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Previous name/number	
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WECC Modeling and Validation Work Group

WECC Joint Synchronized Information Subcommittee

Model Validation and System Performance Analysis for PDCI RAS Event that Occurred on May 30, 2013

VERSION 1.0: February 7, 2014

This report describes model validation studies and system performance analysis for the system event that occurred on May 30 2013 between 15:58 and 16:30 Pacific Daylight Time. The event included multiple DC faults on Pacific HVDC Intertie caused by fires in Southern California. The event triggered operation of PDCI Remedial Action Scheme (DC RAS), including reactive switching and generation dropping in Pacific Northwest.

1. Event Description

Figures 1 to 6 show system measurements taken by Western Interconnection Synchrophasor Program (WISP) from 15:55 to 16:25. These measurements in conjunction with equipment logs provided necessary information to develop sequence of events for model validation studies, as well as a basis for comparison between simulations and reality. Figures 1-1 through 1-4 show key dynamic quantities.

15:57:39 (Event 1) – Momentary PDCI fault, looks like both DC poles are affected, followed by insertion of Fort Rock series capacitors and Tracy shunt capacitors by DC RAS

15:58:50 (Event 2) – A sequence of momentary PDCI faults, looks like one DC pole is mainly affected, followed by one pole operating at full 1550 MW capacity, and the second pole at reduced capacity, total reduction in PDCI power by about 125 MW

15:59:20 (Event 3) – A major PDCI fault, looks like both poles are affected, followed by DC RAS gen.drop at Grand Coulee, Chief Joseph, McNary and The Dalles

15:59:30 – Inserted Malin 500-kV shunt reactor

15:59:35 – Inserted Captain Jack 500-kV shunt reactor

16:01:42 – Fort Rock series capacitors are bypassed in Grizzly – Malin 500-kV line #2

16:02:04 – Fort Rock series capacitors are bypassed in Grizzly – Captain Jack 500-kV line #1

16:03:55 (Event 4) – Momentary PDCI fault, followed by total PDCI power reduction by about 480 MW and redistribution of power loading at Celilo, Fort Rock series capacitors inserted

16:05:51 – (Event 5) Momentary PDCI fault followed by DC RAS gen.drop

16:08:03 – 16:09:26 - PDCI ramp down accompanied by DC faults

The objective of the validation study is to reproduce the key elements of system performance in transient stability simulators from 15:57:30 to 16:01:00.

A secondary objective is to reproduce the event in time sequence powerflow simulators from 15:55 to 16:25.

2. Frequency Response Analysis

Frequency response is calculated at frequency nadir and at the settling frequency.

Delta Power = 2,895 MW (net)

System frequency prior to disturbance: 59.973 Hz

System frequency at nadir: 59.69

System frequency at settling: 59.804 Hz

Frequency response at nadir is 1,023 MW per 0.1 Hz = 2,895 / (59.973 – 59.69) *10

Frequency response at settling 1,713 MW per 0.1 Hz = 2,895 / (59.973 – 59.805) *10

The frequency response at settling (1,713 MW per 0.1 Hz) is well above NERC BAL-003 Frequency Response Obligation (FRO) for Western Interconnection of 840 MW per 0.1 Hz.

The event is also in the higher portion of the historic performance in the Western Interconnection.

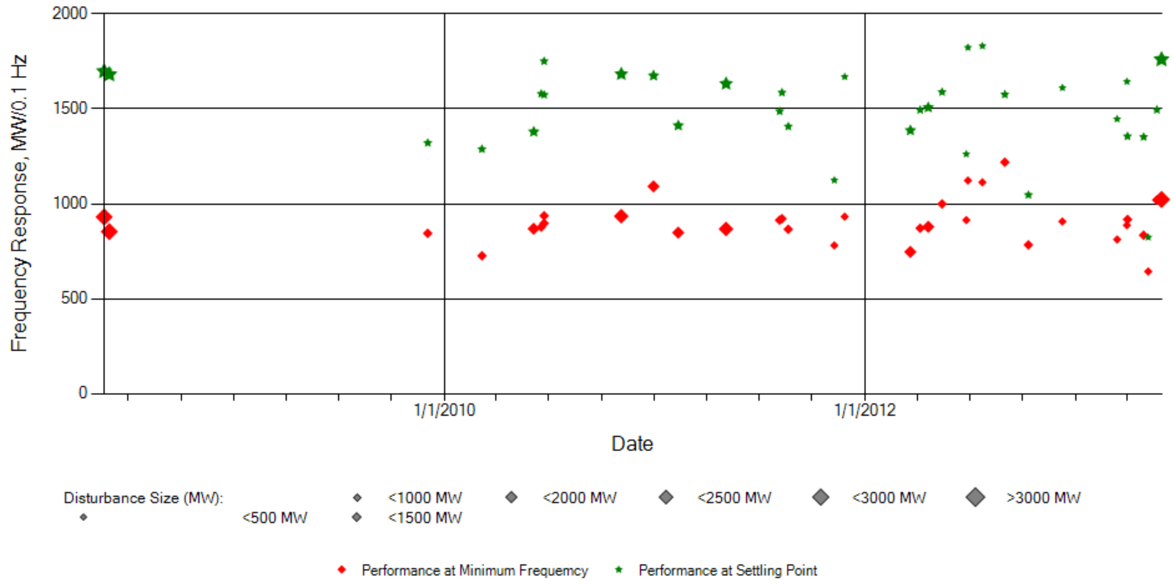

Figure 2-1: historic frequency response baseline for Western Interconnection

3. Oscillation Analysis

Oscillation analysis is performed on the ringdown following PDCI RAS gendrop. An application developed by University of Wisconsin is used to estimate damping and frequencies of inter-area oscillations. A combination of phase angle differences and active power flows are used. The following modes of oscillations are detected in BPA data.

Mode Name	Frequency, Hz	Damping, percent
North-South A	0.24	10.4
North-South B	0.39	12.15
Colstrip	0.698	11.66
	0.891	13.65

The system conditions prior to the event were “low” risk with respect to damping of power oscillations, and the measured damping estimates confirmed that expectation.

4. Validation Base Case Development

WECC 2013 Light Summer operational planning base case was used as a starting point for the study. The amount of system load in the case was relatively close to the total system load at the time of the event.

