WWSIS III: Western Frequency Response and Transient Stability Study

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Final TRC Meeting
Golden, CO
October 2, 2014

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Today's Meeting

- Purpose
  - Review analysis since last TRC call
  - Present conclusions from draft final report
  - Discuss, discuss, discuss
- Topics
  - Transient stability (AM)
  - Frequency response (PM)
  - Schedule/next steps

Since Last Call

- Analysis completed
- Draft final report distributed in August
- Draft executive summary distributed today

Study Scenario Recap

WECC-wide Summary	Light Spring Base	Light Spring Hi-Mix	Light Spring Extreme	Heavy Summer Base	Heavy Summer Hi-Mix
Wind (GW)	20.9	27.2	32.6	5.6	14.3
Utility scale PV (GW)	3.9	10.2	13.5	1.2	11.2
CSP (GW)	0.9	8.4	8.3	0.4	6.6
Distributed PV (GW)	0	7.0	10.4	0.0	9.4
Total =	25.7	52.8	64.8	7.2	41.5
Penetration[1] (%) =	21%	44%	53%	4%	20%

(1) Penetration is % of total generation

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Transient Stability Analysis

- System conditions
  - Primarily heavy summer analysis
  - Plus extreme light load sensitivity case with high coal displacement
- Outages
  - Pacific DC Intertie
  - Aeolus
  - Vincent-Midway
  - Colstrip
  - Laramie River Station

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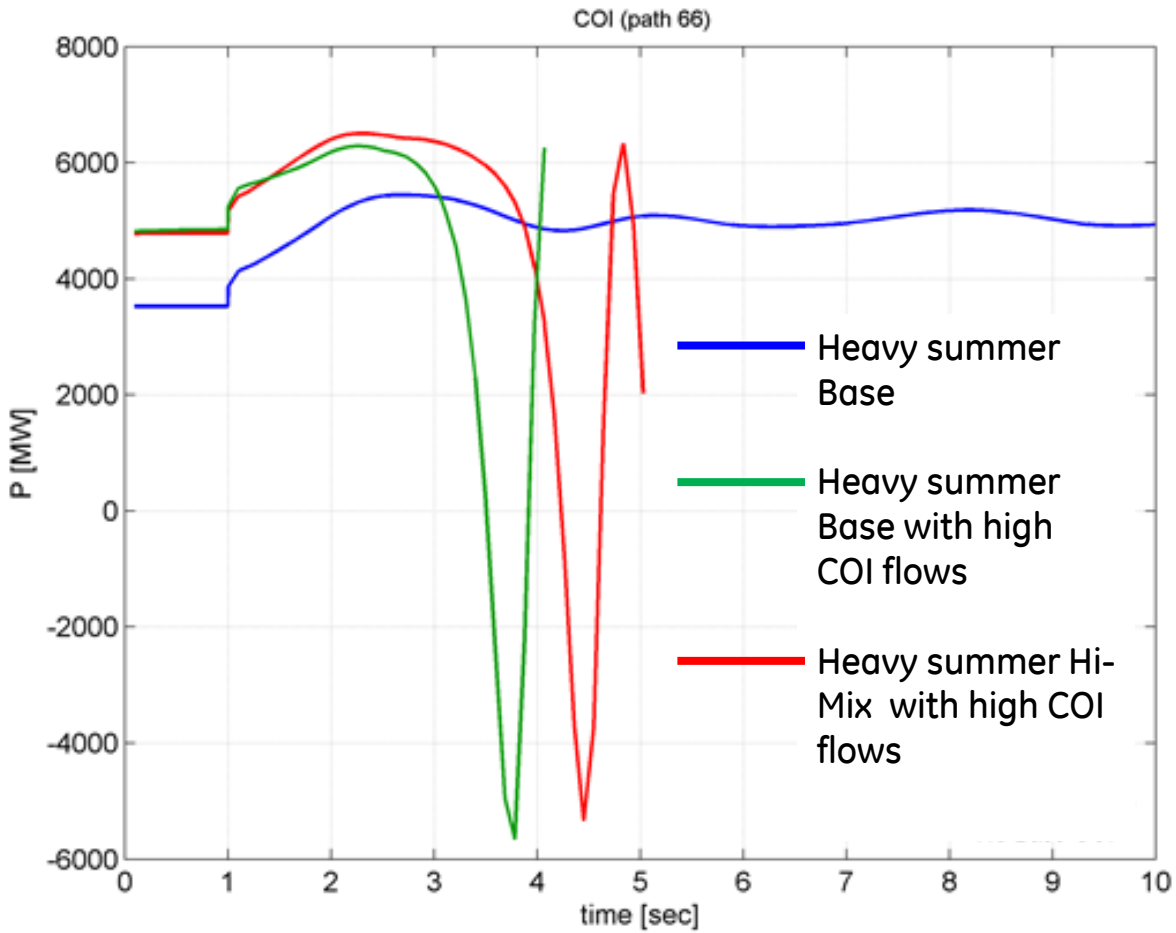
Transient Stability – Heavy Summer



