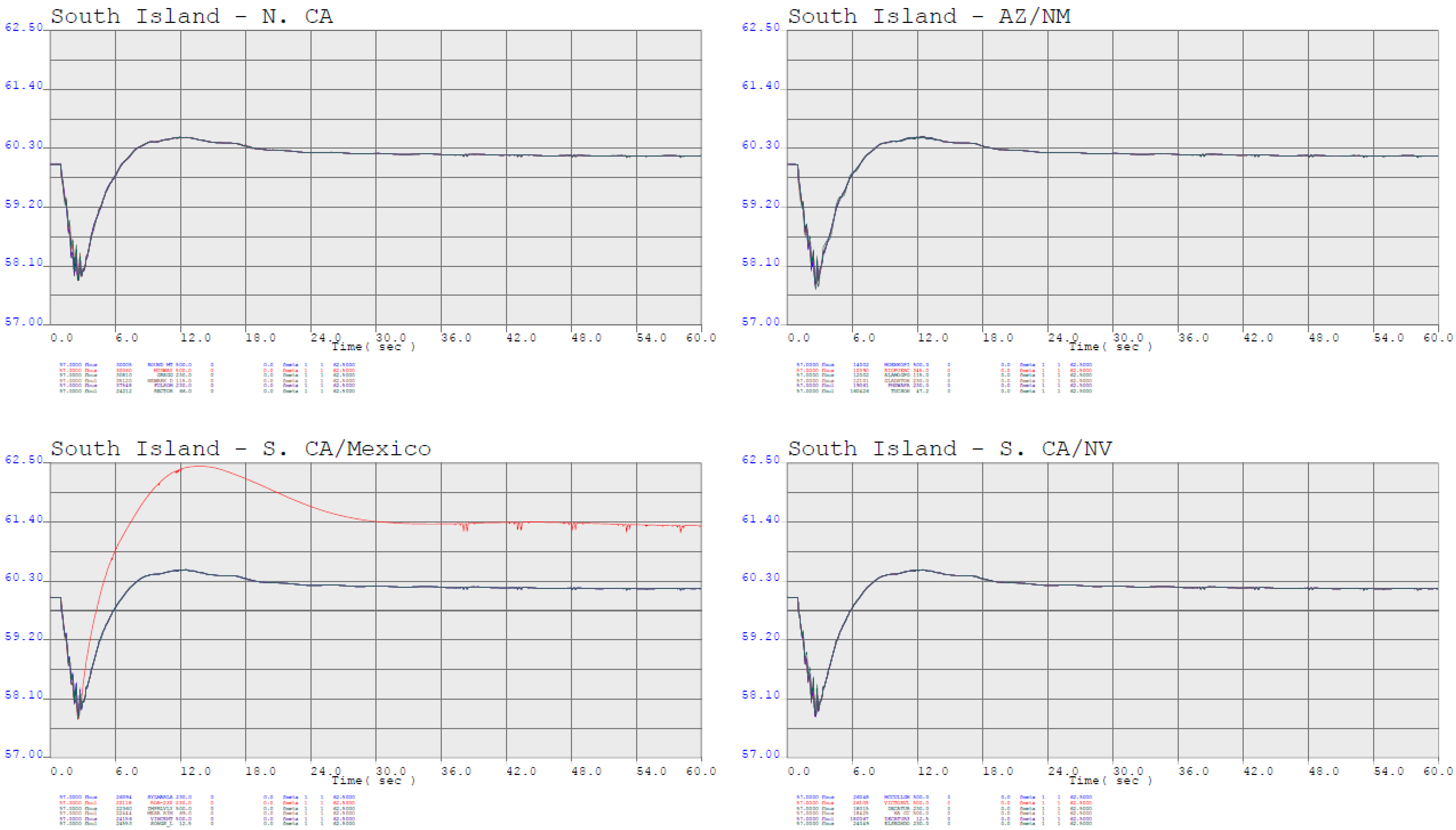
Appendix E – Frequency Performance – DER Sensitivity in South Island for 2019LSP case

