Document name	**Model Validation Report for May 16, 2014 RAS Event**
Category	( ) Regional Reliability Standard ( ) Regional Criteria ( ) Policy ( ) Guideline (X) Report or other ( ) Charter
Document date	August 12, 2014
Adopted/approved by	M&VWG
Date adopted/approved	August 12, 2014
Custodian (entity responsible for maintenance and upkeep)	JSIS
Stored/filed	Physical location: Web URL: http://www.wecc.biz/committees/StandingCommittees/PCC/TSS/MVWG/Shared%20Documents/MVWG%20Approved%20Documents/Model%20Validation%20Report%20for%20May%2016%202014%20RAS%20Event.pdf
Previous name/number	N/A
Status	(X) in effect ( ) usable, minor formatting/editing required ( ) modification needed ( ) superseded by _______________________ ( ) other ________________________________ ( ) obsolete/archived)

WECC Joint Synchronized Information Subcommittee
and WECC Modeling and Validation Work Group

Model Validation Studies for Pacific Northwest RAS Event that Occurred in the Western Interconnection at 23:18 on May 16, 2014

FINAL Report 8-12-2014

I. Conclusions and Recommendations

On May 16 2014, at 23:18:15.85, John Day - Grizzly #1 500-kV line tripped while John Day-Grizzly #2 line was out of service for construction. With both John Day – Grizzly lines out of service and COI flow at about 3,400 MW, the NW RAS operated as designed for the double line outage contingency and keyed 2,563 MW of gen drop at Grand Coulee, Wells, John Day, Biglow Canyon Wind and Dooley Wind. The Chief Joseph Braking Resistor was also inserted as designed. Kemano Unit #1 was tripped by Kemano RAS several seconds later. Springerville Unit #4 was tripped about 40 seconds later due to boiler instability.

The purpose of model validation studies is two-fold:

- Validate accuracy of power system models used in dynamic simulations
- Performing "what if" sensitivity studies with respect to control actions

Based on the analysis and studies performed, the following conclusions and recommendations:

FREQUENCY RESPONSE

1. **Findings: Generation tripping during May 16, 2014 event was comparable to the resource loss contingency for the Western Interconnection per NERC BAL-003-1 Reliability Standard. The interconnection frequency stayed well above 59.5 Hz level (lowest recorded dip was 59.72 Hz), and the interconnection frequency response was consistent with the historic baseline and well above the interconnection Frequency Response Obligation.**

MODELING

2. **Findings: Simulated system frequency matched actual recordings quite well. Some discrepancies were observed in active power pick-up on major paths as well as responses of individual generators.**

Recommendations: Analysis of individual generator responses may provide additional insight in the power pick-up discrepancies. An application has been developed by Eric Bakie at Idaho Power and MVWG to verify the generator frequency response using SCADA data. The application is available to WECC operating entities. WECC power plant frequency response has not been reviewed programmatically since 2003. WECC Power Plant Model Data Task Force will update and review the baseload flag information as needed.

3. **Findings: Majority of operating West-Wide System Model is mapped to a WECC planning case, thereby greatly improving the development of a validation base case. However, major discrepancies exist in wind power plant representation between planning and operating models.**

Recommendation: We encourage expedited reconciliation between planning and EMS models for wind power plants. We recommend consistent application of WECC Wind Power Plant Powerflow Modeling Guidelines for planning and operating models across WECC utilities.

4. **Findings: Relatively large number of wind generators does not have dynamic models in the dynamic database. Significant amount of wind generation was on-line during May 16 event, and had to be load-netted in dynamic simulations.**

Recommendation: MVWG and SRWG need to work with TPs on identifying missing wind power plant models. MVWG will develop a data request for wind and solar generation needed to produce “default” data sets. MVWG will test and provide interim “default” models to TPs until the generators owners provide unit-specific model data.

5. **Findings: Reactive current compensation and cross-current compensation models are needed for sister units. This issue has been observed in 2012 and 2013 model validation studies.**

Recommendation: MVWG needs to expedite the development and implementation of Cross-Current Compensation models.

KEMANO

6. Findings: A response-based Kemano RAS operated on a power swing caused by Northwest RAS. There is no dynamic model for Kemano RAS to study potential interactions.

Recommendation: Modeling of response-based RAS schemes was identified as a top modeling priority from September 8, 2011 outage recommendations. Kemano RAS owners need to provide to MVWG information and ultimately a dynamic model for Kemano RAS scheme.

7. Findings: Studies show that the operation Kemano RAS operation may not have been necessary to preserve transient stability of Kemano – BC Hydro tie-line during May 16 event.

Recommendation: A response based scheme needs to balance reliability (operate when needed) and security (do not operate unnecessarily). Kemano RAS owners need to review the security of Kemano RAS in the context of this event.

8. Findings: Kemano generators play a very important role in dynamic behavior of the Western Interconnection. However, there is no adequate visibility of the Kemano dynamics, as the closest PMU at BCH's Willingston 500.

Recommendation: Kemano owners to install PMUs to monitor:

- Kemano 287-kV bus frequency, bus voltage phasor, and current phasors, active and reactive power in each of Kemano power plant transformers
- Measurements used to initiate Kemano RAS

PMU data is to be streamed continuously at 30 samples per second to Peak Reliability RC, BC Hydro and neighboring utilities. Kemano owners to work with WECC JSIS and WISP and determining data requirements.

NORTHWEST RAS AND CHIEF JOSEPH BRAKING RESISTOR

9. Findings: Studies show that the operation of Chief Joseph braking resistor may not have been necessary to preserve system stability during May 16 event. Studies also indicate that Chief Joseph brake operation amplified power swing at Kemano.

Recommendation: Chief Joseph braking resistor is used to absorb accelerating energy during power swings. Operation of Chief Joseph brake may not have been needed during May 16 event.

Chief Joseph brake is used as a safety net, and BPA needs to review security of the brake controller to minimize the unnecessary operations.

BPA also needs to provide a dynamic model for Chief Joseph controller.

SPRINGERVILLE #4 TRIP

10. **Findings: Springerville unit#4 tripped on low frequency during May 16 event, although the frequency stayed well within the envelope of NERC PRC-024 Reliability Standard. System frequency for May 16 event is compared with simulated two Palo Verde outage. Two Palo Verde outage would have caused a lower system frequency than what was observed during May 16 RAS event, and therefore 2PV outage would have likely caused the trip of Springerville unit #4. Springerville#4 trip would have had minimum impact on system frequency nadir, and some impact power pick-up and voltages on California – Oregon Intertie**.

Springerville #4 owners are taking steps to resolve issues that caused unit trip during May 16 event.

II. May 16, 2014 Event Description

On May 16 2014, Friday, at 23:18:15.85, the John Day - Grizzly #1 500-kV line tripped while John Day-Grizzly #2 line was out of service for construction. With both John Day – Grizzly # 1 and #2 lines out of service, the NW RAS operated as designed for the double line outage contingency and keyed 2,563 MW of gen drop at Grand Coulee, Wells, John Day, Biglow Canyon Wind and Dooley Wind, and inserted the Chief Joseph Braking Resistor.

NW RAS generation trip included:

Plant	Units	MW Dropped
BIGLOW CANYON	TOTAL GEN	419.4
DOOLEY WIND	TOTAL GEN	183.1
GRAND_COULEE	CKT2 TO G-6-9	236.5
GRAND_COULEE	G20	471
GRAND_COULEE	G21	508
JOHN_DAY	G09	113
JOHN_DAY	G12	112
JOHN_DAY	G14	111
JOHN_DAY	G16	114
WELLS	G03	73.86
WELLS	G05	73.85
WELLS	G08	73.55
WELLS	G09	73.75
TOTAL		**2563**

Kemano unit 1 tripped with approximately 110 MW. BC Hydro reported that the tripping of the Kemano unit was due to the combined frequency response of the eight Kemano generators, which were producing about 750 MW pre-disturbance with a net export into the BC Hydro system of 380 MW. The RAS on the Kemano-Kittimat 287-kV lines tripped one unit as designed (Kemano unit #1) when the net export from Kemano system to BC Hydro is greater than 420 MW.

Within approximately one minute of the NW Gen Drop, the Springerville unit #4 tripped with approximately 445 MW due to an apparent internal plant protection, although the system frequency was well within the NERC PRC-024 off-nominal frequency ride-through envelope. SRP reported that the Springerville unit #4 tripped off line due high furnace pressure and the loss of both ID Fans. SRP has identified potential “fixes” that could be applied to prevent the tripping of the unit for future frequency deviations (Springerville unit #4 also tripped during NW RAS event on January 29, 2014).

The system frequency dropped down to 59.73 Hz during the event, which is well above the first level of the coordinated under-frequency load shedding program set at 59.5 Hz. No loss of load is reported during the event.

John Day – Grizzly #1 Line was restored at about 23:20:30, about 2 minutes after it was tripped.

Figure 1 shows a 3-minute recording of the system frequency during the event.

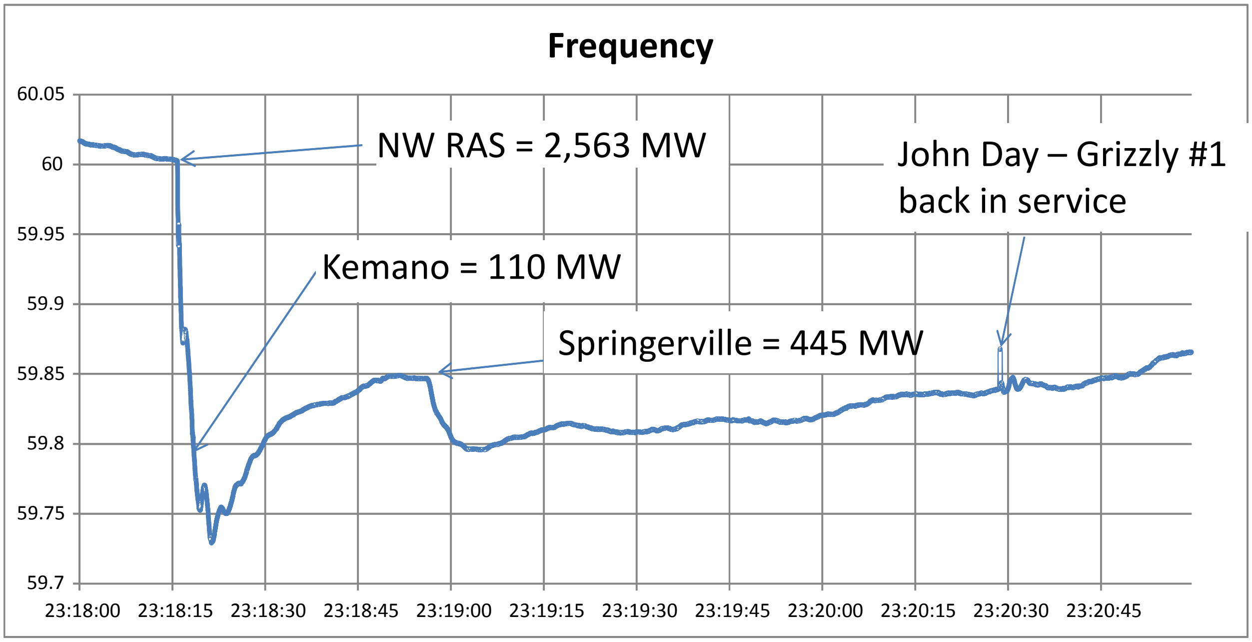


Figure 1: system frequency during May 16, 2014 disturbance.

III. System Frequency Performance During May 16, 2014 Event

No loss of load has been reported during the event.

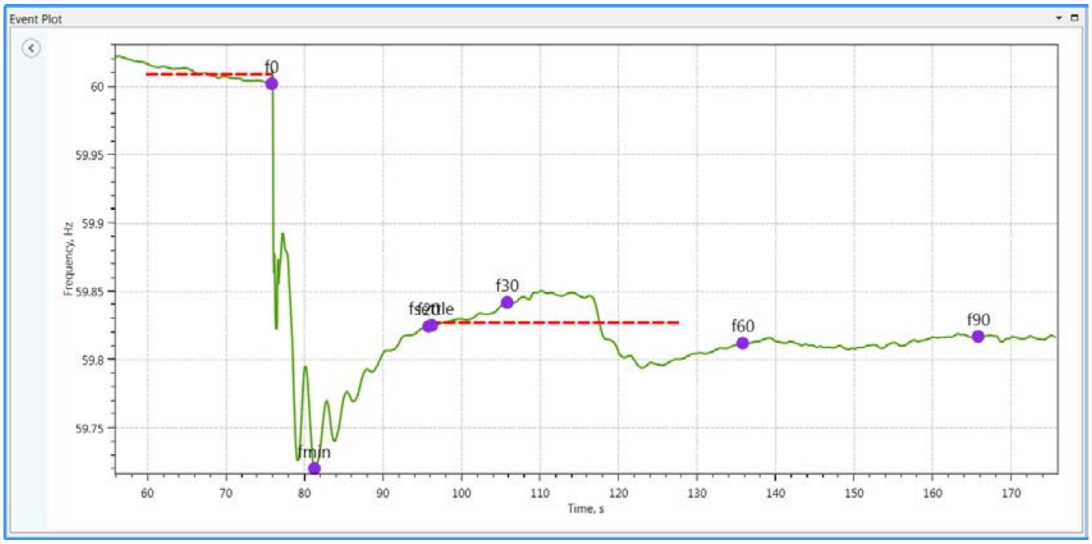


Figure 2: System frequency response – determining NERC Point A and Point B

Frequency response metrics are consistent the historic baseline, as highlighted in Figure 3.

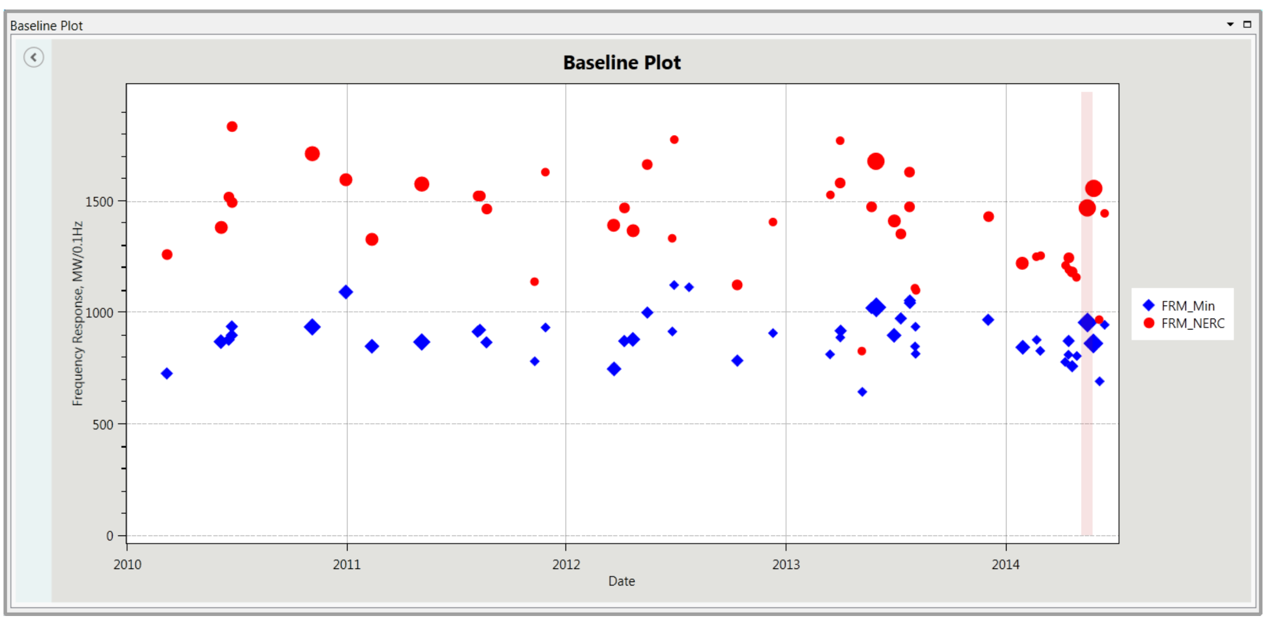


Figure 3: historic frequency response baseline in the Western Interconnection:
Red dots – frequency response is measured at Point B consistent with NERC BAL-003-1 methodology
Blue diamonds – response is measured at frequency nadir
Size of dots and diamonds is proportional to the size of the event

Interconnection-wide frequency response performance is performed:

Frequency – Point A (initial)	Hz	60.009
Frequency – Point B (settle)	Hz	59.827
Frequency – Point C (nadir)	Hz	59.720
Contingency (NW RAS+Kemano)	MW	2,673
NERC Frequency Response Measure	MW per 0.1 Hz	1,468
Nadir-based frequency response	MW per 0.1 Hz	924
Western Interconnection total generation	GW	97

The system frequency performance surpasses Frequency Response Obligation for Western Interconnection per NERC BAL-003-1, and consistent with historic baseline.