Base with high COI flows created by decommiting SONGS, dispatching NW hydro up.

Trip Pacific DC Intertie

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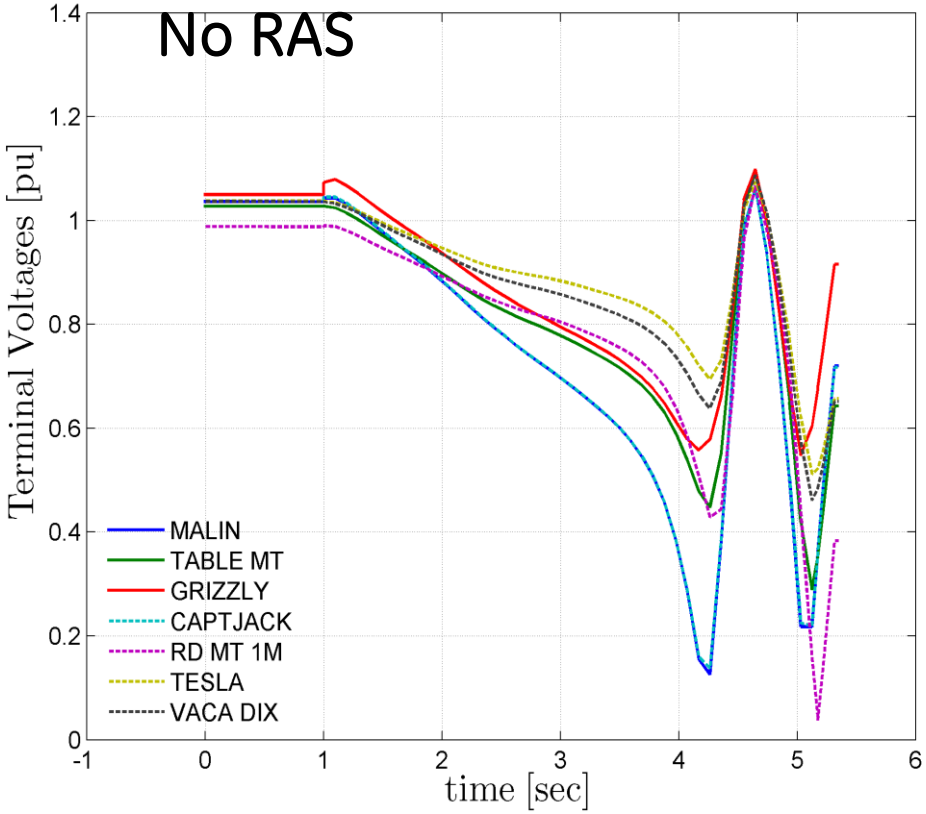
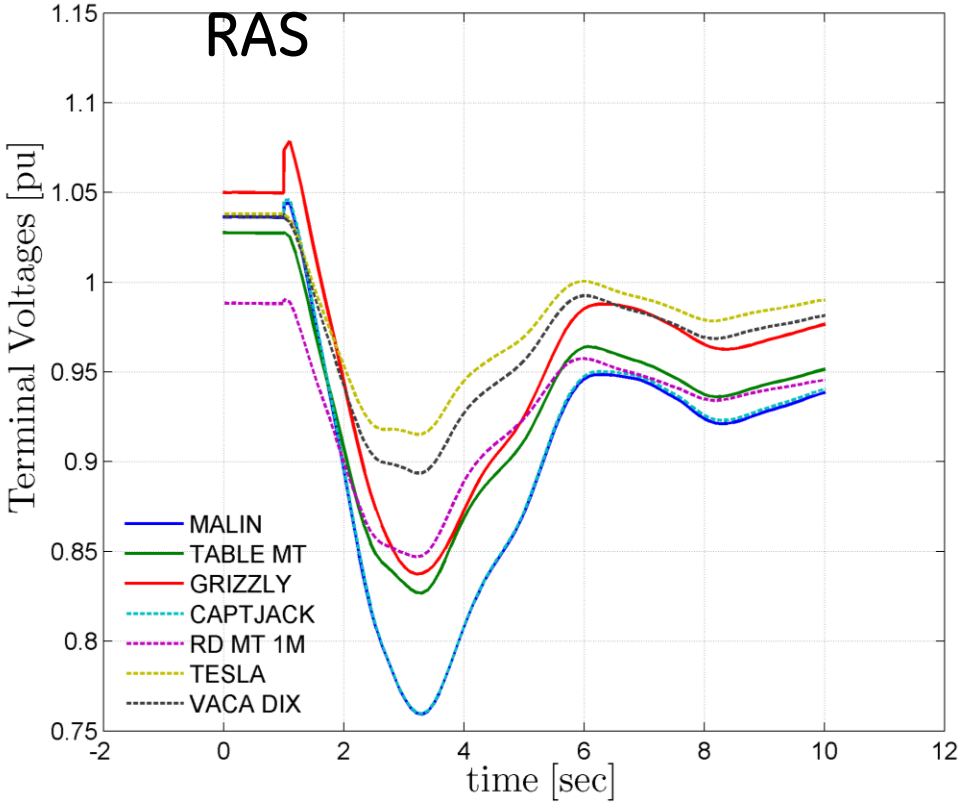
Transient Stability – Heavy Summer