DER Sensitivity Approach A – 6225 MW Redispatch proportional to Area Pgen ratios

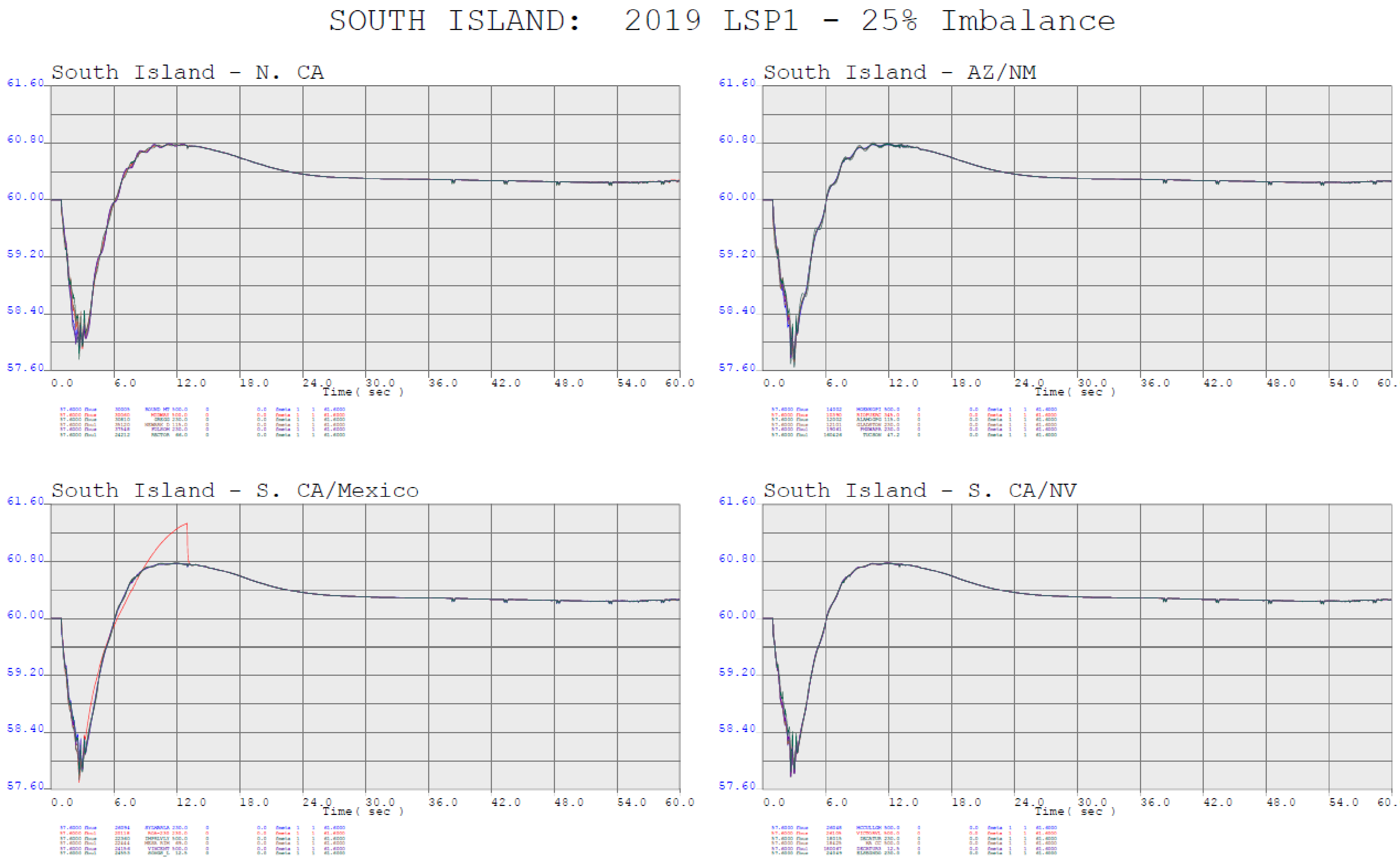


DER Sensitivity Approach B – 6225 MW Redispatch proportional to Area Pload ratios