IV. Validation Base Case Development

2014 Light Summer WECC Operational Planning base case (planning case) is used as a starting point in the model validation studies.

Figure 4 shows a process diagram.

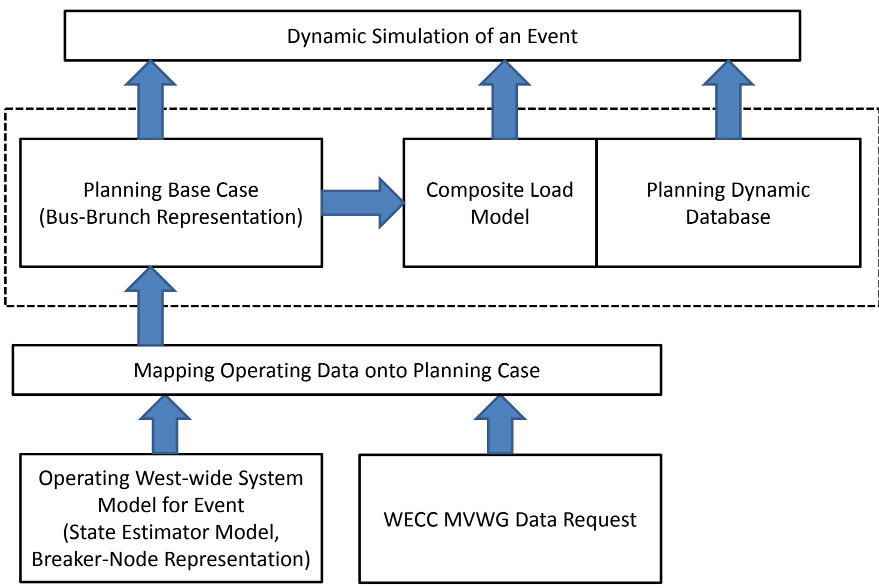


Figure 4: validation base case development process

WECC Modeling and Validation work group issued a data request for generation and key transmission flows prior to the event. Peak Reliability RC provided an operating West-wide System Model base case (WSM case) just prior to the disturbance. The operational information was mapped onto 2014 planning case. Regional loads were scaled to match the key tie-line flows. Also, dynamic simulation of event is performed directly using WSM and results are benchmarked against PMUs and 2014 planning case.

V. Dynamic Model

2014 operational dynamic data base is used in the validation studies.

Wind Generation.

Large amount of wind generation was on-line during May 16 event. A significant number of wind generators in Tehachapi area had no dynamic models in WECC dynamic data base. Several hundred MWs of generators had to be “netted” in dynamic simulation. Wind generation models in Pacific Northwest were unstable due to model additions, and were replaced with stable data used in 2013 studies.

Reactive Current Compensation.

Reactive Current Compensation is required to maintain stability between two sister units connected to the same bus:

- XCOMP sign is changed from +0.052 to –0.052 for RI STUB, RI SOUTH, RI NORTH units
- XCOMP sign is changed from +0.05 to –0.05 on MAGCORP units
- XCOMP of –0.05 for Little Goose units

Cross-Current Compensation.

John Day and The Dalles generators went unstable during the simulation. John Day and The Dalles generators have Line Drop Compensation for voltage support and Cross-Current Compensation to ensure stability of sister units. Current generator models include Line Drop Compensation, but there is no Cross-Current Compensation model in PSLF. Not having CCOMP model is adequate as long as sister units are identical and have the same active and reactive power loading, as often set-up in planning cases. Operationally, units are often loaded at different levels, and therefore go unstable without CCOMP models. To mitigate the issue, John Day generators were re-dispatched to same “average” level.

SVSMO1 dynamic model is added for Keeler SVC

Composite Load Model

Composite load model records are developed using WECC Load Model Data Tool. Shoulder season hour 22 are used to estimate load composition.

VI. Simulations

Simulated sequence of events:

Time (sec)	Action
0	Open John Day – Grizzly 500-kV line #1
0.125	RAS Gendrop – Dooley, Biglow Canyon, Grand Coulee, Wells, and John Day
0.125	Close Chief Joseph braking resistor
0.64	Open Chief Joseph braking resistor
2.3	Trip Kemano unit #1
2.3	Malin MSC cap #1 tripped
2.65	Ostrander reactors are tripped
2.72	Pearl capacitors are inserted
2.88	Slatt shunt capacitors are inserted
5.3	Malin shunt reactor is inserted
32.9	Grizzly shunt reactor is inserted
40.9	Springerville Unit#4 tripped

*Initial report had Kemano tripping at about 7 seconds after the initial event. PMU data analysis and model validation indicate that the tripping occurred earlier

Figures M1 to M6 and S1show comparison between actual and simulated responses.

VII. West-Wide System Model Studies

West-Wide System Model (WSM) is a node breaker (full topology) state estimator model from Peak Reliability RC. GE PSLF version 19 has capabilities to read node-breaker power flow model and link it with the WECC dynamic database. Peak Reliability RC and WECC performed model validation studies using the state estimator snapshot taken prior to the event. Figures WSM-1 to WSM-6 compare (i) PSLF simulations done using bus-branch WECC planning model, (ii) PSLF simulations done using node-breaker WSM model, and (iii) actual PMU recordings. WSM model agrees with WECC planning model, and both capture the main features of the May 16 event reasonably well.

VIII. Sensitivity Studies

Sensitivity “what if” studies are conducted once the system model is validated reasonably well

Kemano RAS:

Kemano RAS tripped Kemano unit #1 with 110 MW for a power swing following Pacific Northwest gen drop.

Questions:

a. Was Kemano RAS operation necessary during the May 16 conditions?
b. Would the system remain stability and adequate performance if Kemano RAS did not operate on May 16?
c. Would a two Palo Verde outage trigger Kemano RAS operation?

May 16 sequence of events was simulated with and without Kemano tripping. Two Palo Verde outage was simulated on May 16 base case.

Conclusions and Recommendations:

a. There are no dynamic models to simulate Kemano RAS in dynamic simulations. Kemano owners are required to provide description of their RAS scheme and associated dynamic models.
b. Although Power swing at Kemano was relatively large, as suggested by Figure K1, Kemano RAS operation may not have been needed for the system stability during May 16 event, as seen from simulations in Figure K2.
c. Kemano RAS owners are suggested to look into improving security of their RAS scheme
d. 2 Palo Verde outage caused a less severe power swing at Kemano compared to May 16 RAS event, and not likely to initiate Kemano RAS operation (Figure K3).

Springerville #4 Trip

Springerville unit #4 tripped on May 16 due to boiler instability caused by low frequency about 40 seconds after the initiating event. The closest to Springerville PMU is one at Coronado 500-kV bus. Figure S1 shows a good agreement between actual and simulated voltages and frequencies at Coronado 500-kV substation.

Questions:

a. Would Springerville unit #4 trip for a 2 Palo Verde outage?
b. What would have been the impact on California – Oregon Intertie should 2 Palo Verde outage occurred and Springerville unit tripped after that

Studies:

Simulations of 2 Palo Verde outage were performed to compare the frequency at Springerville#4 with the frequency during May 16 RAS event.

Simulations of 2 Palo Verde outage plus Springerville#4 trip were performed to determine any impact the additional generation would have had on the stability of California – Oregon Intertie.

Conclusions:

a. Springerville frequency would have been lower for 2 Palo Verde outage compared to system frequency during May 16 event, therefore it is very likely that Springerville unit would have tripped for 2 Palo Verde outage (Figure S3)
b. Springerville trip following 2 Palo Verde outage would have had some, but not significant, impact on the COI voltages and power pick-up (Figure S4)

Springerville#4 owners are working on resolving technical issues that resulted in the unit's trip.

Interaction between Northwest RAS and Kemano RAS:

NW RAS dropped 2,500 MW of generation and initiated operation of Chief Joseph braking resistor, which created a power swing that resulted in the operation of Kemano RAS.

Questions:

a. Generator dropping amounts are determined based on planning studies, usually considering conservative system conditions. Given actual system conditions, was dropping of 2,500 MW of generation was necessary, or lower gen drop amount would have suffice?
b. What the impact of lower gen drop would have been on the Kemano power swing?
c. What the impact of Chief Joseph braking resistor not operating would have been at Kemano power swing?

Studies:

Simulations of May 16 event were performed without operation of Chief Joseph brake.

Simulations of May 16 event were performed with lower amount of NW RAS gen drop.

Conclusions and Recommendations:

a. Reducing amount of NW gen drop had minimum impact on Kemano power swing (Figure N1)
b. Chief Joseph brake operation had observable impact on Kemano power swing (Figure N-2).

To answer whether a smaller amount of gen drop would have been sufficient under May 16 condition, a full set of contingency analysis would need to be done per NERC TPL standards, including thermal, voltage stability and dynamic simulations. The system performance must be met for line outages initiated by 3-phase faults, while May 16 event was high impedance fault with low fault current

BPA planning needs to consider improving the security of controller that operates Chief Joseph braking resistor to minimize the unnecessary operations.

Kemano Power System Stabilizer

Kemano generators use dual-input Power System Stabilizers (PSS). The PSS synthesizes the integral of accelerating power from speed and power measurements. The calculation of PSS gain “Ks2” is dependent on generator inertia. It was observed during recent review of PSS settings conducted by Shawn Patterson and WECC JSIS that the calculations of Kemano PSS gains “Ks2” assume wrong generator inertia.

Question:

a. What would be the impact of changing the Kemano PSS gain “Ks2” to match generator inertia?

Table below shows generator inertia and associated PSS settings:

Kemano	Generator Inertia, H	PSS washout ime constant, Tw	PSS Gain Ks2 to match H	PSS Gain Ks2 as is
G1	3.2	5	0.781	0.5
G2	4.74	5	0.527	0.33
G3	4.68	5	0.534	0.37
G4	3.2	5	0.781	0.5
G5	4.68	5	0.534	0.37
G6	5.25	5	0.476	0.33
G7	3.2	5	0.781	0.5
G8	5.25	5	0.476	0.33

Simulations were performed with new PSS settings. Study results are summarized in Figure KP1.

Conclusion:

a. Changing Kemano PSS gain “Ks2” would have had a slightly negative impact on Kemano power swing.

Kittimat Load Model Composition

Composite load model is used in the studies. Kittimat aluminum smelter is represented with default model, where 10% of load are induction motors driving frequency-dependent loads (pumps and fans), and 90% of load is constant resistance load. A sensitivity study is done with respect to a more demanding load characteristic, where 20% of loads are induction motors driving constant torque load, and 80% of load is constant current. No significant change in performance is observed in this study, as shown in Figure KIT1.

Frequency Response Margin

Simulations were run where the amount of gen.drop is increased until the system frequency nadir approached 59.5 Hz, the level at which the coordinated under-frequency load shedding plan starts. We simulated up to 4,000 MW of generation dropping in Pacific Northwest, by tripping additional hydro-power generation at John Day and Chief Joseph. Figures E1 and E2 show frequency recordings in various parts of the interconnection, they all stay above 59.5 Hz level. Figure E3 shows voltages at key tie-lines which are known to be affected by gen.drop events. Voltages in Kemano area are affected the most by increased gen.drop under the studied condition. While the system frequencies stayed above 59.5 Hz, we do not suggest increasing the amount of gen.drop beyond the existing levels in the Western Interconnection.