Heavy Summer Hi-Mix, No RAS



Heavy Summer Hi-Mix, RAS



Outage = trip Pacific DC Intertie
RAS = trip two 138MW generators

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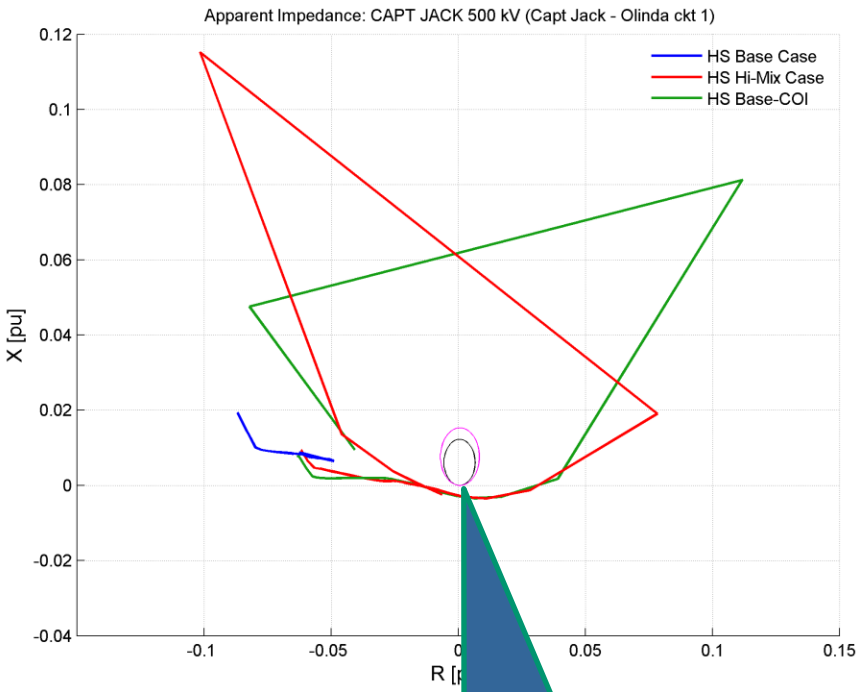
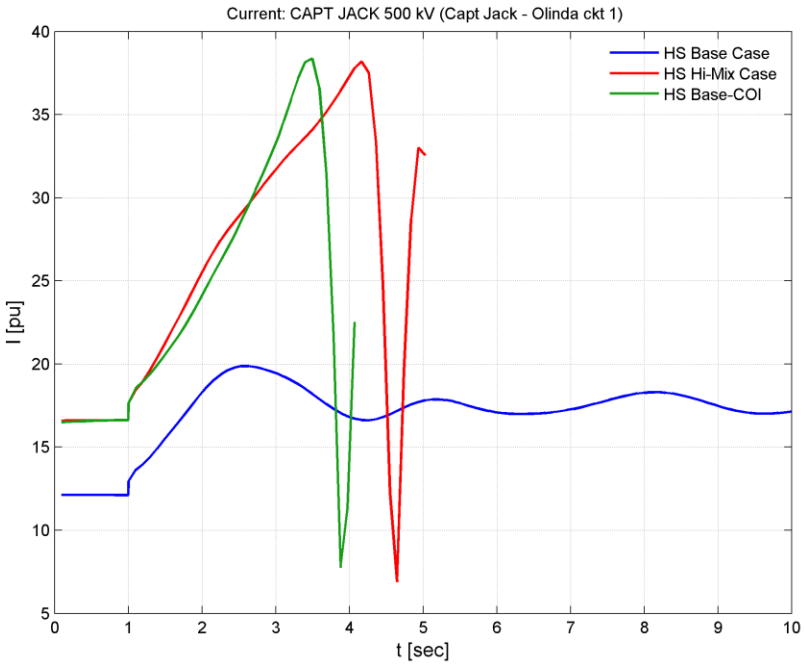
Apparent Impedance and Current Plot: HS cases, PDCI event