West-wide System Model (WSM) base case was used as the primary source for generation levels. WSM generation is usually "net" generation, and the station service load needs to be accounted for when mapping generation from WSM to WECC planning case.

WECC MVWG also developed spreadsheets with generation, key line flows, voltage profile, HVDC line flows, and phase shifter information. The spreadsheets can be linked to utility historians to extract the data, thereby making the process repeatable. Utilities are expected to provide EMS data following a request for preparation of a model validation base case. We would like to reduce our dependency on WSM export cases.

MVWG also developed initial version of epcl programs to help with base case modifications to match EMS data. Further development of the program is planned.

The development of the validation base case was significantly faster than previous efforts done in the past.

The following powerflow modeling issues are observed in WECC planning case:

- Many of 230/34.5-kV wind power plant step-up transformers in Pacific Northwest had fixed tap ratio set to 1.0 for high and low sides. This resulted in abnormally high reactive power flow from the system to wind power plants. To the best of our knowledge, most wind power plants have high side voltage tap set to 241.5-kV, or 1.05 fixed tap ratio. Making the above correction improved reactive power consumption and voltage profile by wind power plants
- Several phase shifters are modeled as conventional type 1 transformers. It is necessary to model them as type 4 transformers, as well as to specify their phase angle control limits.

5. Dynamics Modeling Issues

Initial runs had several models becoming unstable in the middle of the run.

Generators connected to the same bus require either Reactive Current Compensation (RCC) or some type form of Cross-Current Compensation. Reactive Current Compensation is most commonly used, and is modeled as **negative "xcomp"** in generator records. Typical "xcomp" value is -0.05 per unit. Cross-Current Compensation is used when better voltage support is required, and currently implemented at The Dalles, John Day and several Willamette Valley plants operated by US Army Corps of Engineers. These generators will have Line Drop Compensation (LDC), represented as **positive "xcomp",** and rely on Cross-Current Compensation to provide stability. Cross-Current Compensation requires an additional model "ccomp", which is not used currently.

Little Goose generators [44211] went unstable during the run. The generators share the same bus and have “xcomp” set to zero. Resetting “xcomp” to an expected setting of –0.05 made the generator response stable.

Magcorp generators [65021] are connected to the same bus and have “xcomp” of +0.05.It is very likely to be data conversion issue, as RCC is a positive number in PSS®E and a negative number in PSLF. Macorp generators are in Pacificorp area, who are PP®E users. By changing “xcomp” to –0.05, the run became more stable.

S.Clara generator [24127] is connected to 66-kV bus, and also wen unstable during the run. We set “xcomp” –0.05 to make response stable.

Every generating unit in a base case must have a step-up transformer, connecting generators to high-voltage buses should be avoided.

Errors identified in July 4 2012 report are still present, including “xcomp” of 0.15 for Klamath Falls generator model [genrou 45448 "KFALLCT1" 18.00 "1 "]. We checked the baseline test report and “xcomp” should be set to zero.

6. Model Validation Studies

The sequence of events is simulated in GE PSLF software. Figures 6-1 through 6-3 compare simulated and actual dynamic responses.

a) Frequency response and power pick-up on major paths

Model has reasonable correspondence with actual event recordings in representing:
- Initial system frequency drop following DC RAS
- Initial power pick-up on major paths

Model has shown deficiencies in representing “post-transient” response:

- System frequency recovery is greater than that observed in reality
- Power pick-up on major paths is lower

Mode Name	Frequency, Hz	Damping, percent	Frequency, Hz	Damping, percent
North-South A	0.24	10.4	0.222	29
North-South B	**0.39**	**12.15**	**0.414**	**12.75**
Colstrip	0.698	11.66	0.57	37.8
	0.891	13.65	0.79	8.65

North-South mode B is the dominant mode with highest energy. The model identified the dominant mode reasonably well. Other modes did not have sufficient energy and their identification was not accurate.

7. Model Sensitivities

The initial studies indicate that the simulated settling frequency is higher than what was observed in reality. Therefore, additional model sensitivity studies were attempted to improve match between the model and reality.

Heat-recovery steam generators in a combined cycle plants are expected to operate “baseloaded”.

The following heat-recovery steam generators were “baseloaded” in the base case.

Table gens [Last: 17 , Max: 30000] 2013-05-30-1555-R28.sav

Table Options Help CurRow: 10

BUS-NO	NAME1	KV1	ID	ST	BL	FL	QTAB	PGEN	QGEN	QMAX	QMIN	PI
11117	NEWMN4S1	13.80	1	1	2	4	0	53.0	1.4	71.2	-56.7	0
11261	NEWMN5S1	13.80	1	1	2	4	0	90.0	4.0	108.8	-57.6	0
26150	VALLEY8G	18.00	8	1	2	4	0	62.0	11.4	200.0	-100.0	0
26151	HAYNES8G	18.00	8	1	2	4	0	73.0	1.7	200.0	-100.0	0
18428	HA CC3	18.00	1	1	2	4	0	162.0	26.6	170.0	-100.0	0
10396	LEF_S1	18.00	1	1	2	4	1	148.0	-13.4	0.0	0.0	0
47590	CHEH S1	18.00	1	1	2	4	0	166.0	-2.3	123.0	-82.0	1
65170	BLNDL G1	12.50	1	1	2	4	0	25.0	2.3	15.0	-12.0	0
65171	BLNDL G2	12.50	1	1	2	4	0	11.0	1.5	7.0	-6.3	0
65393	CURRNTS1	18.00	1	1	2	4	0	108.0	-55.0	150.0	-55.0	0
35883	MEC STG1	18.00	1	1	2	4	0	156.9	-20.1	132.0	-78.0	0
38572	WEC3-ST	13.80	1	1	2	4	1	91.3	19.5	60.0	0.0	0
70409	ST.VRAIN	22.00	G1	1	2	4	0	127.0	66.3	165.0	-80.0	0
71003	BAC_MSA GEN3	13.80	S1	1	2	4	0	20.0	-4.7	15.6	-4.7	0
22981	TDM STG	21.00	1	1	2	4	0	285.3	19.1	195.0	-173.0	0
22265	PEN_ST	18.00	1	1	2	4	0	190.4	13.0	120.0	-14.0	0
22996	INTBST	18.00	1	1	2	4	0	112.5	13.8	97.6	-86.3	0
64954	TRACYW10	18.00	1	1	2	4	0	125.0	-26.3	150.0	-65.0	0

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Jim Bridger unit 2coal-fired generator is also modeled as “baseloaded.”