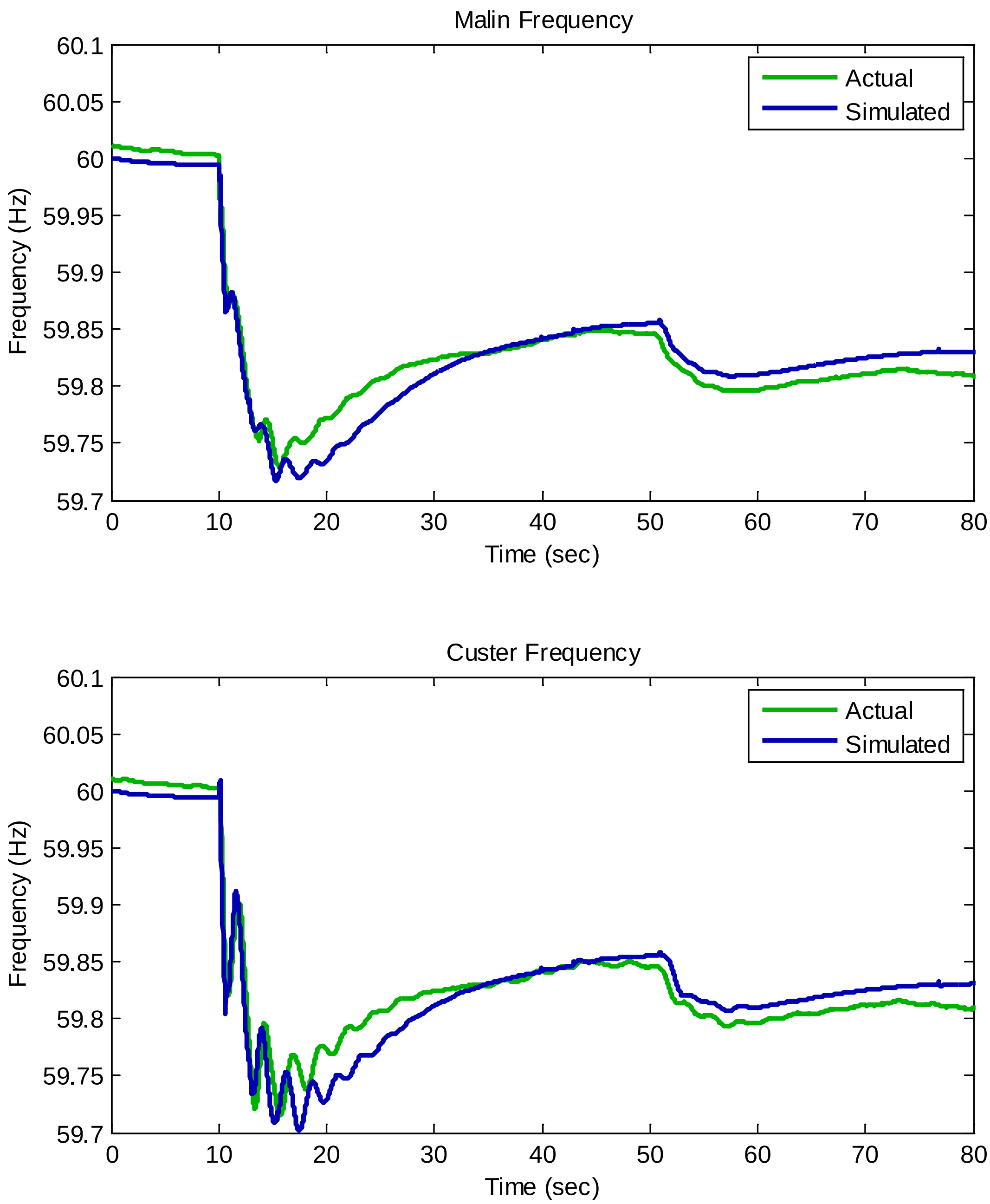


Figure M1: Simulated versus Actual Frequency

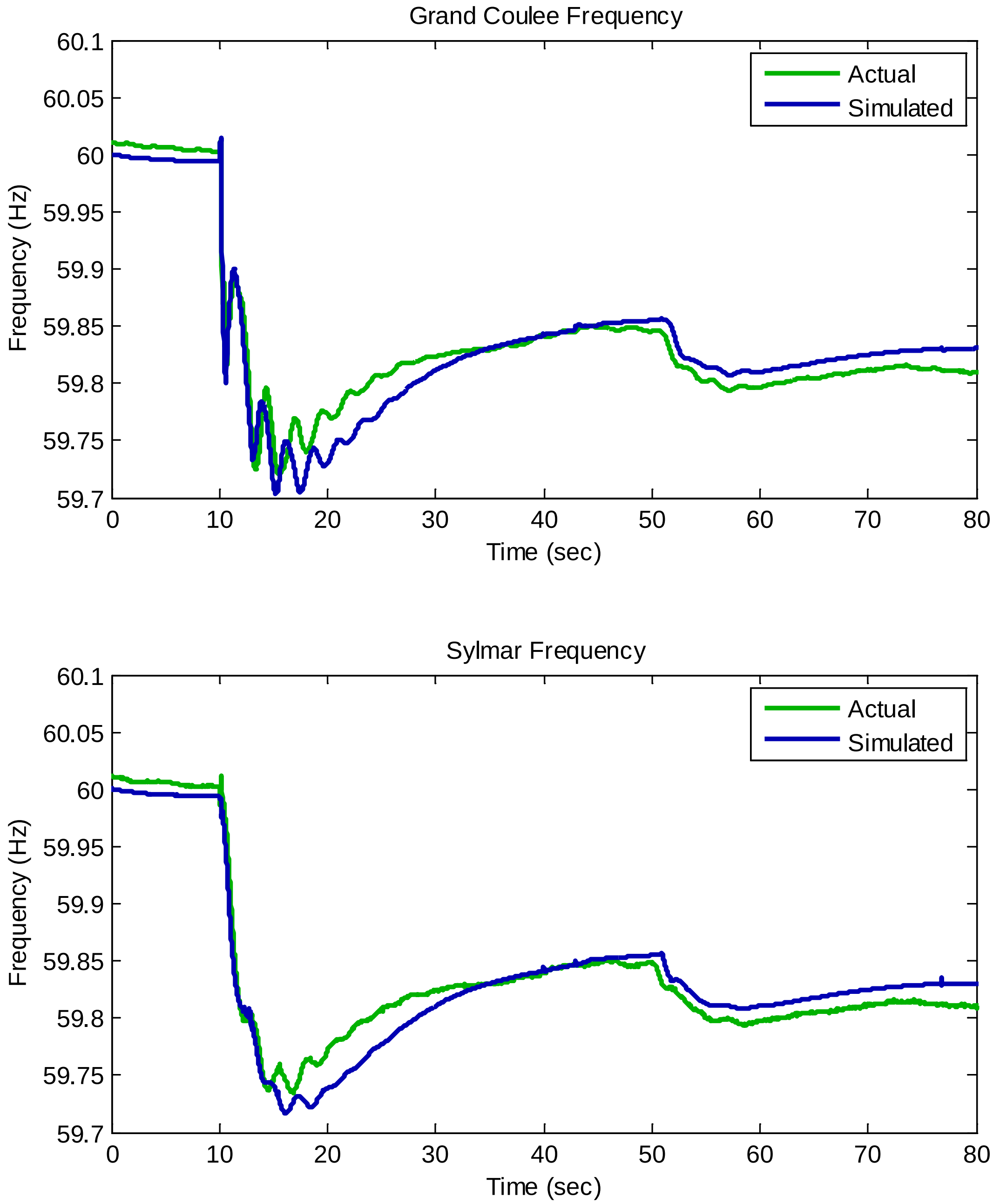


Figure M2: Simulated versus Actual Frequency

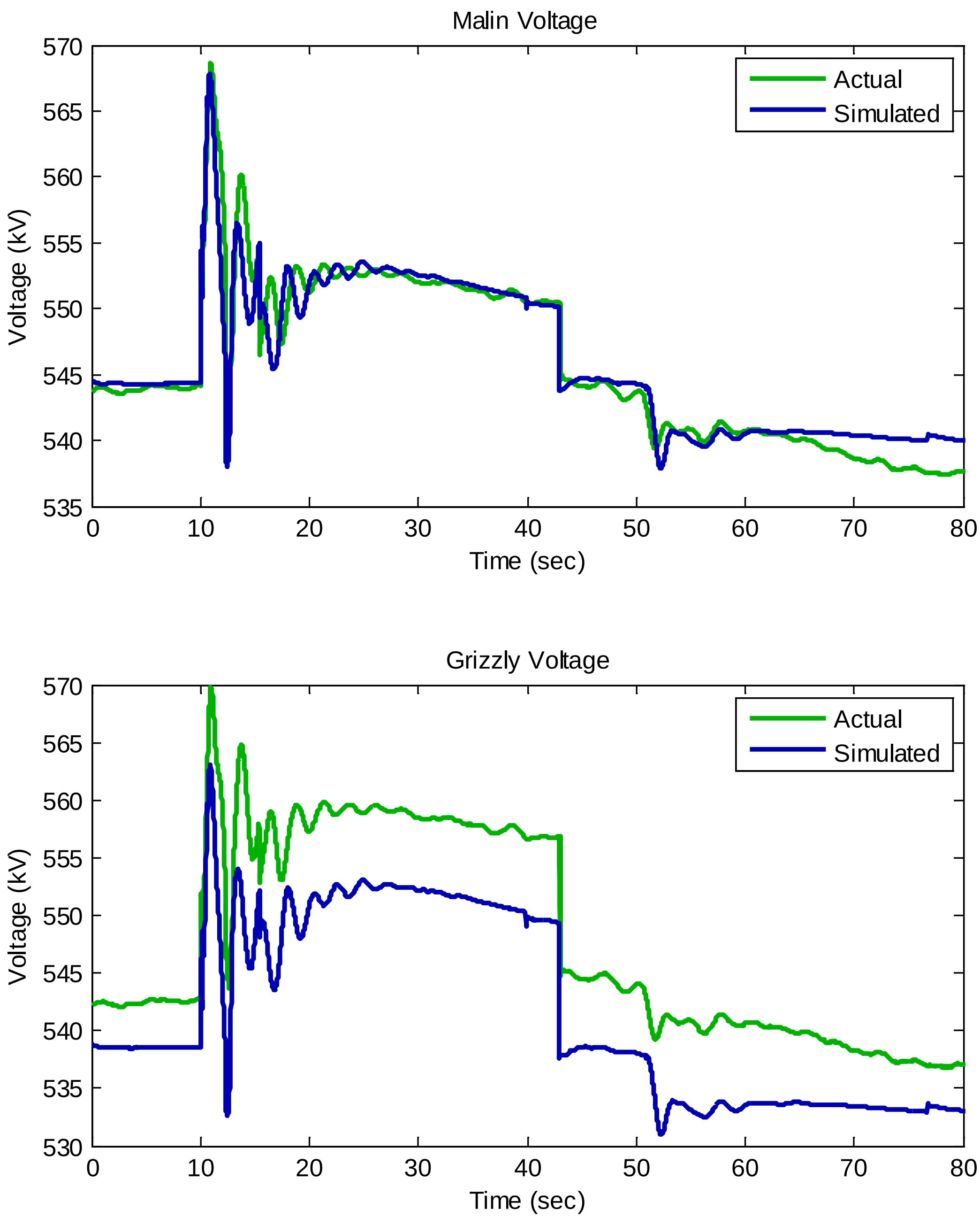
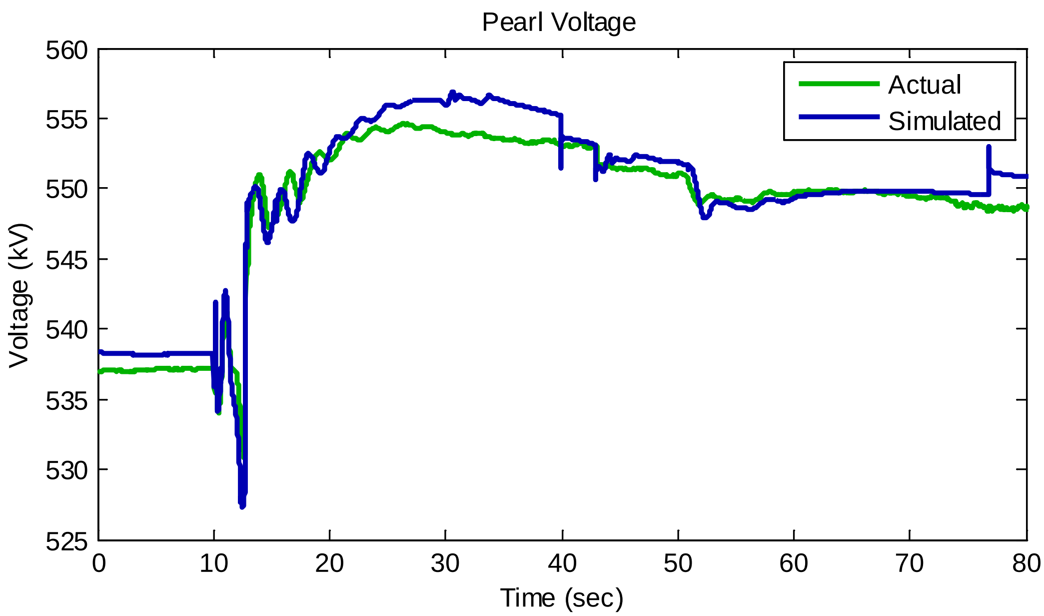