Zone 1 circle 100% Zline
Zone 2 circle 125% Zline

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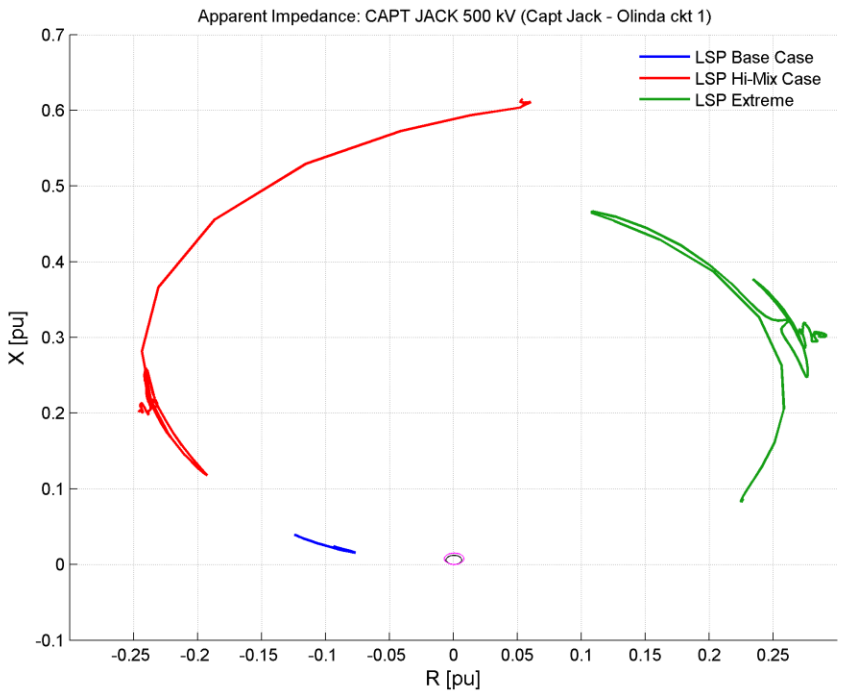
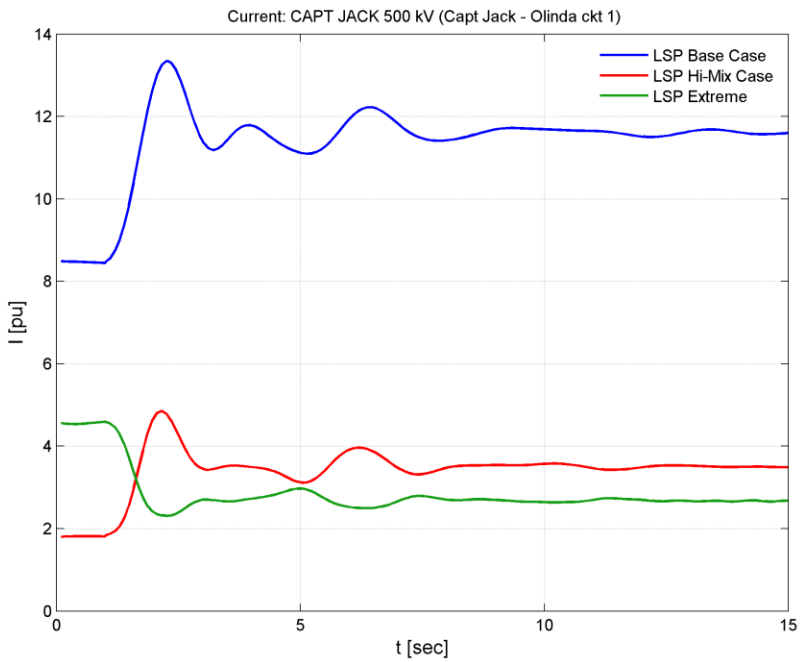
Apparent Impedance and Current Plot: LSP cases, 2PV event