A number of gas-turbine generators in combined cycle plants are modeled under load control.

These changes had some, but not significant, impact on the system frequency settling, as seen in Figure 7-1 compared to Figure 6-4.

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#
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lcfb1    15168 "MES-CT4 "  18.00 "1" : #9 "type" 0.0 "db" 0.0 "
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lcfb1    15161 "HGC-CT3 "  16.00 "1 " : #9 "type" 0.0 "db" 0.0
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Recommendations

Based on model validation studies of May 30 2013 PDCI RAS event and July 4 2012 Arizona generation outage, efforts to improve frequency response modeling are needed.

1. Data Request

1. MVWG and SRWG to conduct a generation data request for several large under-frequency events, and use the data to confirm baseload flag and load controller information. WECC Modeling and Validation Working Group developed a PI-based application for data extract that is available on WECC MVWG web-site.

2. Data Management

2. WECC System Review Working Group to populate the "turbine type" field in "gens" tables
3. WECC System Review Working Group to review "baseload" flag information in base cases.

Figure 1-1: Pacific HVDC Intertie total active power (at Sylmar)

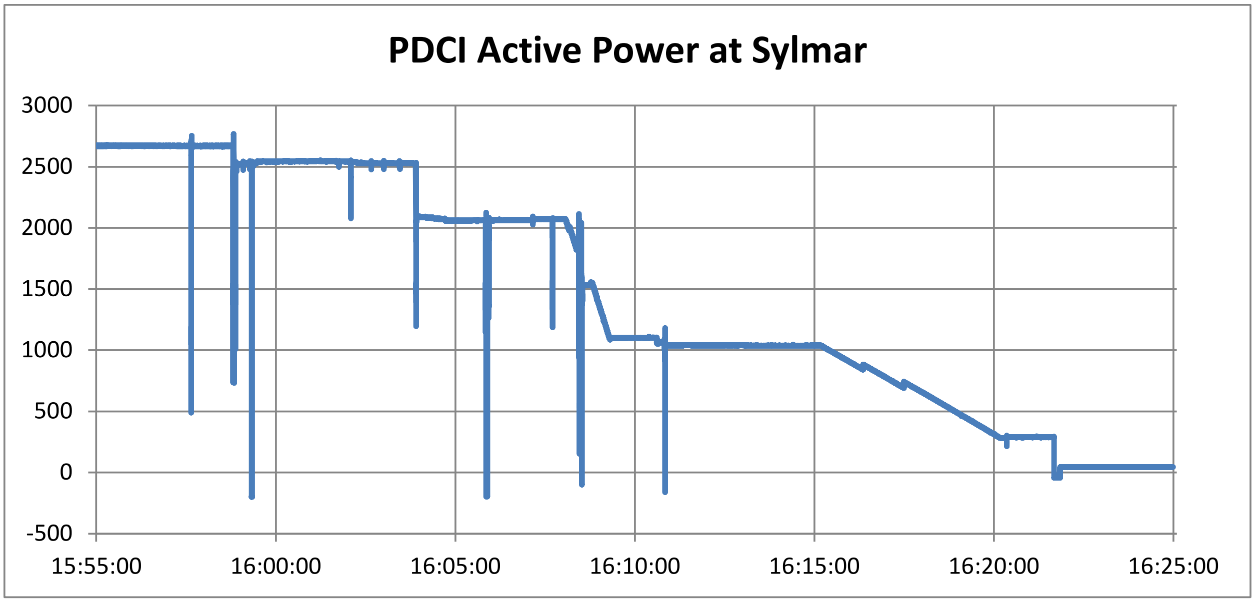

Figure 1-2: Pacific HVDC Intertie Converter 1 and 2 active power (at Sylmar)