Figure M3: Simulated versus Actual Voltages



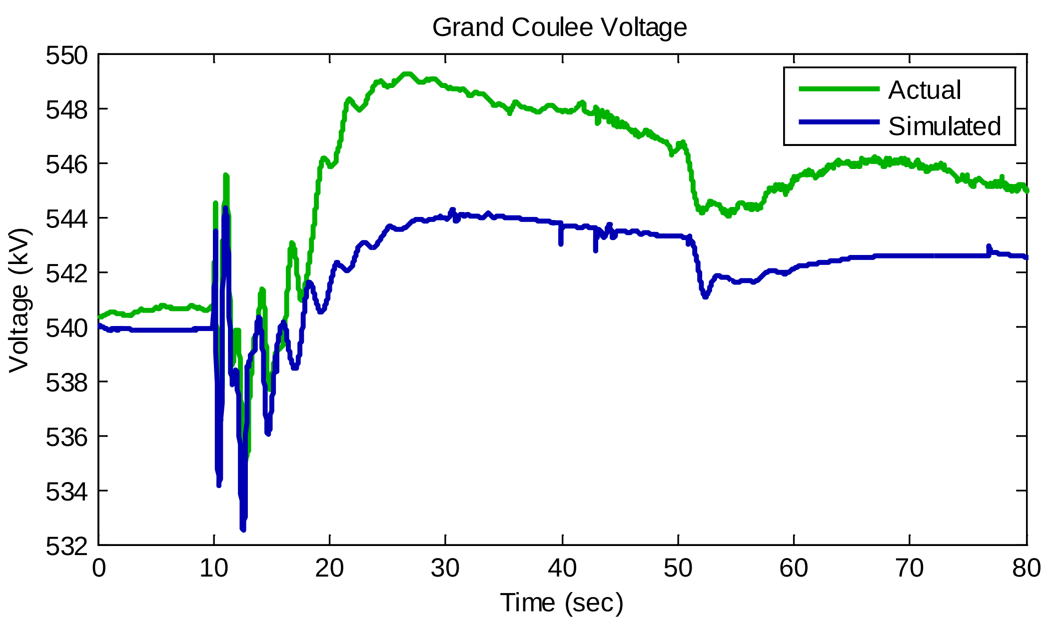


Figure M4: Simulated versus Actual Voltages

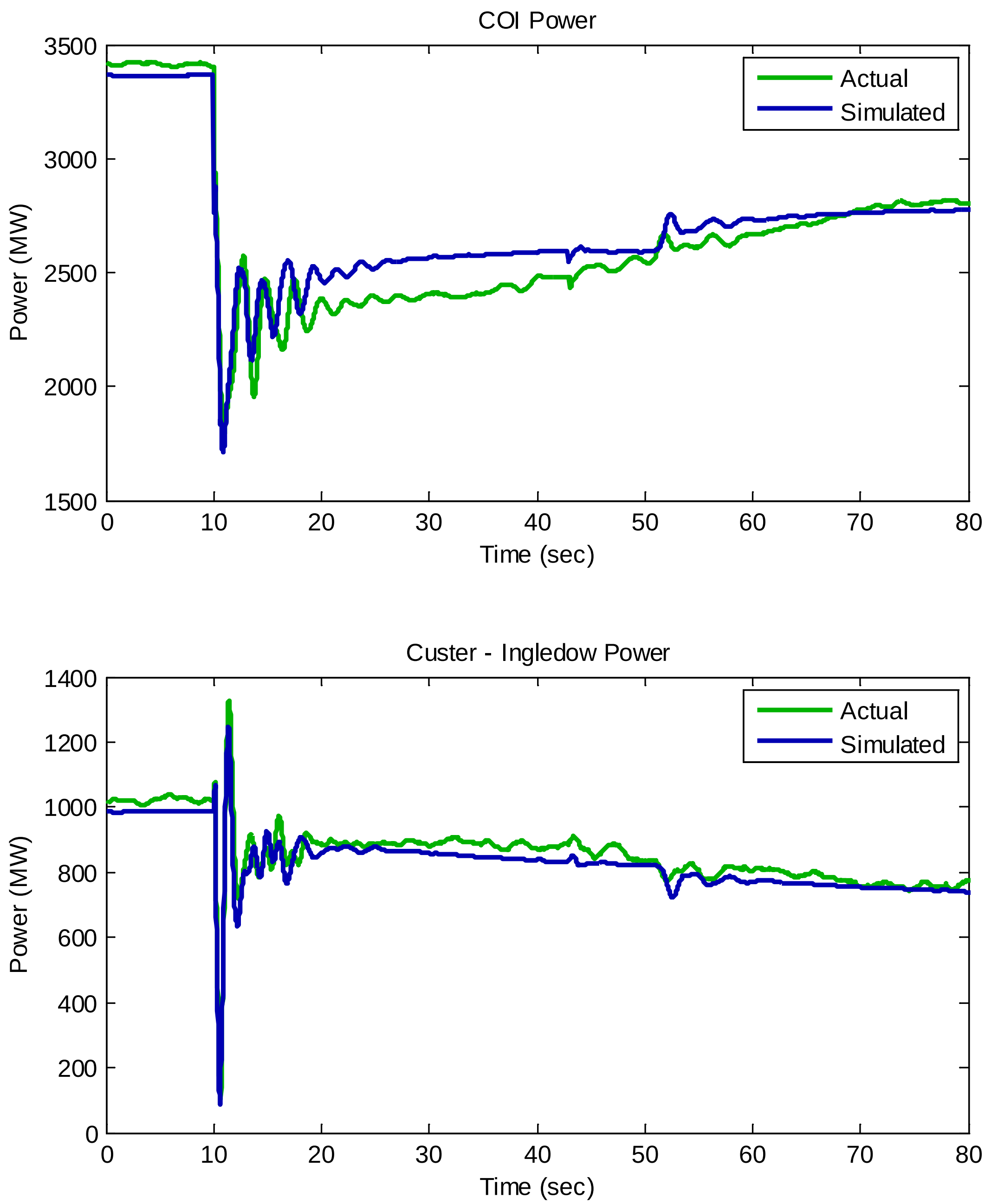


Figure M5: Simulated versus Actual Power Flows

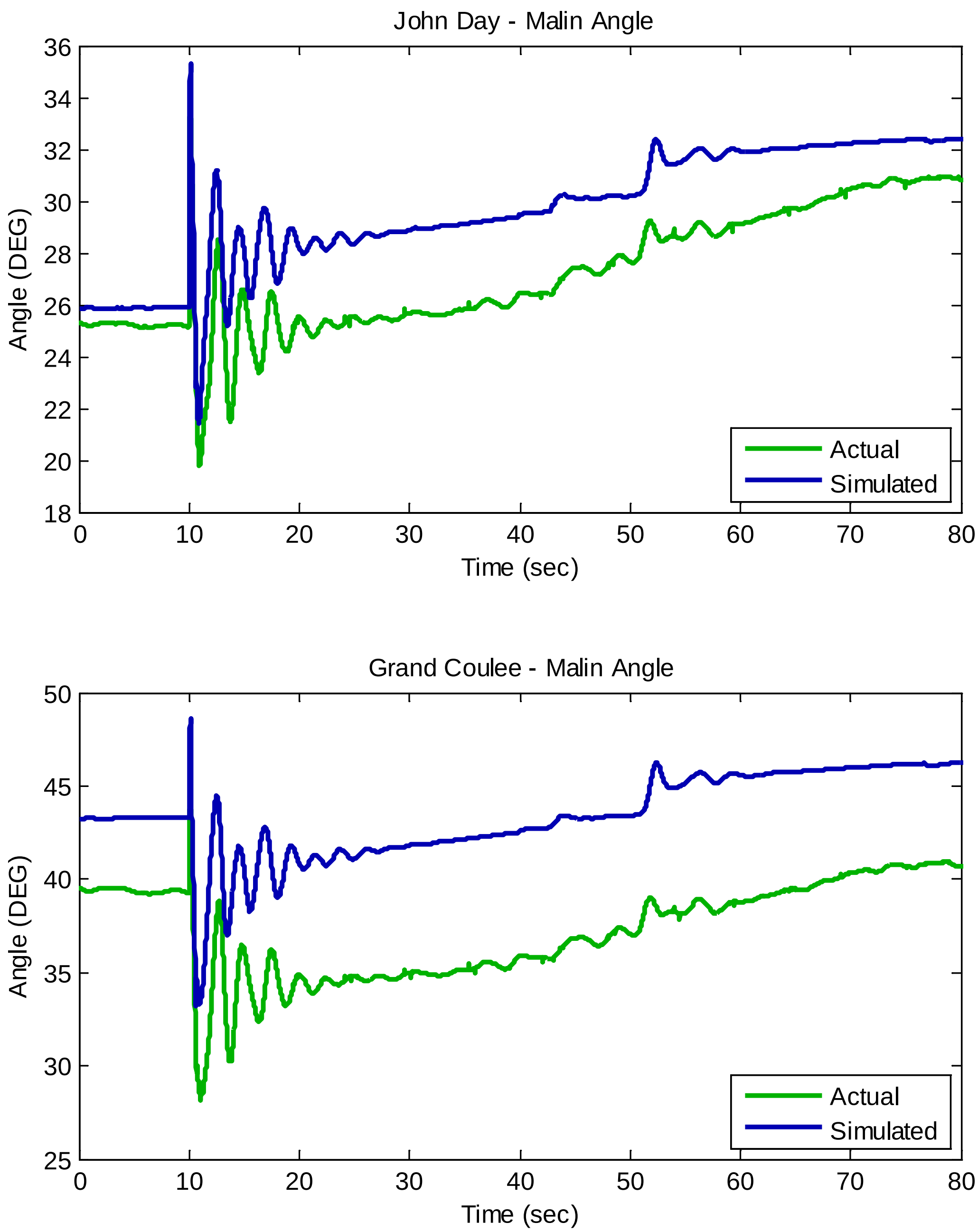


Figure M6: Simulated versus Actual Phase Angles

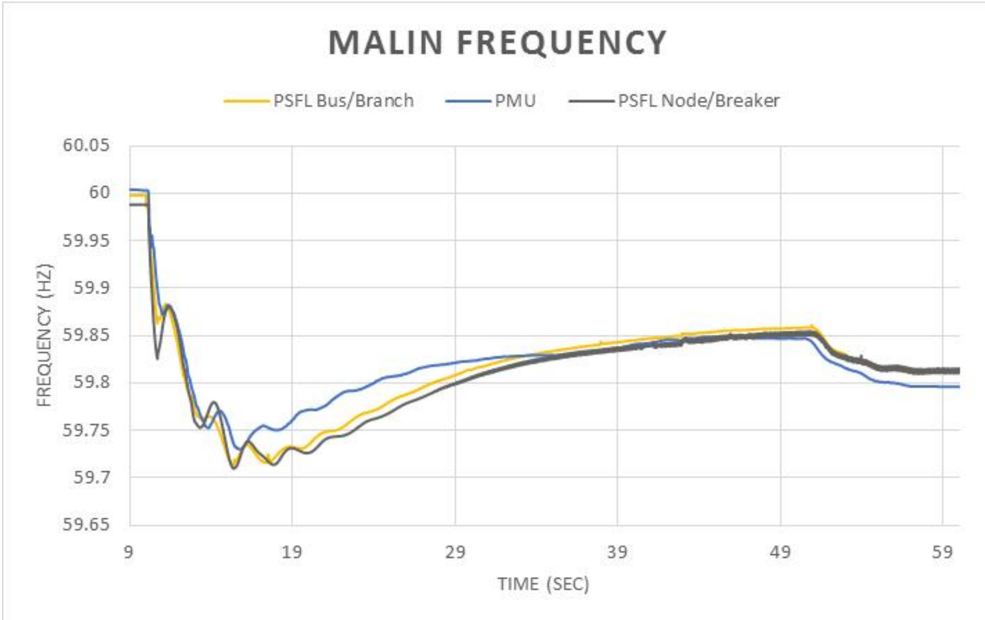


Figure WSM-1: Malin 500-kV Bus Frequency

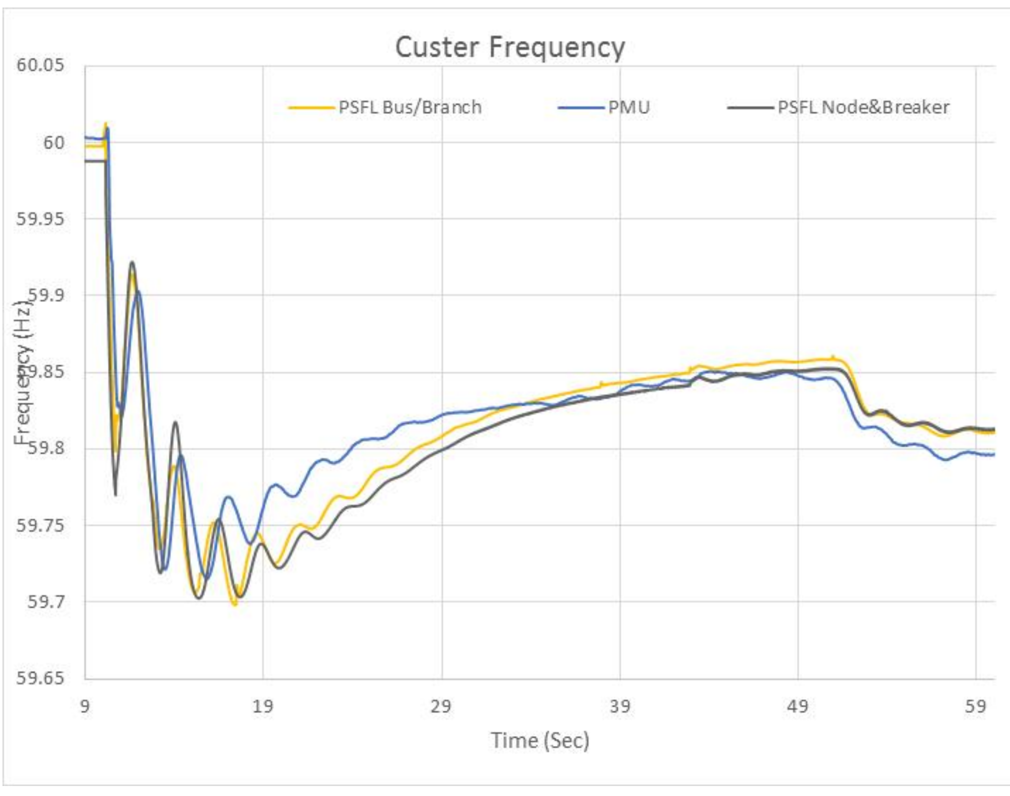


Figure WSM-2: Custer 500-kV Bus Frequency

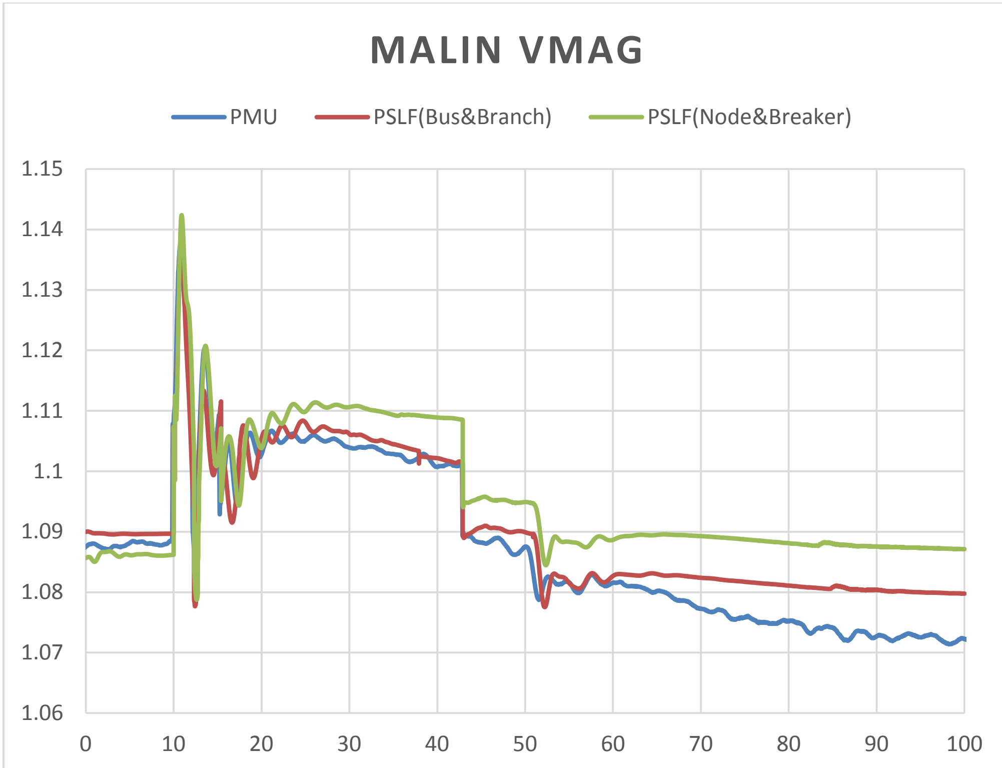


Figure WSM-3: Malin 500-kV Bus Voltage

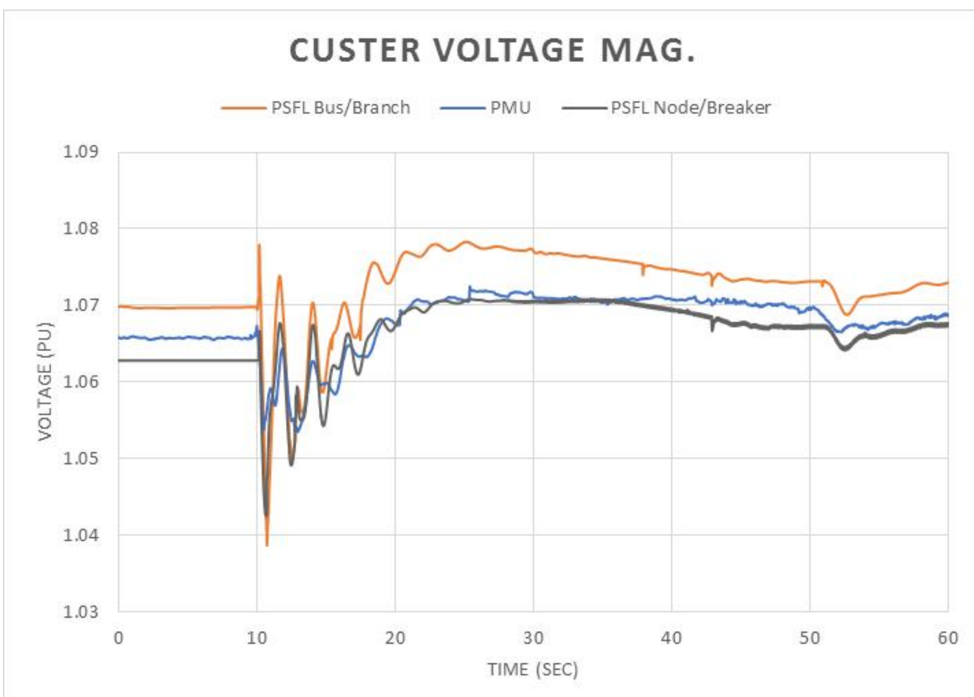