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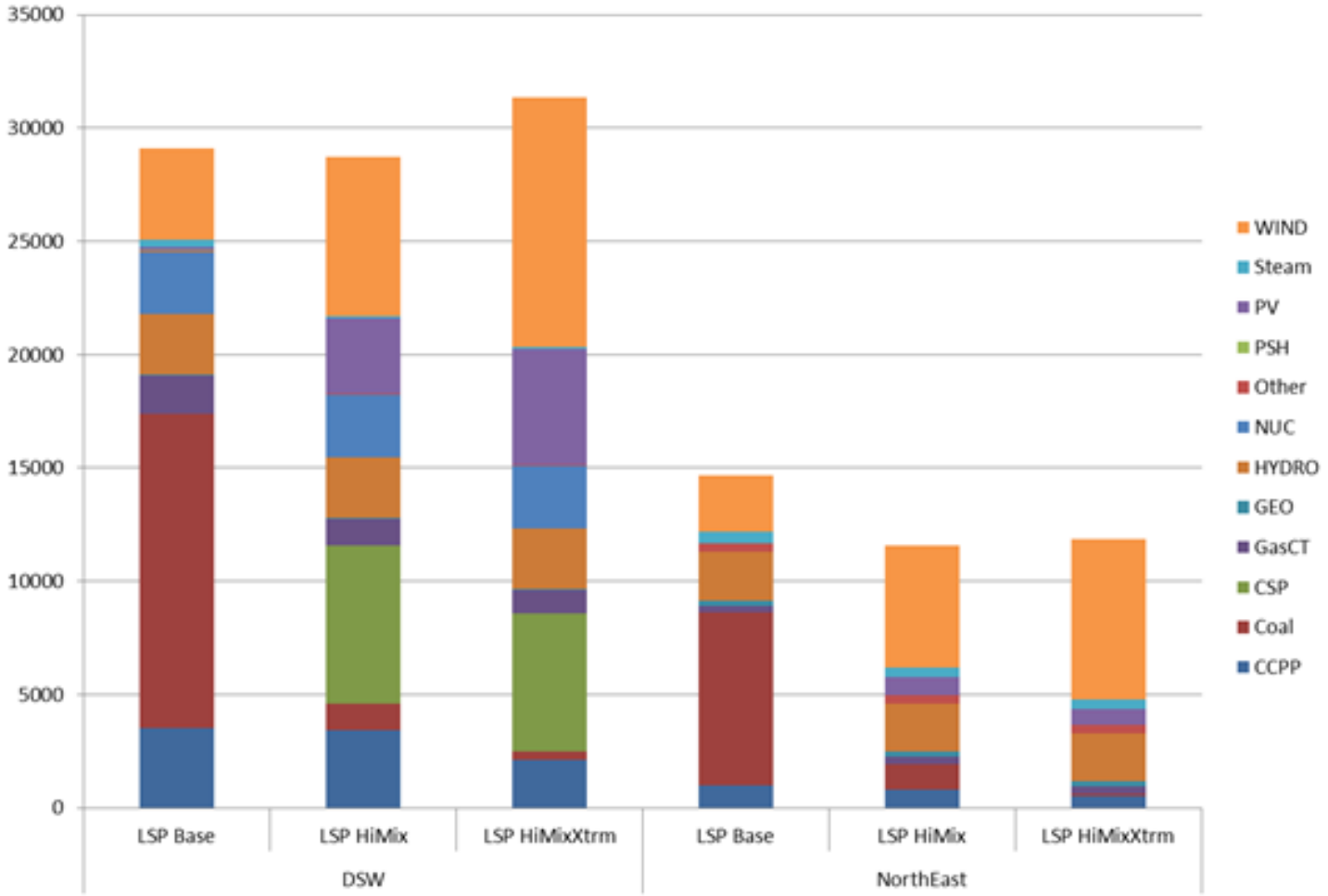
Path Loadings