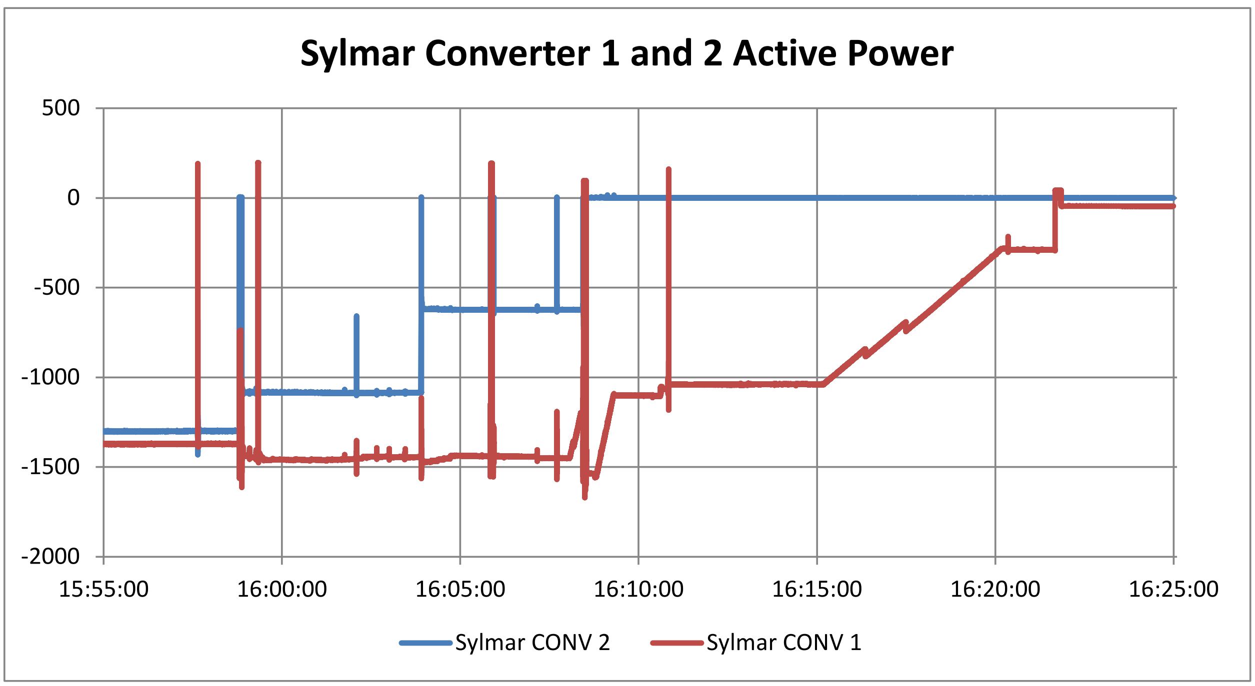

Figure 1-3: System Frequency

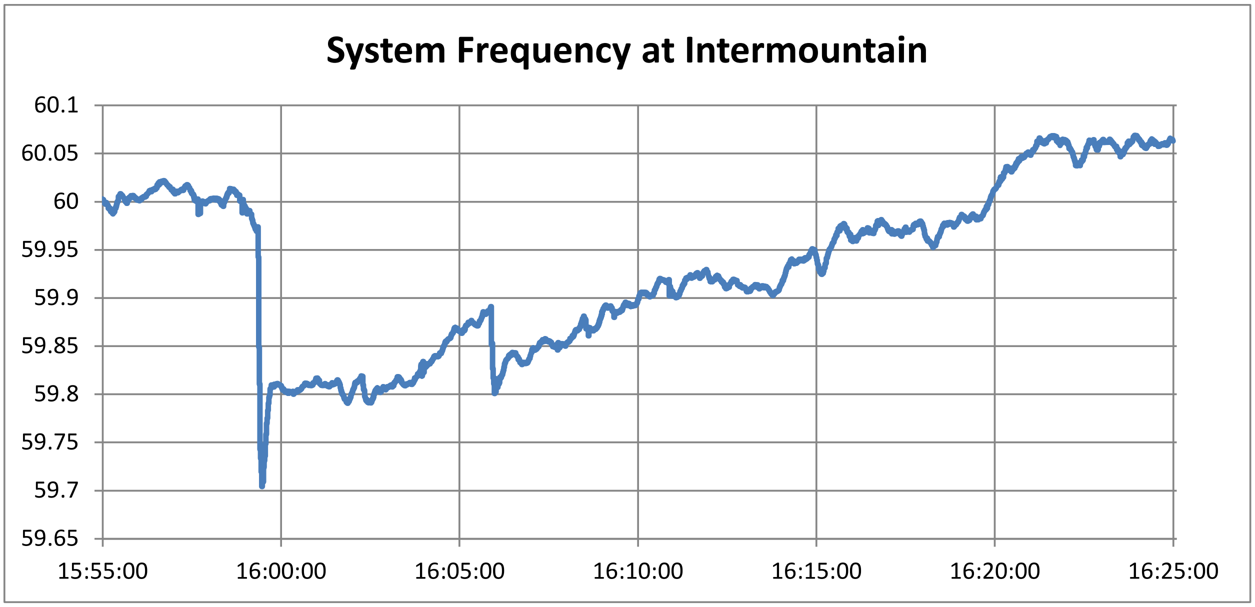

Figure 1-4: California – Oregon Intertie

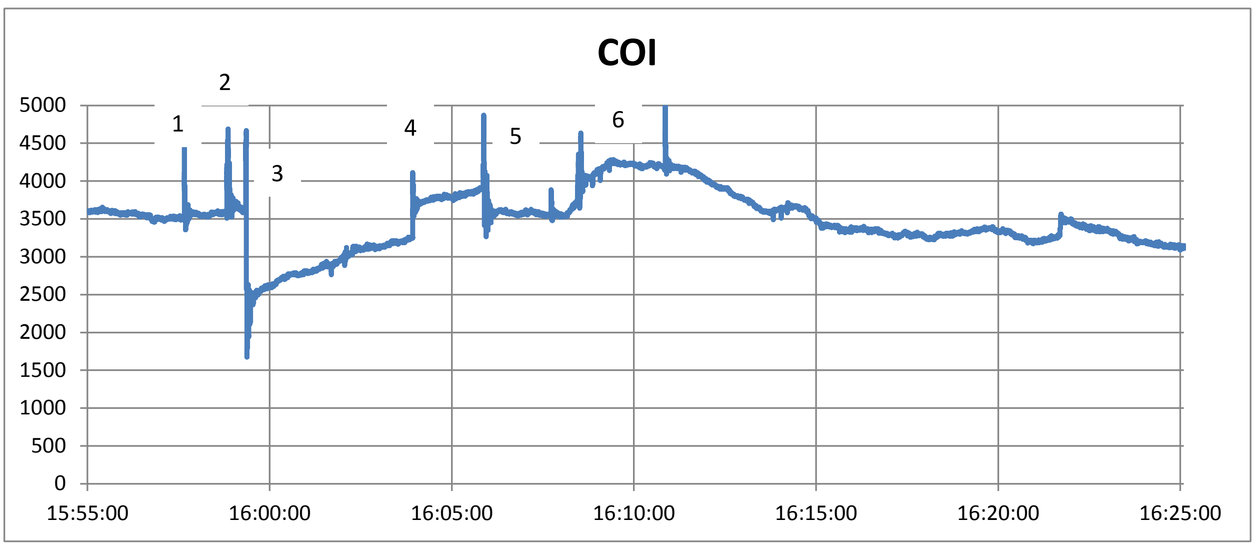

Figure 5-1: Little Goose generators [44211] become unstable with WECC dynamic data