Figure WSM-4: Custer 500-kV Bus Voltage

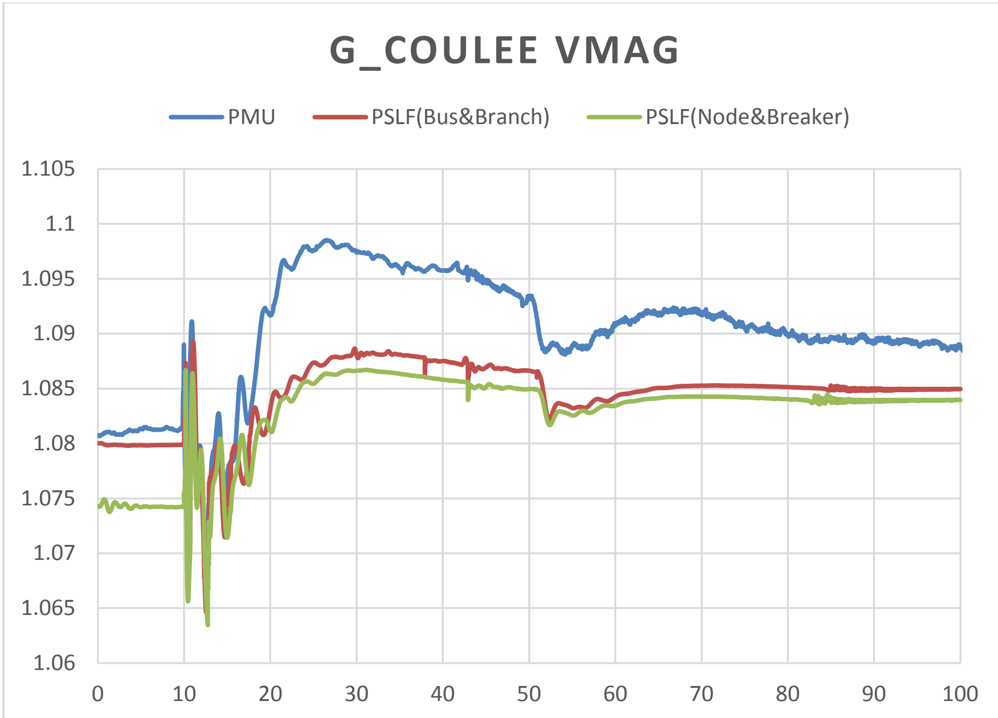


Figure WSM-5: Grand Coulee 500-kV Bus Voltage

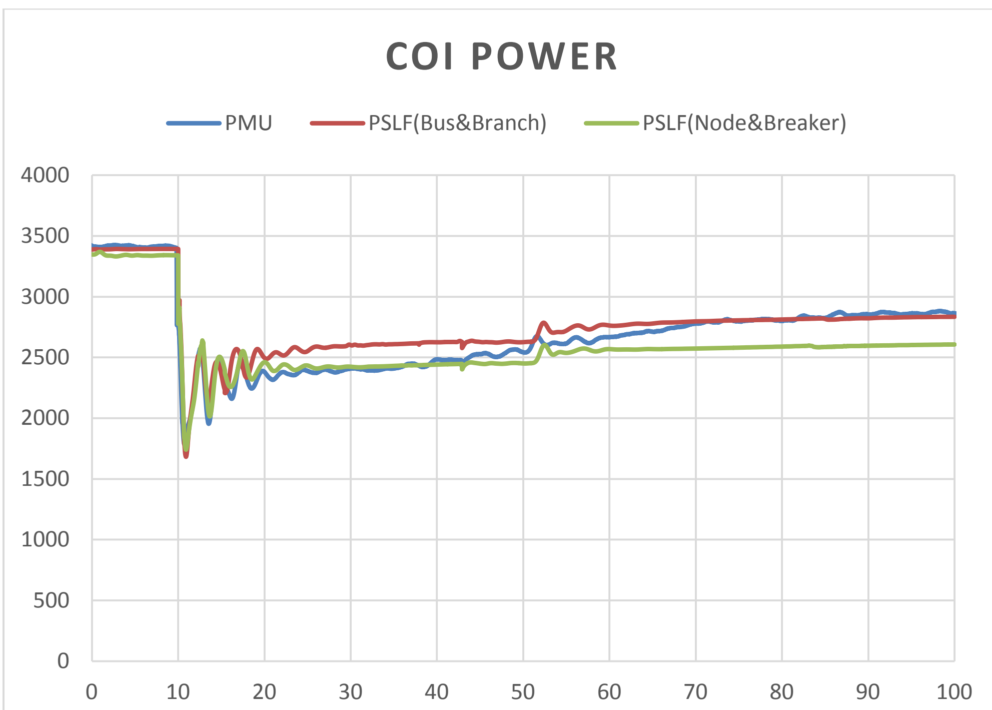


Figure WSM-6: COI total power

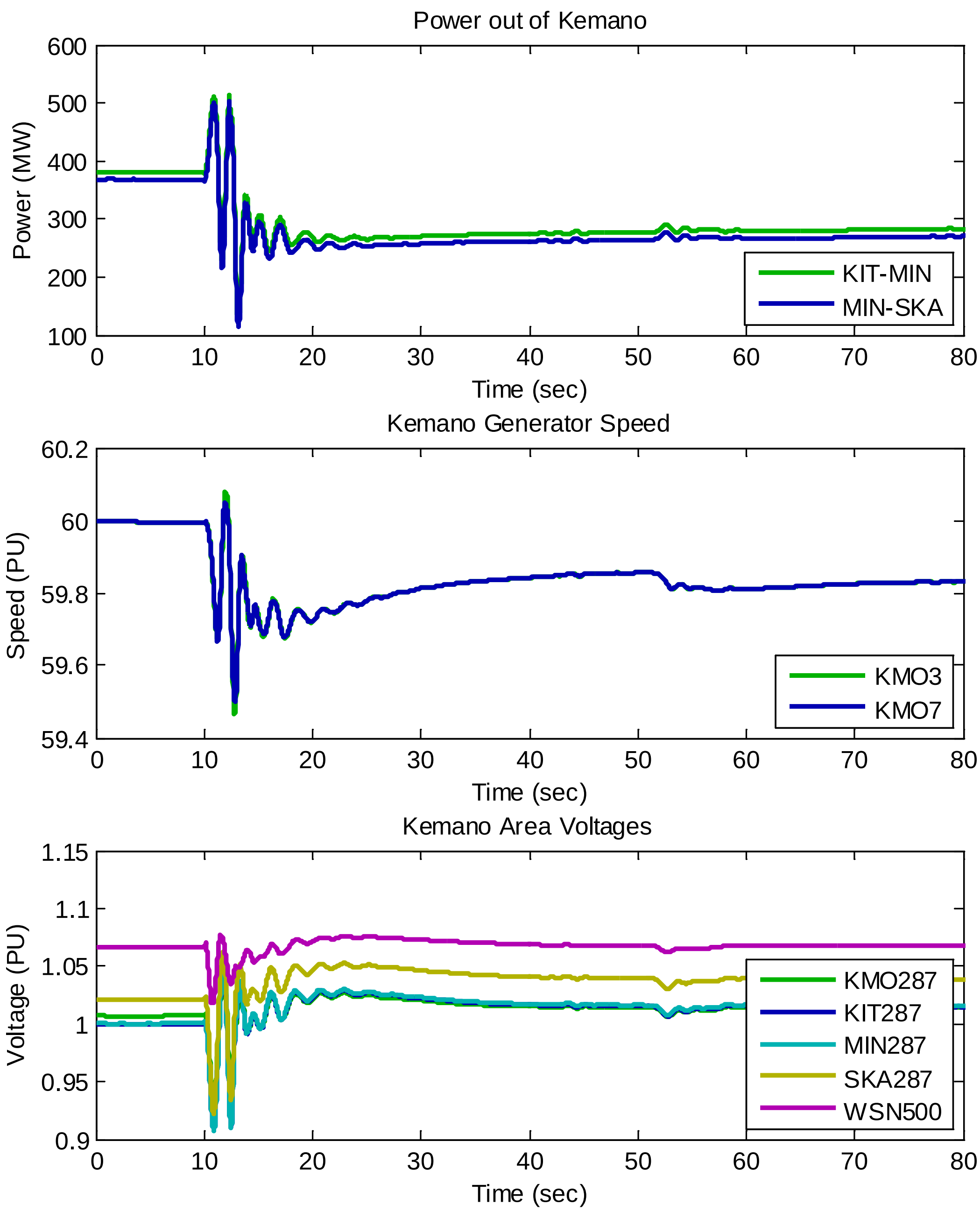


Figure K1: Simulated Kemano Dynamics during May 16 RAS event

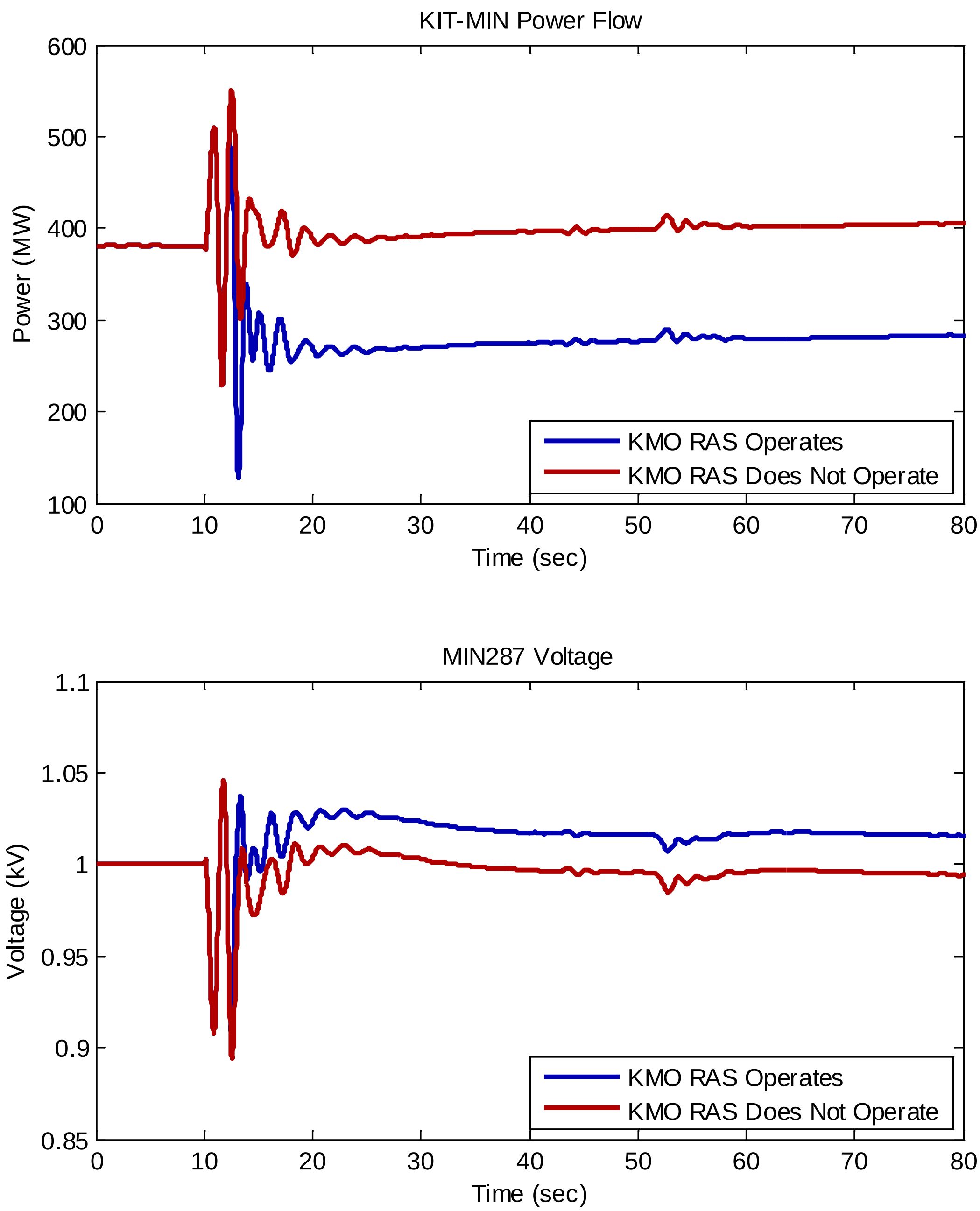


Figure K2: Comparison of Simulated Kemano Dynamics with Kemano RAS operating and not operating for May 16 condition

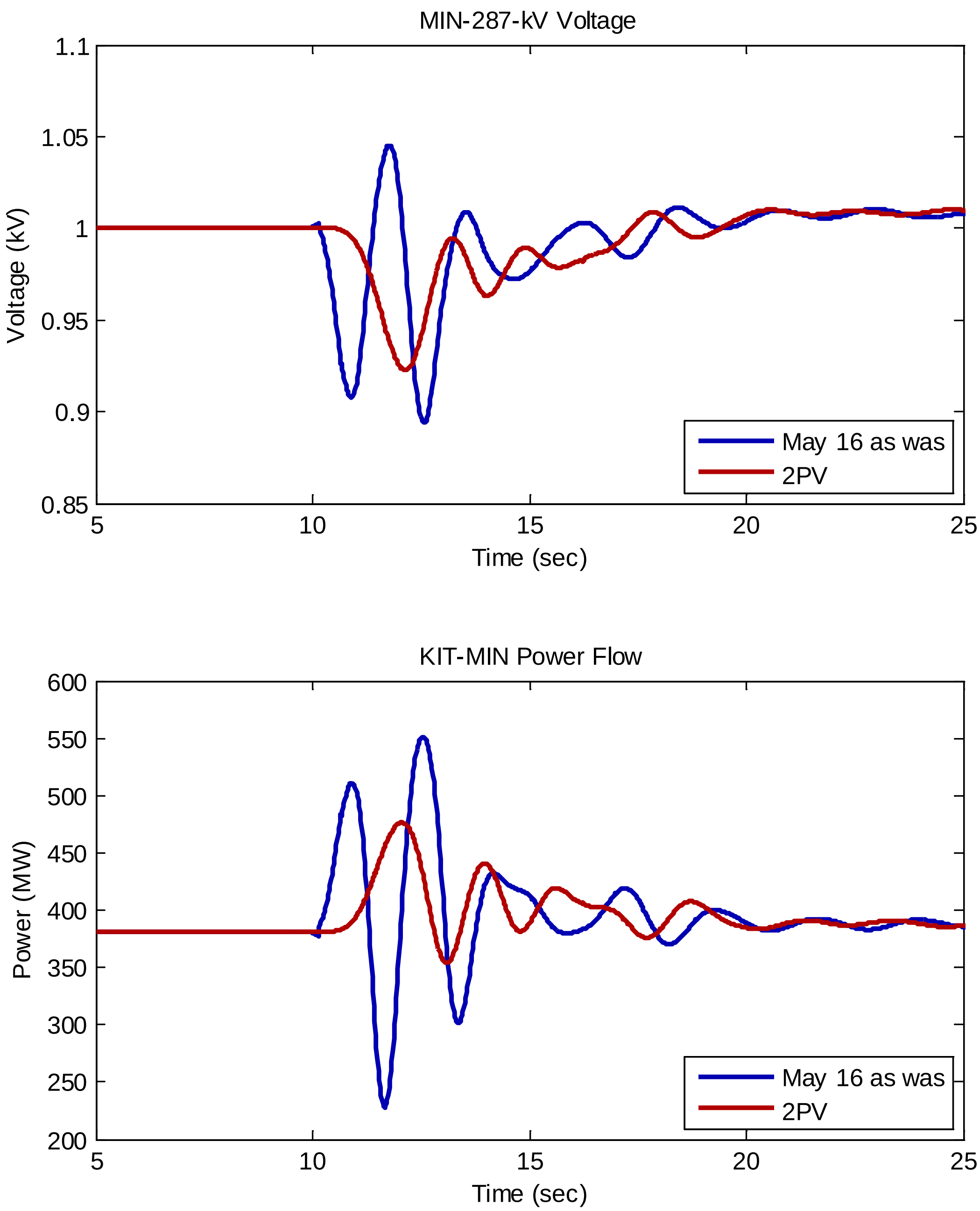


Figure K3: Comparison between May 16 RAS event and 2 Palo Verde as seen at Kemano