Path Number	Path Name	Path Loading (MW)			Path Rating (MW)
		LSP Base	LSP Hi-Mix	LSP Extreme	
10	West of Colstrip	2,025	297	-193	2,598
15	Midway-Los Banos	1,467	4,545	5,997	4,800-5,400
22	Southwest of Four Corners	1,829	-339	485	2,325
26	Northern-Southern California	1,140	-2,654	-4,181	4,000
30	TOT 1A	414	154	875	650
37	TOT 4A	357	259	1,088	810
43	North of San Onofre	664	1,018	-682	2,440
46	West of Colorado River (WOR)	4,204	7,126	7,365	10,623
48	Northern New Mexico (NM2)	-18	-357	-1,790	-1,970
49	East of Colorado River (EOR)	3,100	3,588	4,062	9,300
66	California-Oregon Interface (COI)	2,346	-267	-1,593	4,800 / -3,675

Coal Displacement



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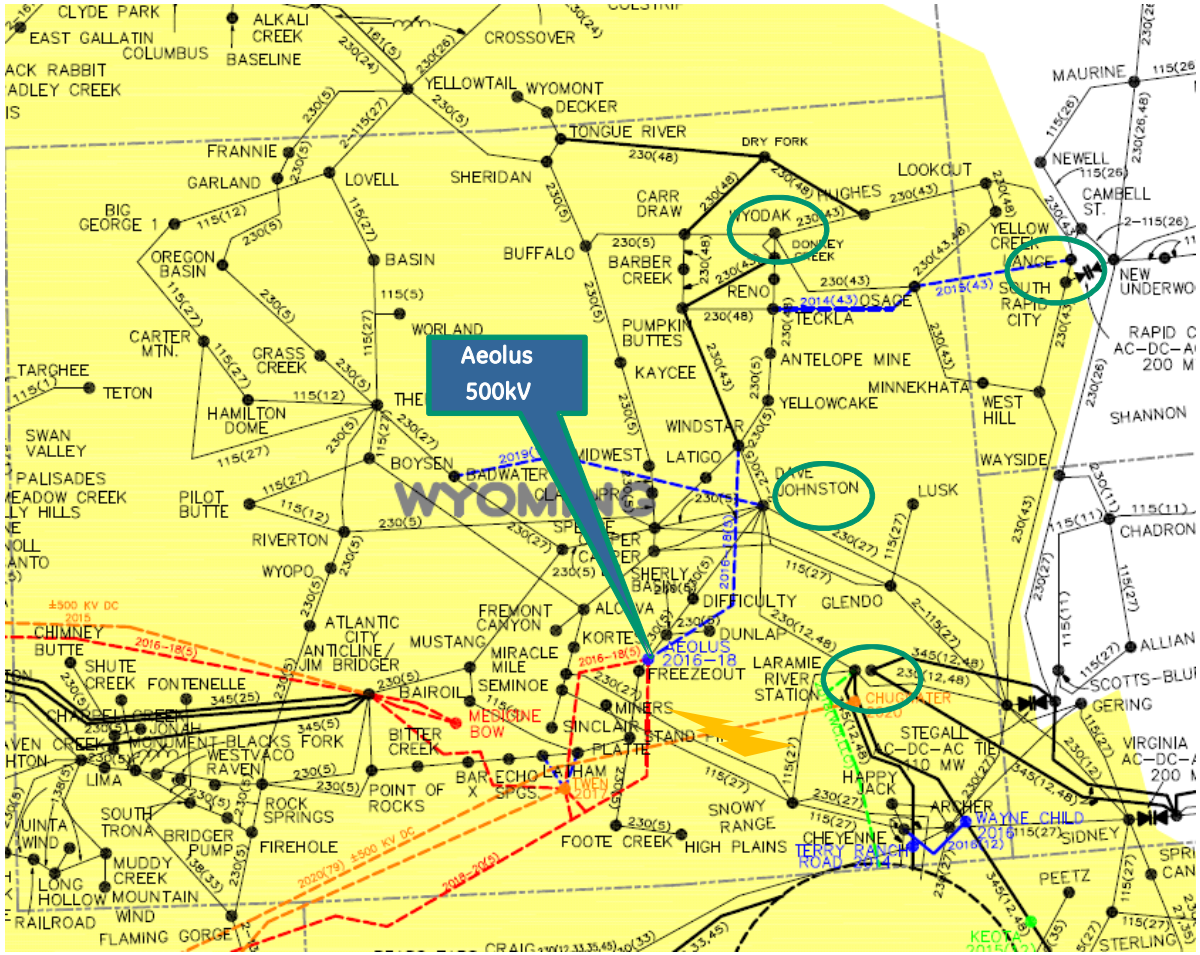
Transient Stability – Aeolus Fault