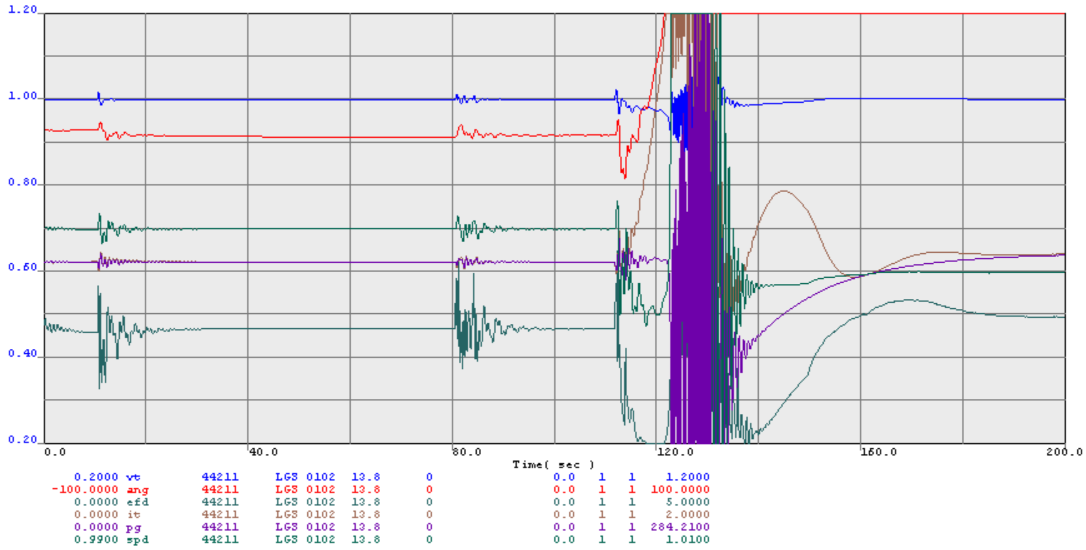

Figure 5-2: Little Goose generators [44211] response with corrected dynamic data

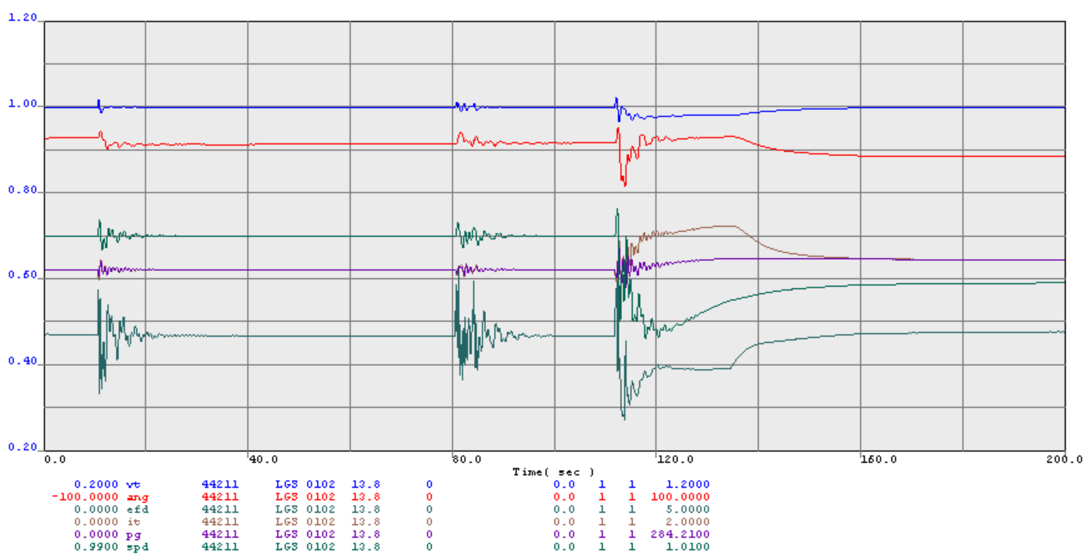

Figure 5-3: S.Clara generator [24127] becomes unstable with WECC dynamic data

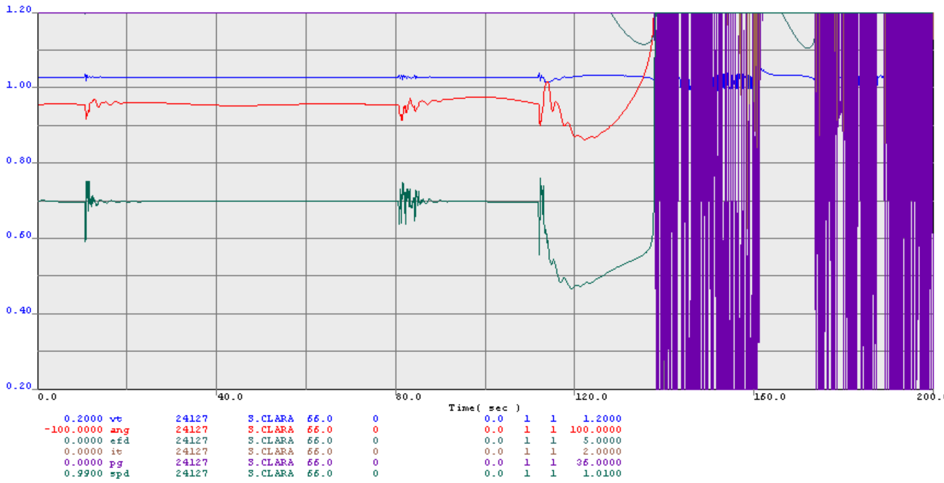

Figure 5-4: S.Clara generator [24127] with corrected dynamic data (ultimately, the generator step-up transformer needs to be represented in powerflow base case)

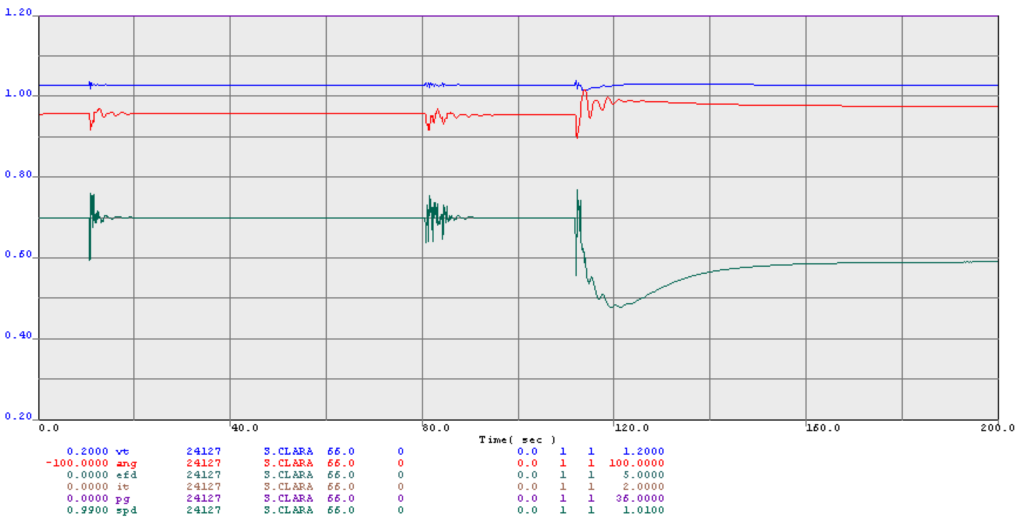

Figure 5-5: Magcorp generators [65021] exhibit sustained oscillations with WECC dynamic data