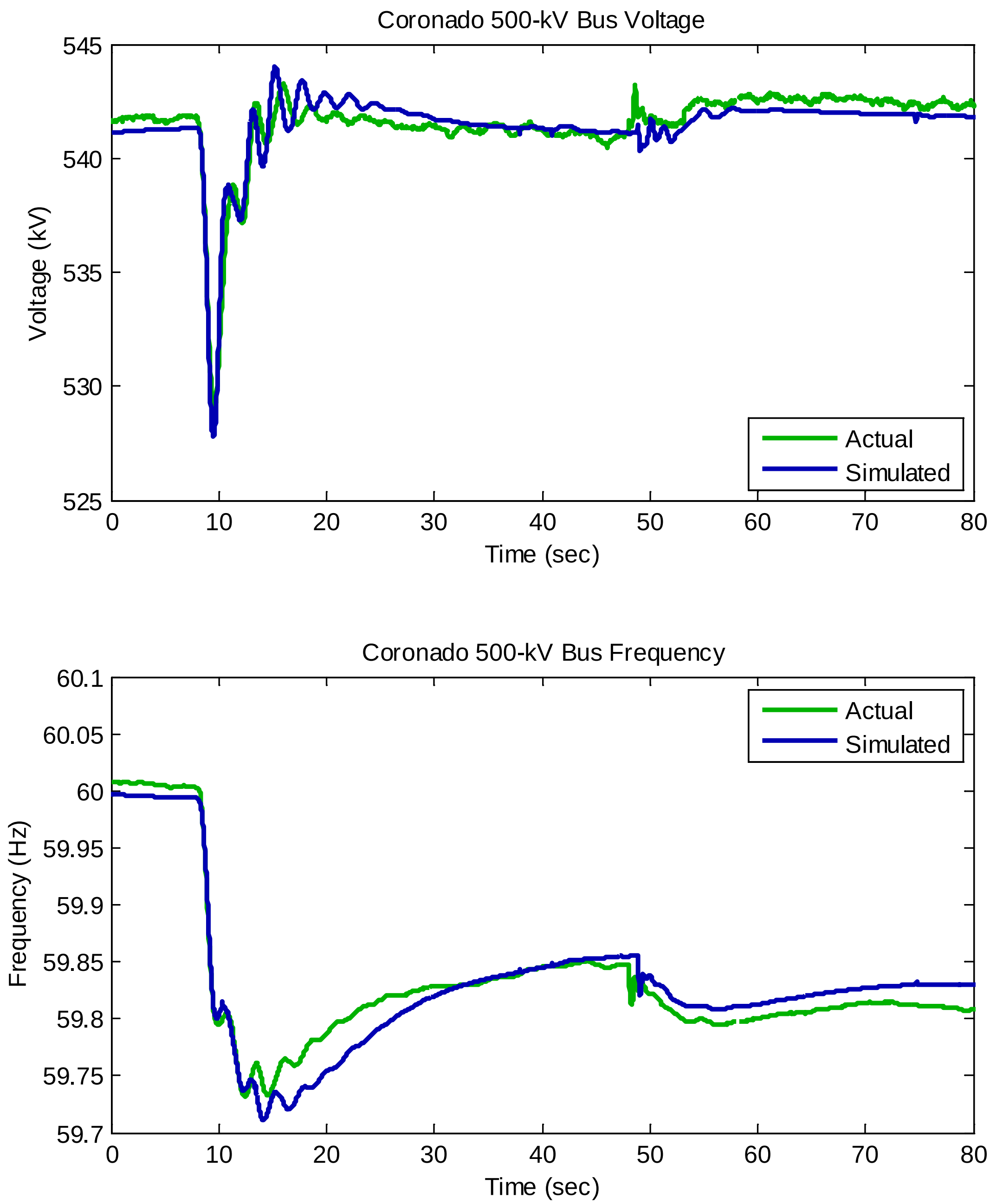


Figure S1: Simulated versus Actual Coronado 500-kV Voltage and Frequency During May 16 Event

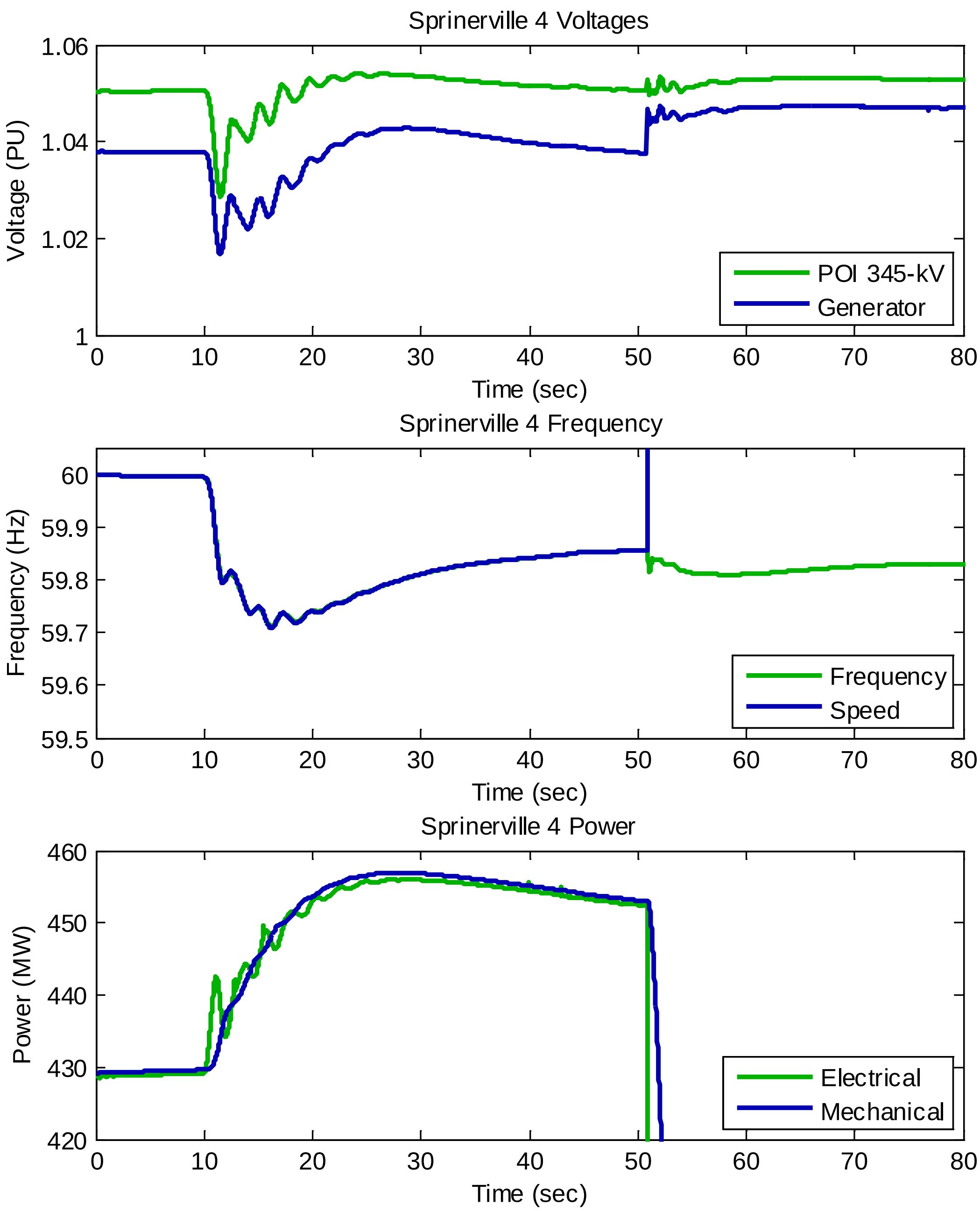


Figure S2: Simulated Springervile 4 Dynamics During May 16 RAS Event

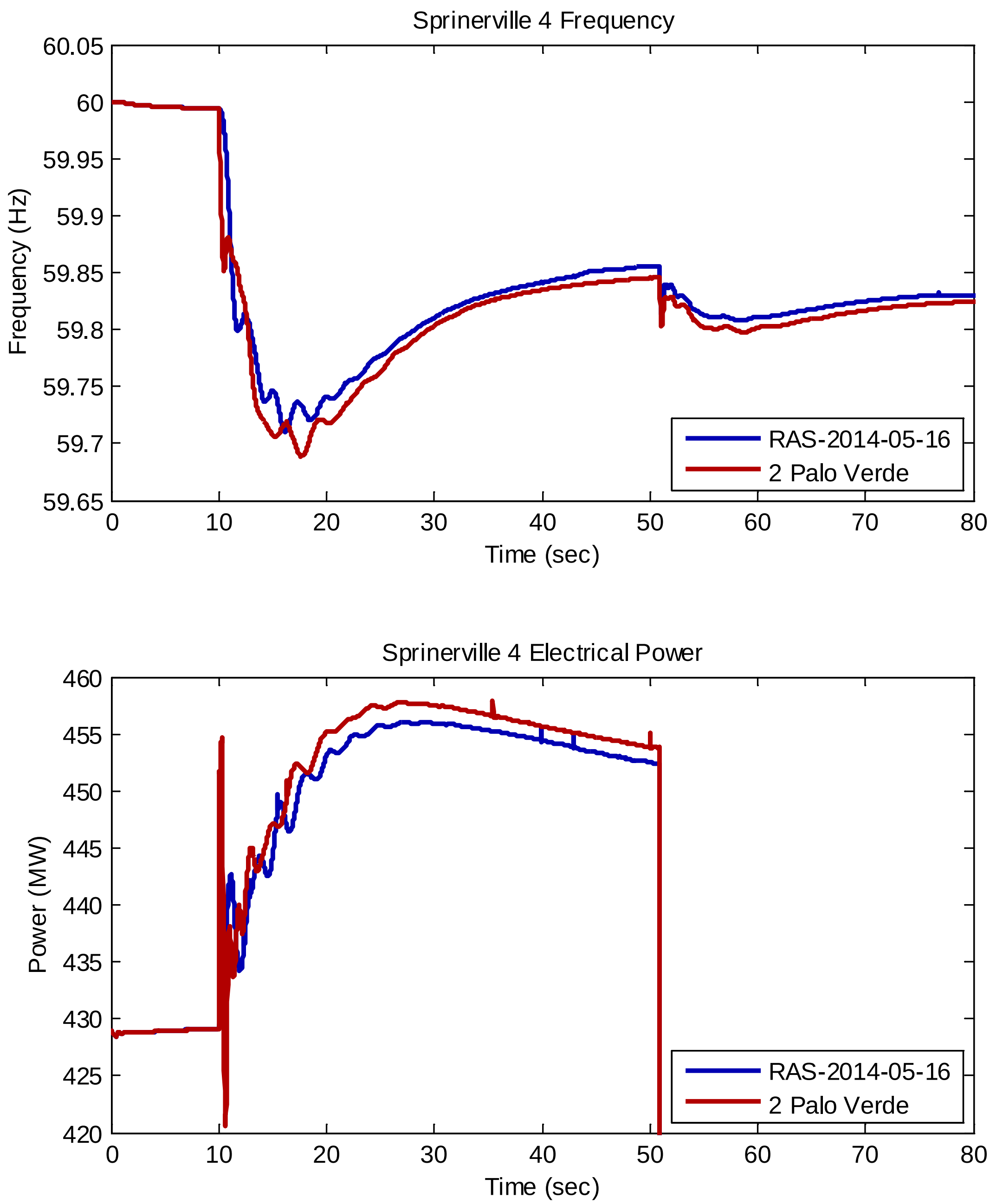


Figure S3: Comparison of Simulated Springervile Dynamics During May 16 RAS Event and 2 PV event

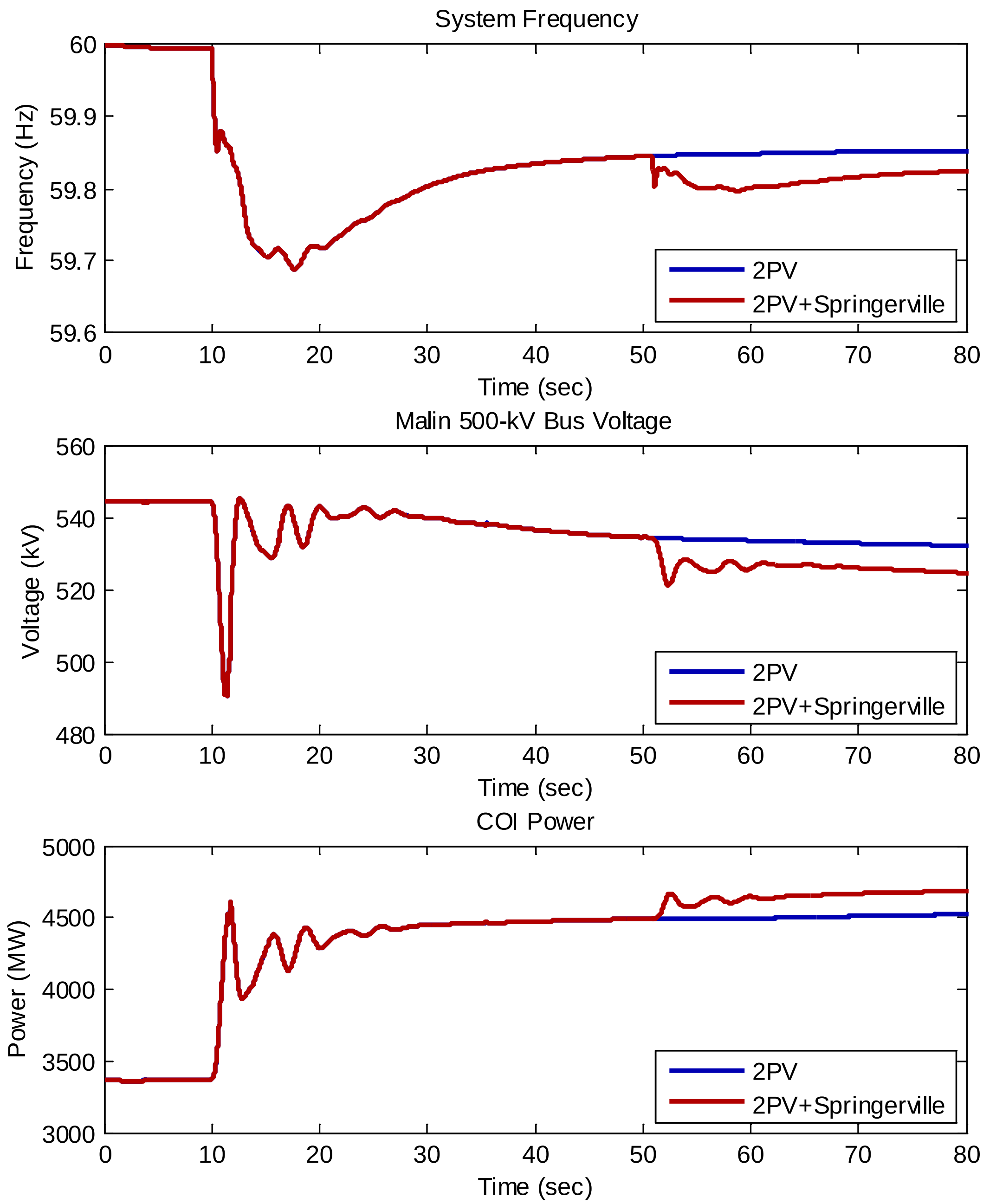


Figure S4: Comparison of Simulated Springervile Dynamics During May 16 RAS Event and 2 PV event