SOUTH ISLAND: 2019 LSP1 (6225 MW DER) - 25% Imbalance

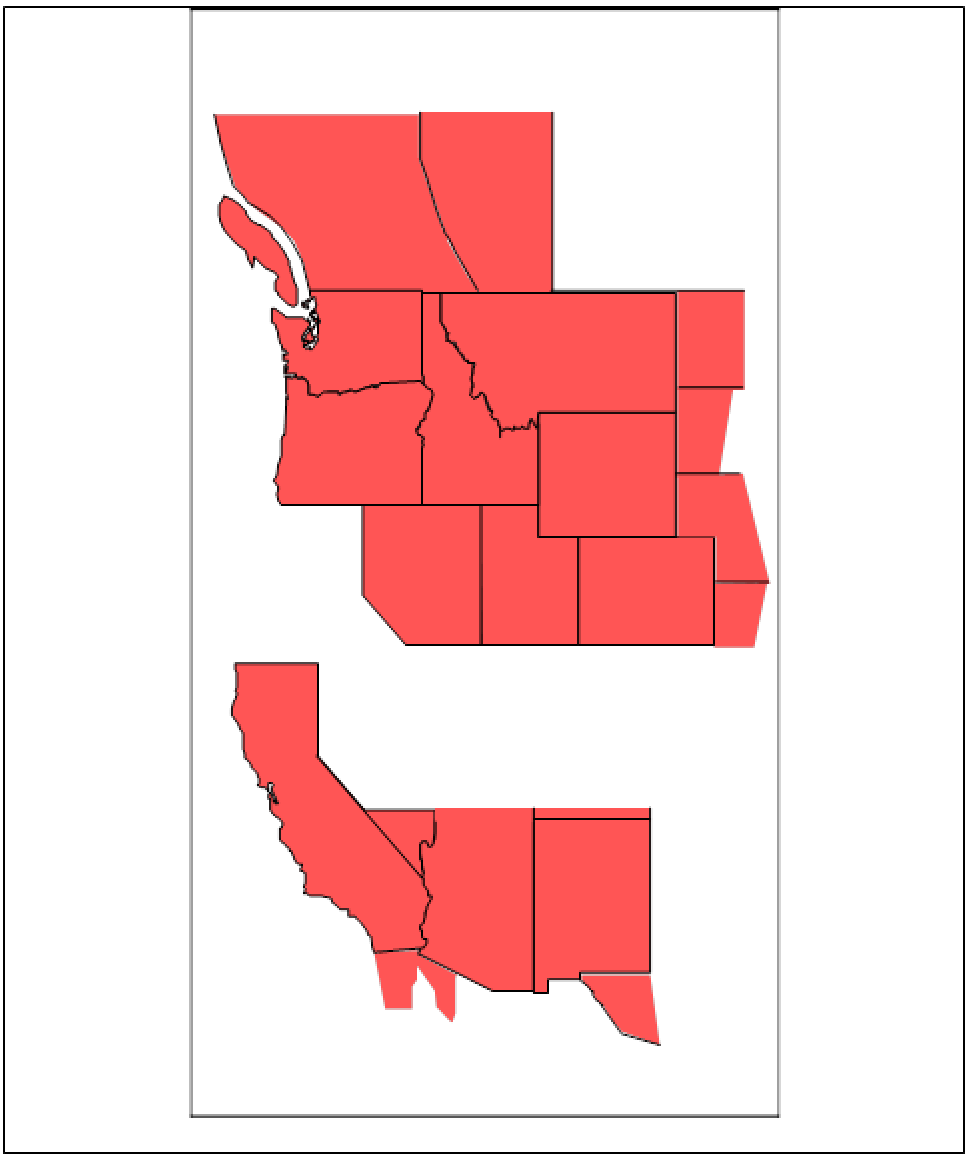


2019LSP 25% South Island Without DER – Reference For Comparison



Appendix F – WECC NE/SE Separation Scheme

The WECC Region is designed to detach into a North and South Islands as a result of the WECC-1 Remedial Action Scheme (RAS). Depending on the region and the company referring to it, this scheme has many names including: NE/SE separation scheme, the COI RAS, PACI RAS, AC RAS, Four Corners Scheme, and Pacific Intertie Transfer Trip Scheme. WECC-1 is installed to prevent overload, low voltage, and instability in the connected system should one or more lines between John Day, Buckley, Marion in the north and Vincent in the south trip for whatever reason. In addition, selected 500-kV lines north of John Day, Buckley, and Marion have line loss logic to initiate WECC-1 for specific operating conditions. The separation cut-plane is shown in the figure below.



The separation occurs between the following entities:

- BPA and PG&E on the COI at Malin and Round Mountain Substations;
- BPA and WASN at Captain Jack and Olinda Substations;
- PG&E and PACW at Cascade Substation;
- PG&E and NVEN (SPP) at NVE's California, Truckee, and North Truckee Substations;
- NVEN (SPP) and SCE at NVE's Silver Peak Substation;
- NVEN (SPP) and NVES (NEVP) at NVE's Robinson Summit Substation;
- PACE and APS at Four Corners and between PACE and NVES (NEVP) at Red Butte and Harry Allen; and
- Tri-State and PNM at the Gladstone Substation.

To complete the separation between the North and South Islands, WACRSP and WARM trips the following:

- Glen Canyon-Sigurd 230-kV line;
- Shiprock-Lost Canyon 230-kV line;
- Glade- Hesperus 115-kV line; and
- San Juan-Hesperus 345-kV line.