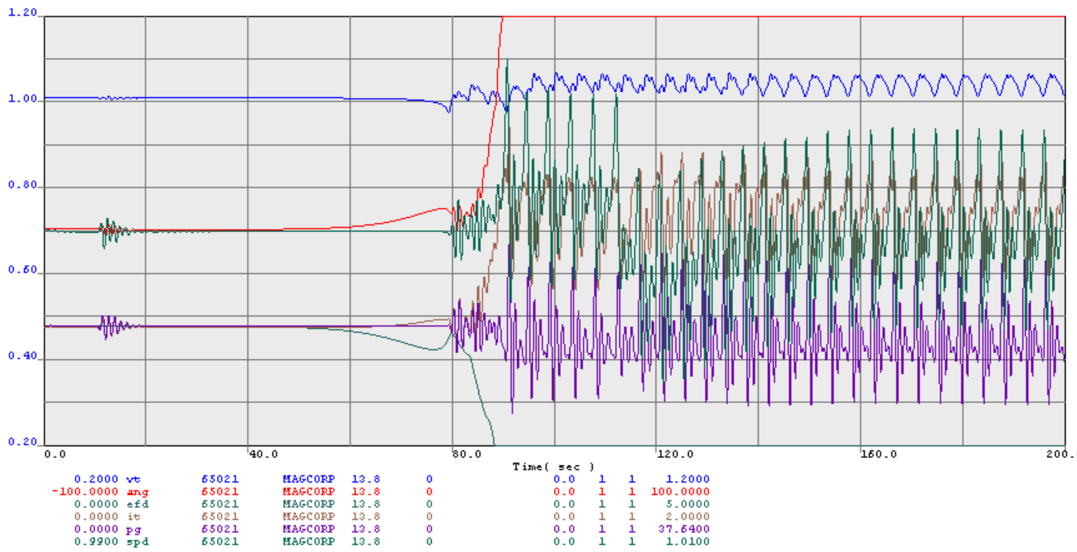

Figure 5-6: Magcorp generator [65021] response with corrected “xcomp” dynamic data