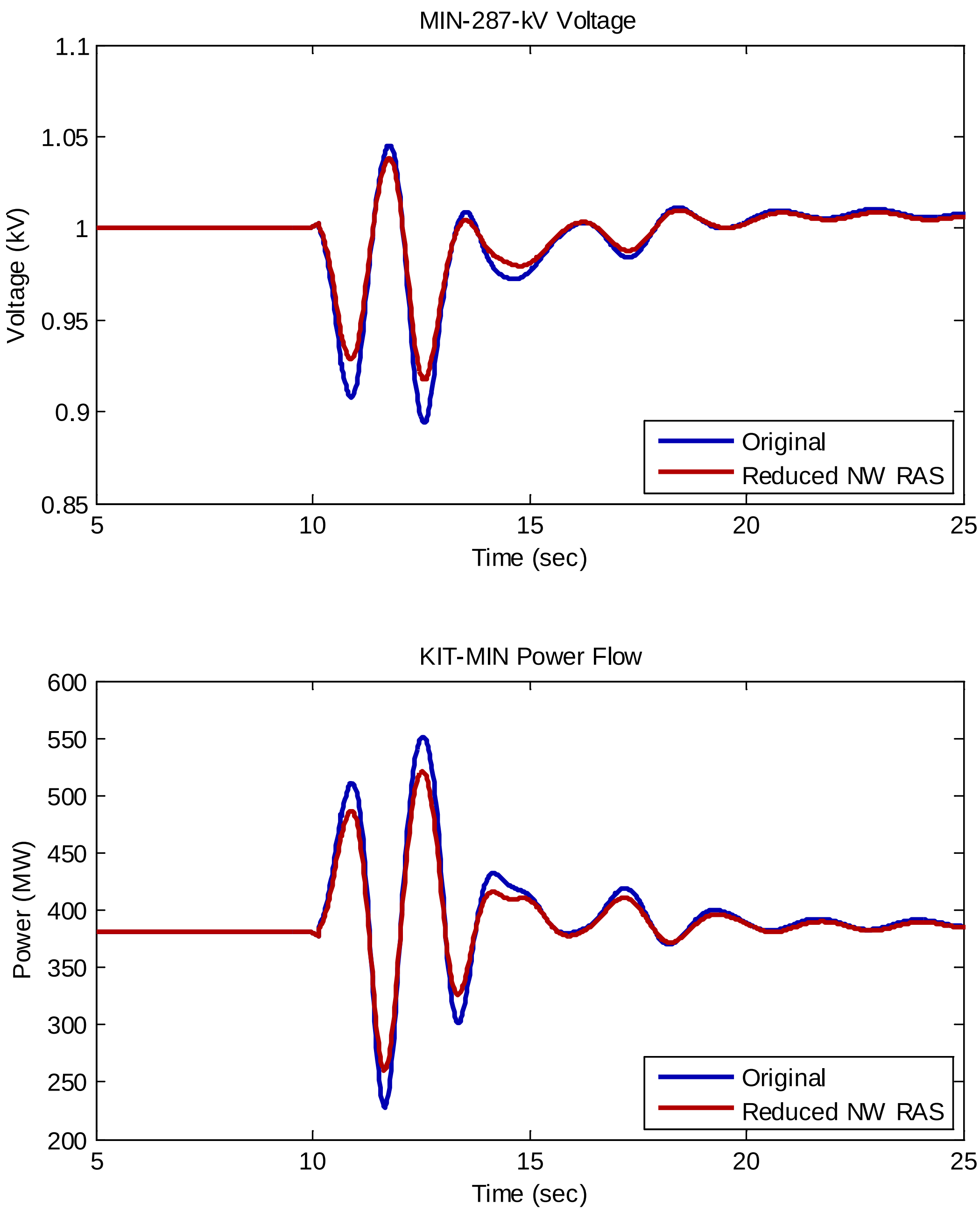


Figure N1: Sensitivity with respect to reducing NW RAS gen.drop

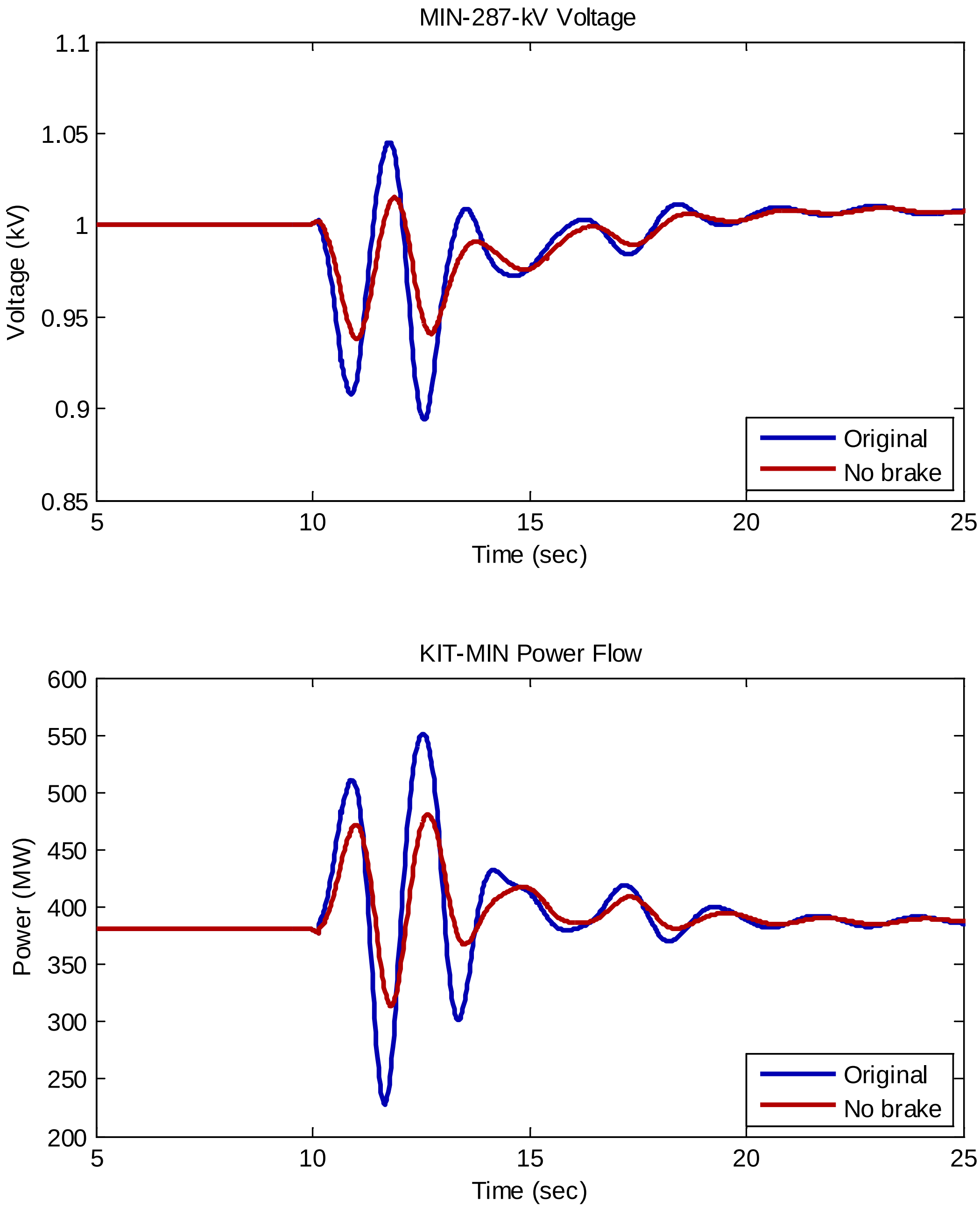


Figure N2: Sensitivity with respect to operation of Chief Joseph braking resistor

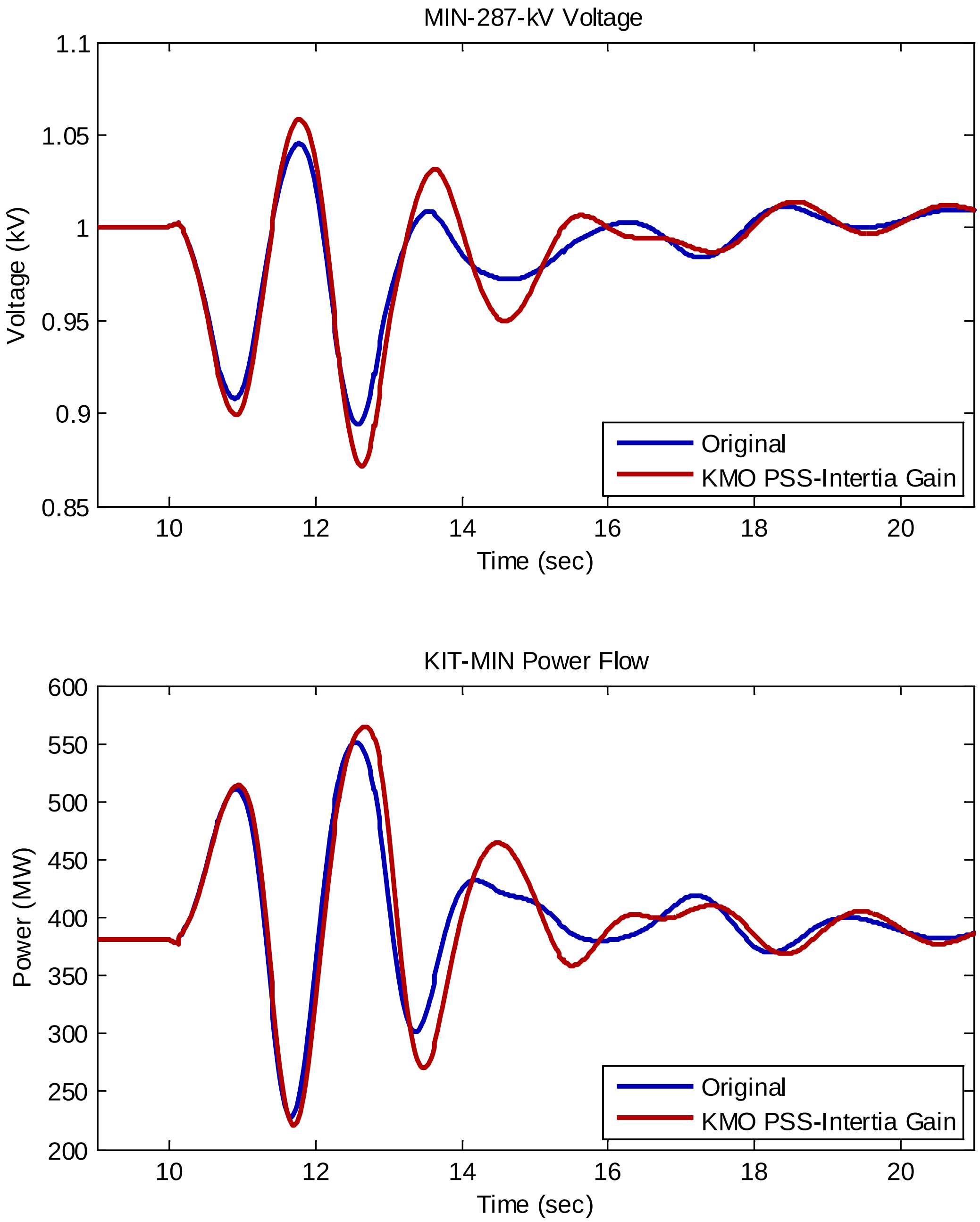


Figure KP1: Sensitivity with respect to Kemano PSS settings

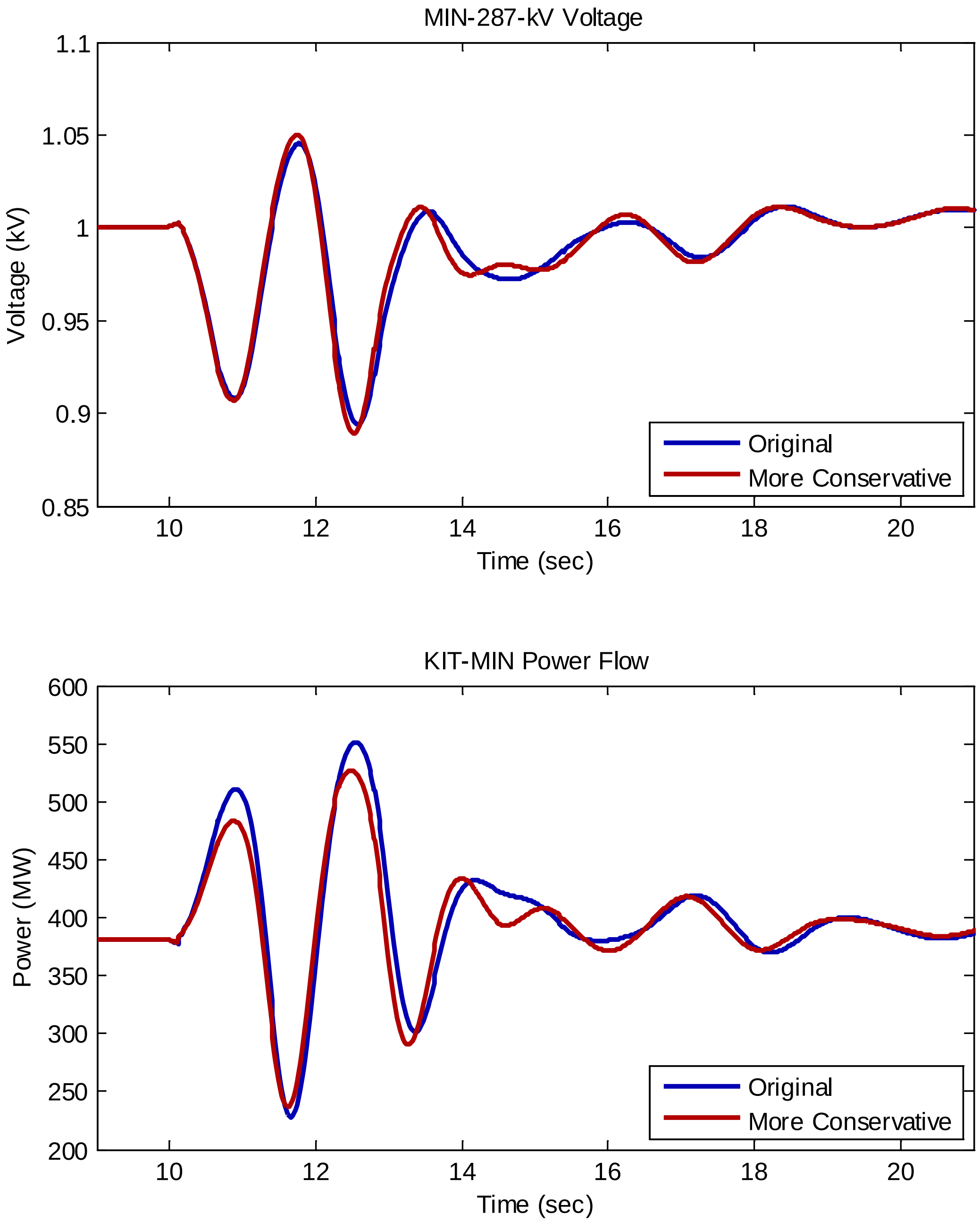


Figure KIT1: Sensitivity with respect to Kittimat Load Composition- Original: 90% constant impedance, 10% motors with Driven Load D=2- Conservative: 80% constant current, 20% motors with Driven Load D=0