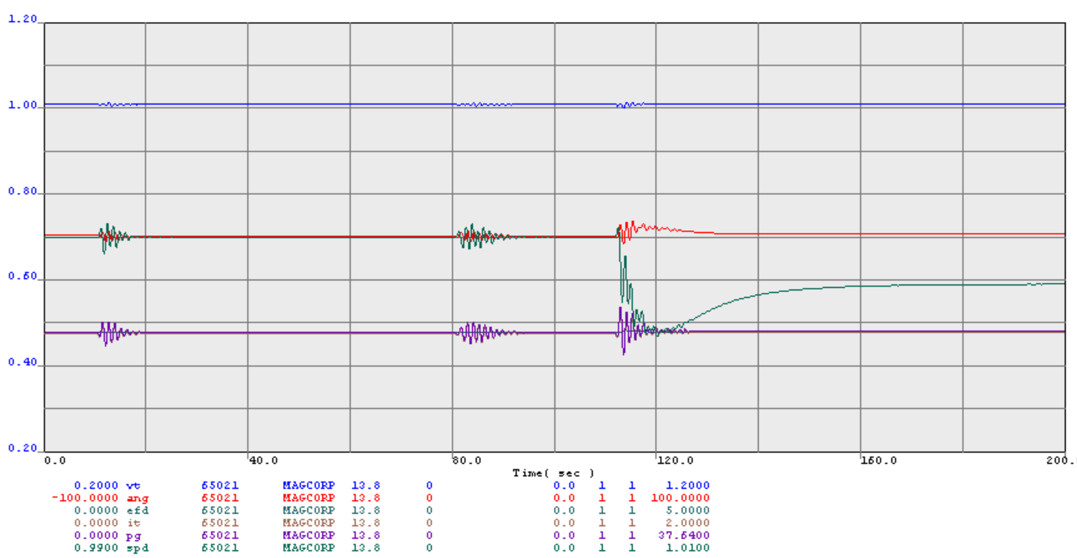

Figure 6-1: California – Oregon Intertie

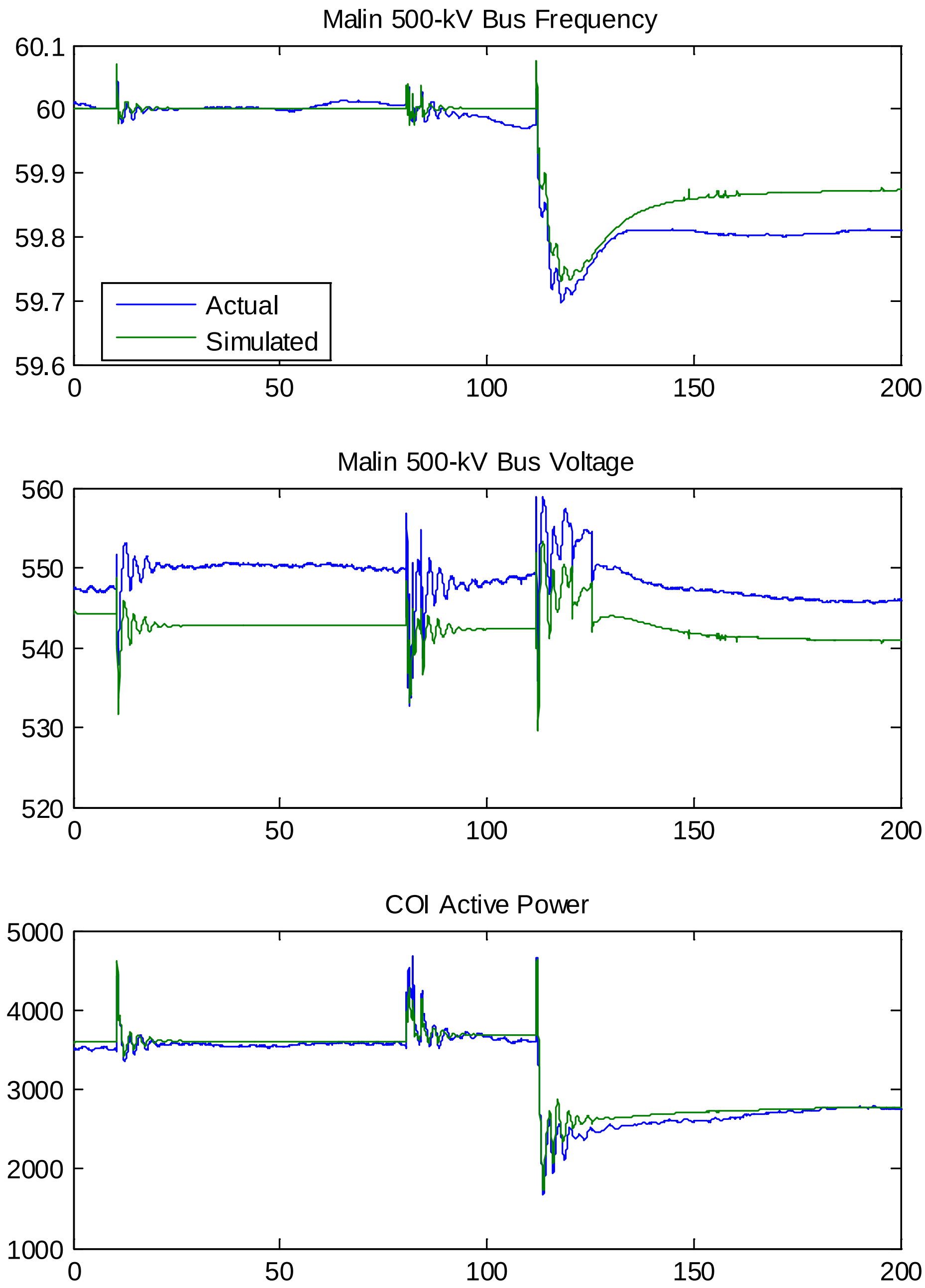

Figure 6-2: Pacific HVDC Intertie

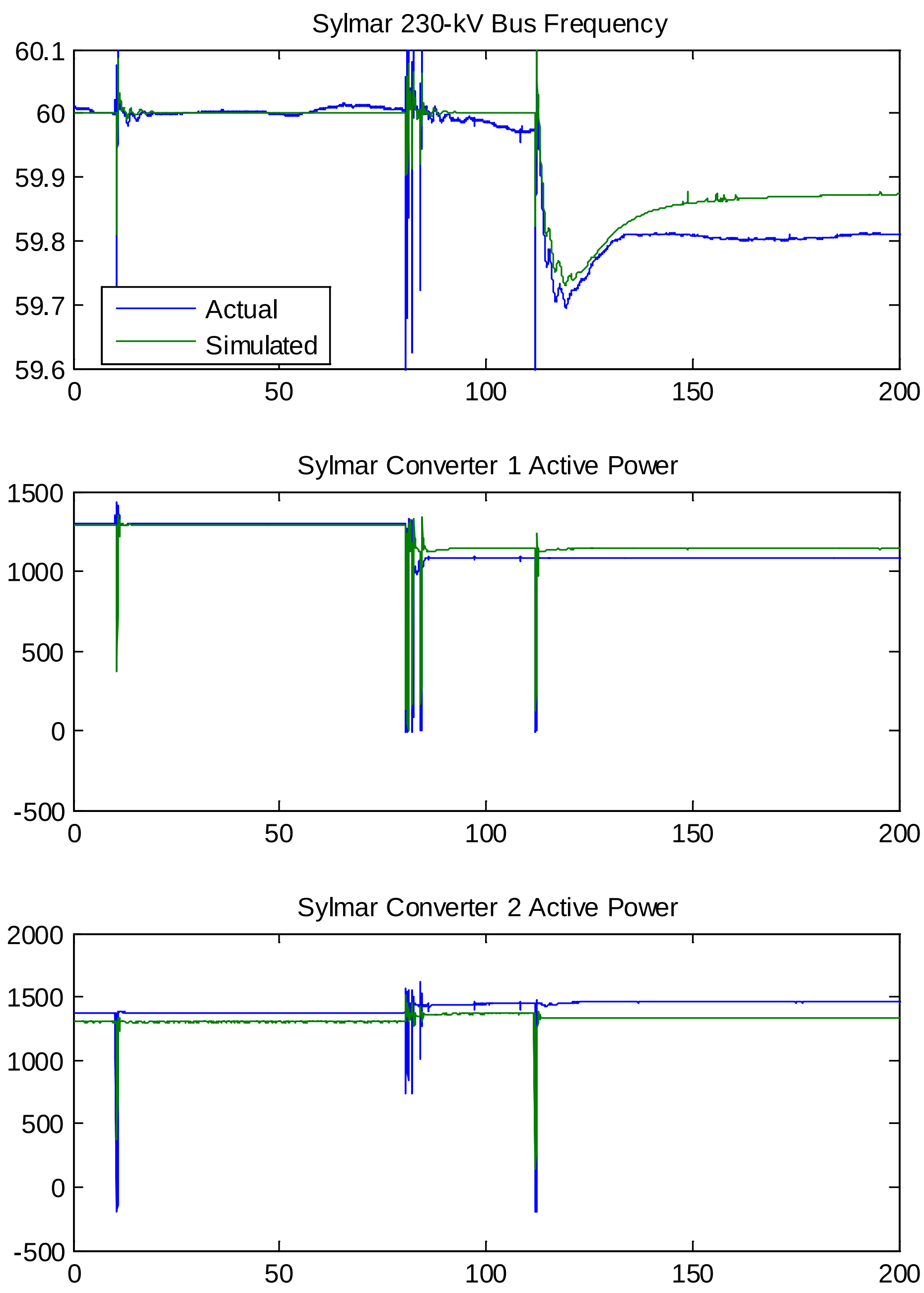

Figure 6-3: Northern Intertie

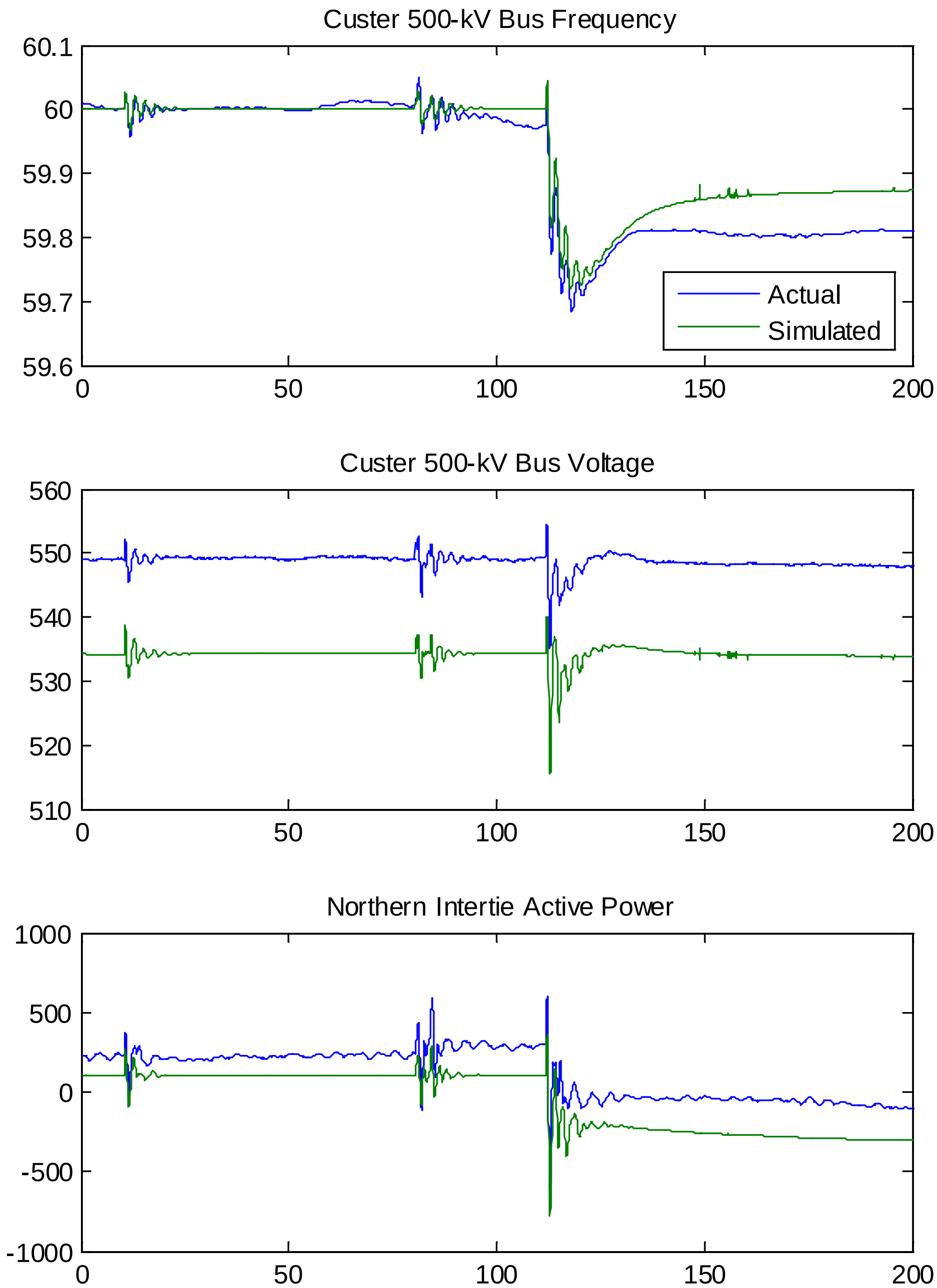

Figure 6-4: System Frequency

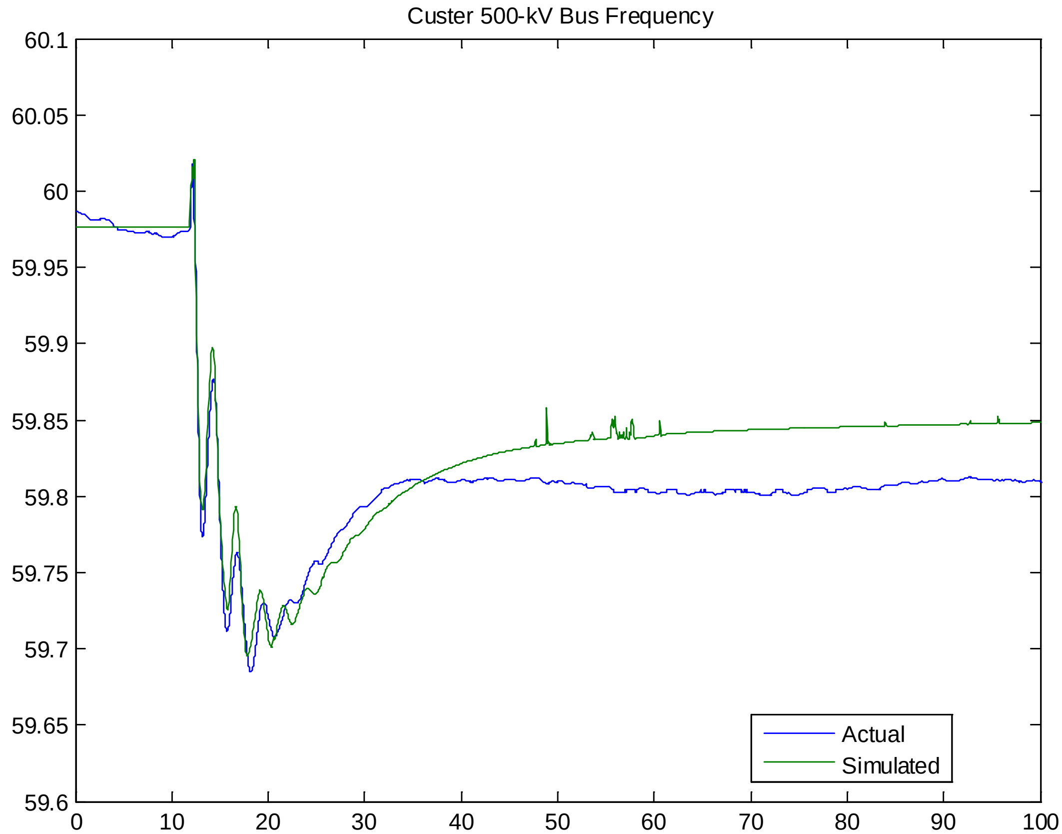

Figure 7-1: system frequency with increased number of baseloaded generators and load controls