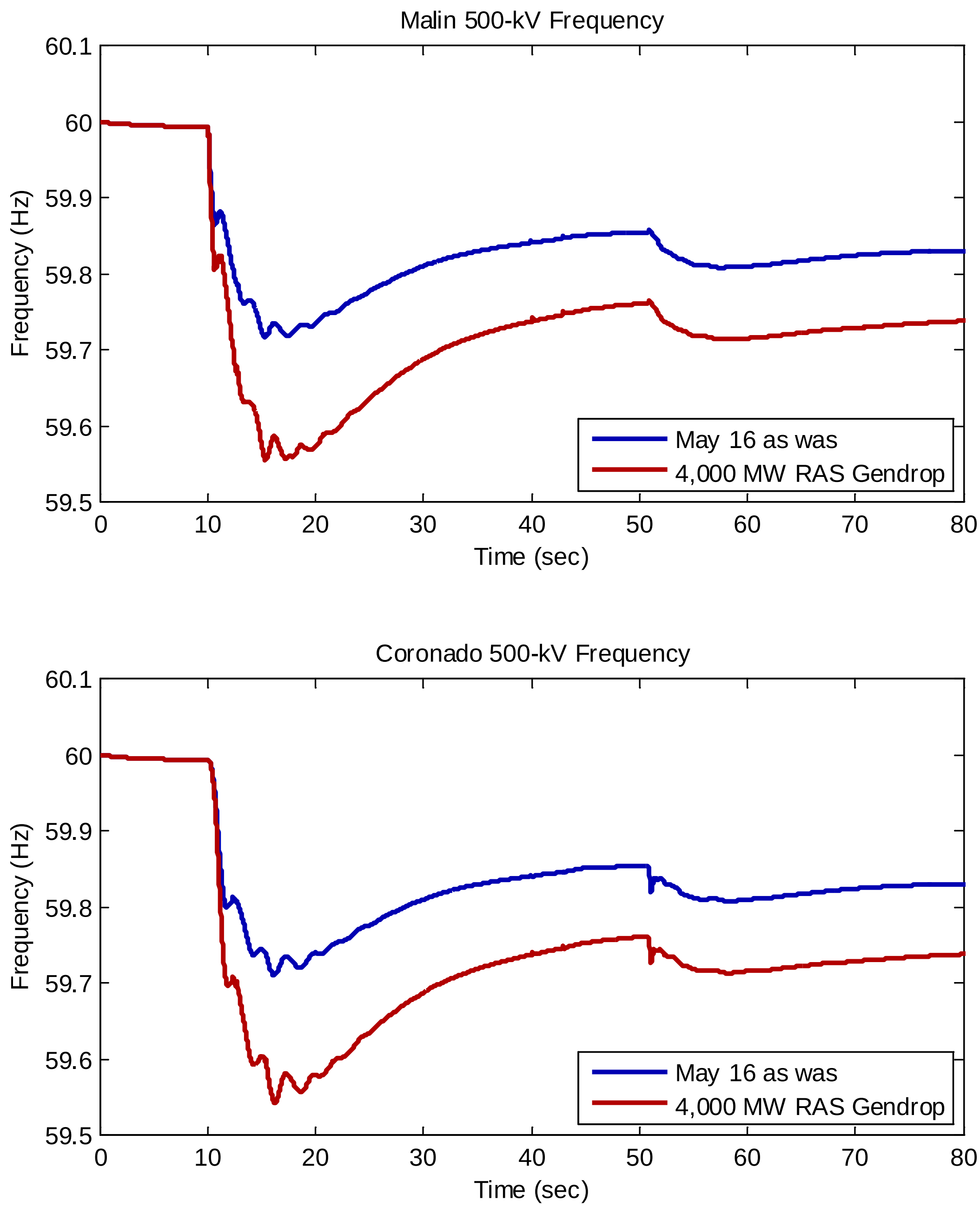


Figure E1: Impact of extreme generation drop

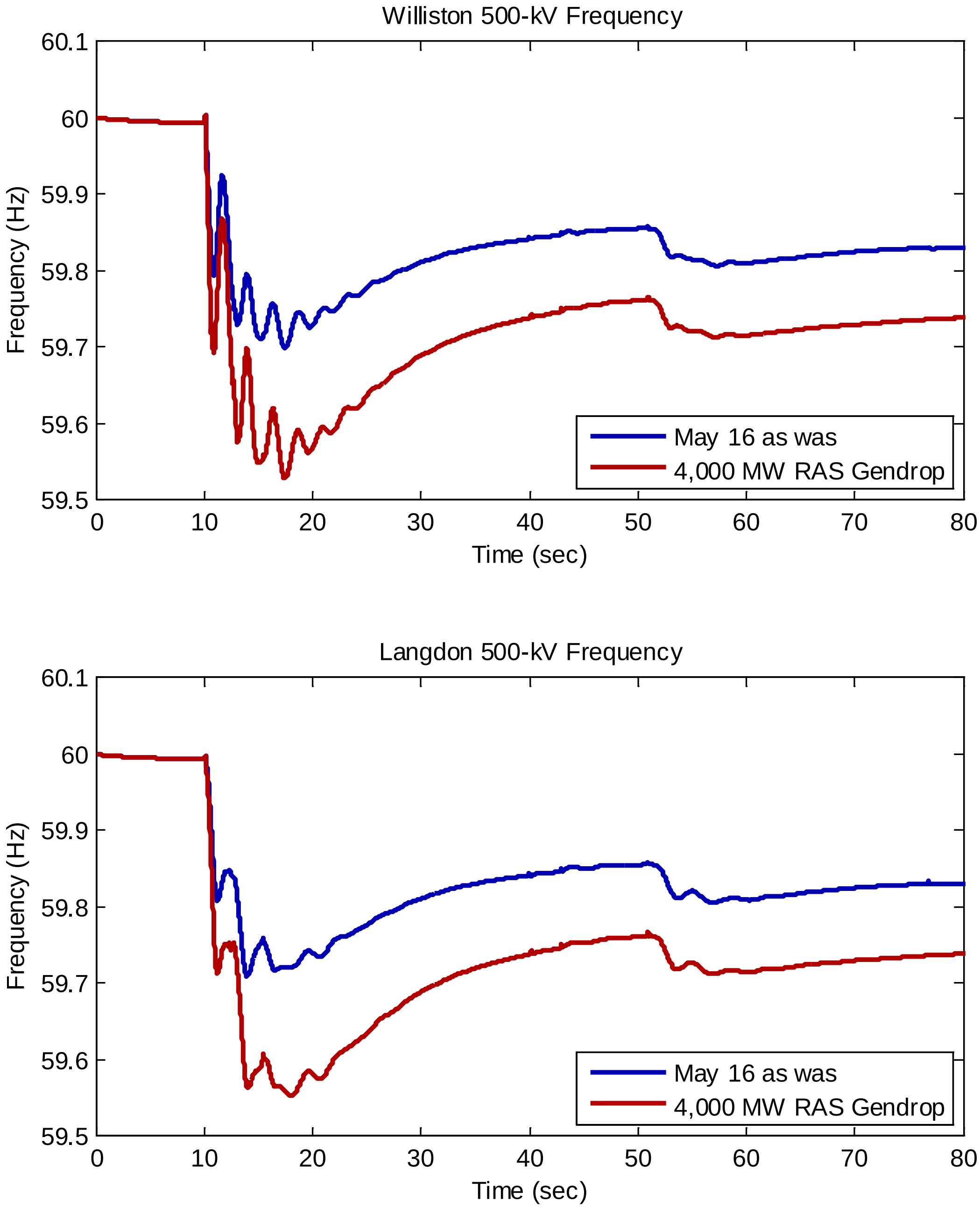


Figure E2: Impact of extreme generation drop

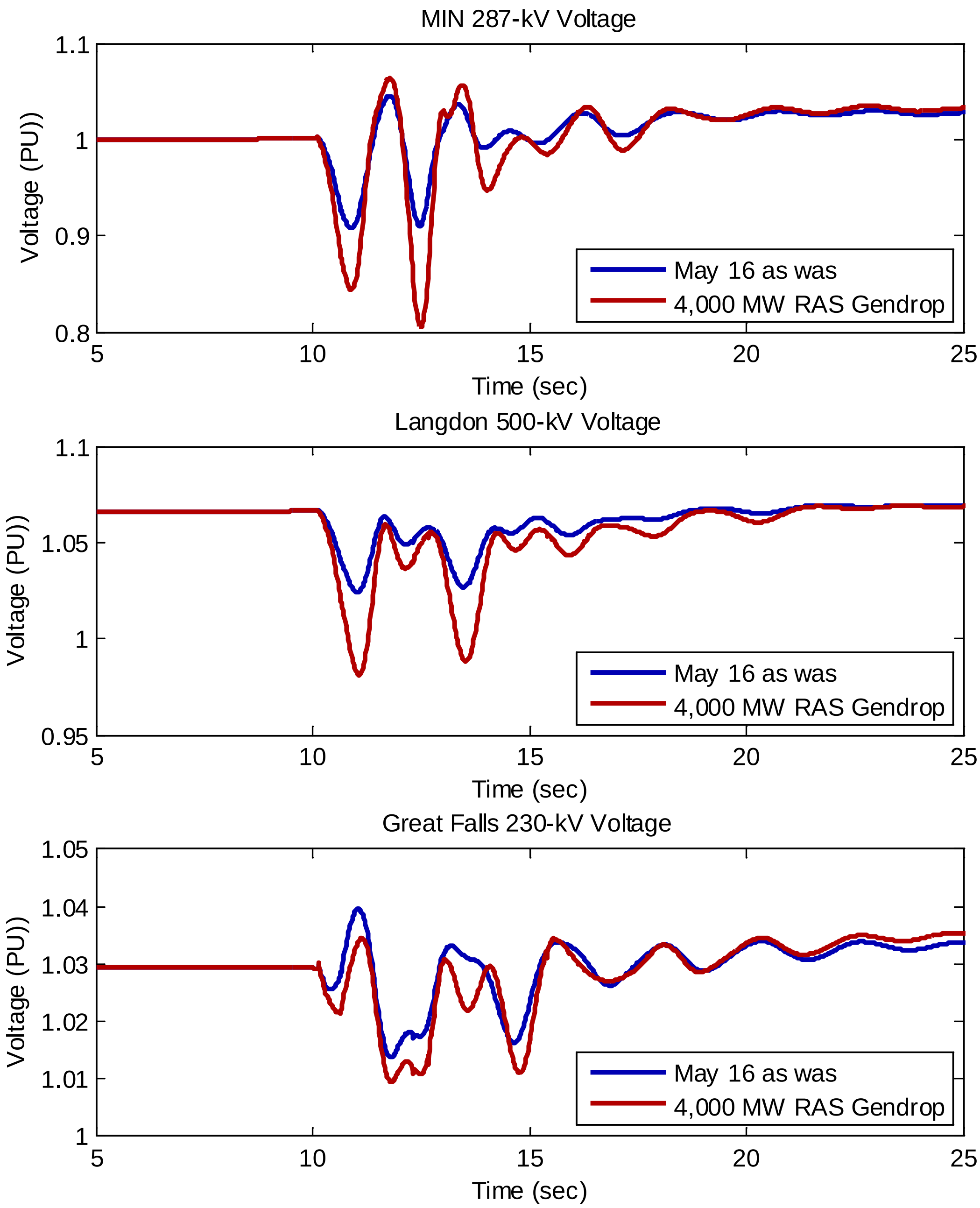


Figure E3: Impact of extreme generation drop

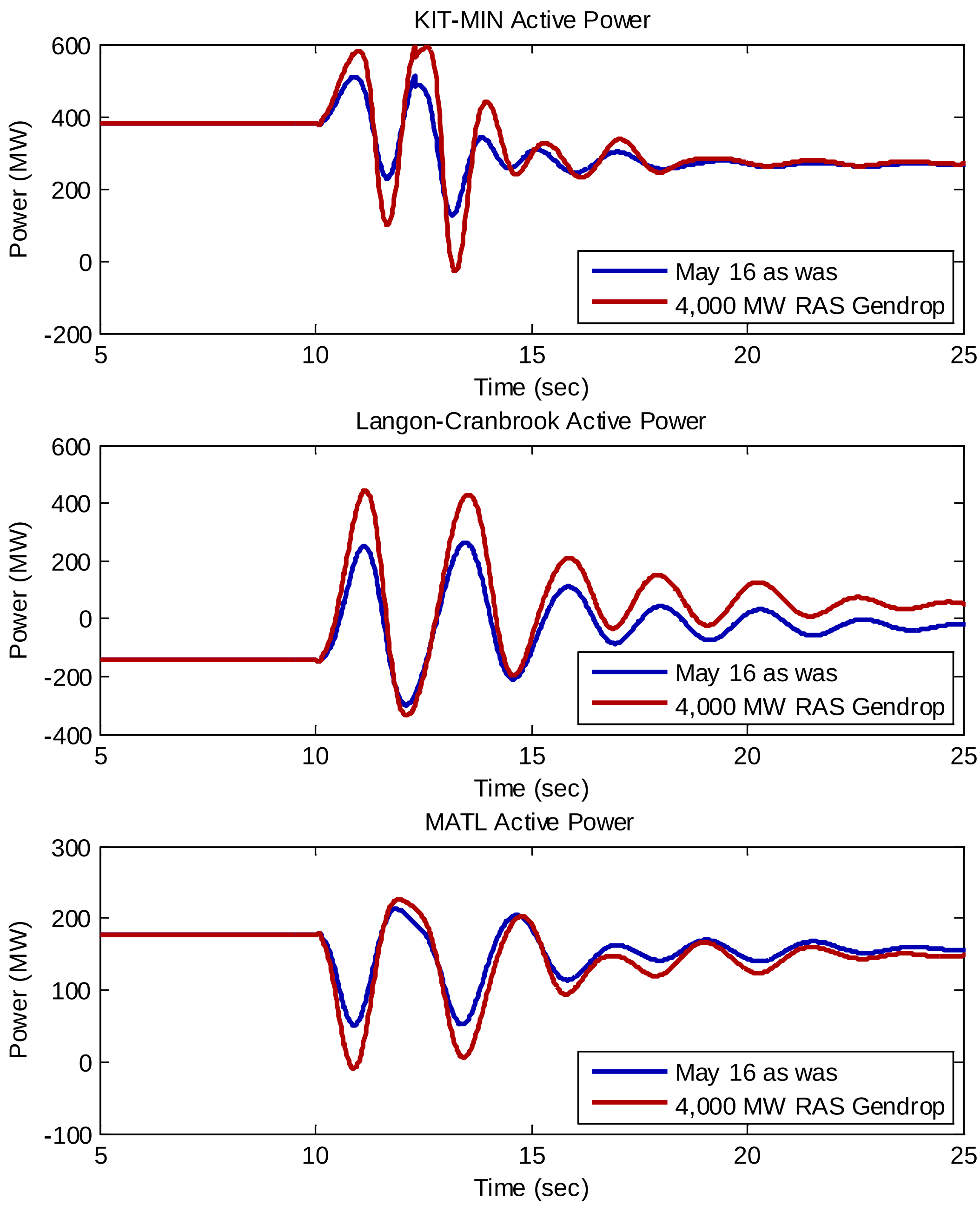


Figure E4: Impact of extreme generation drop