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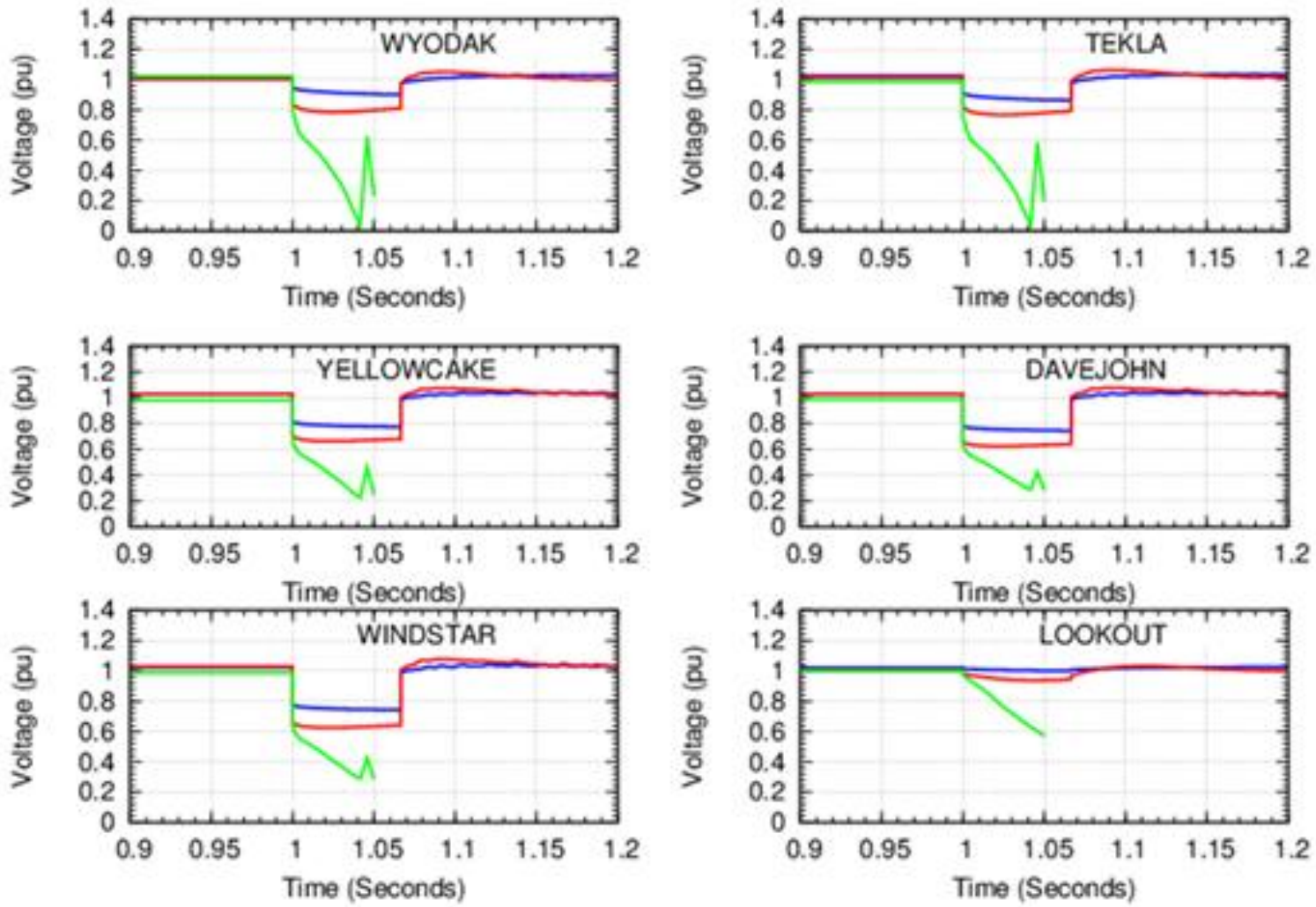
Transient Stability – Aeolus Fault

Light Spring Base
Light Spring Hi-Mix
Light Spring Extreme



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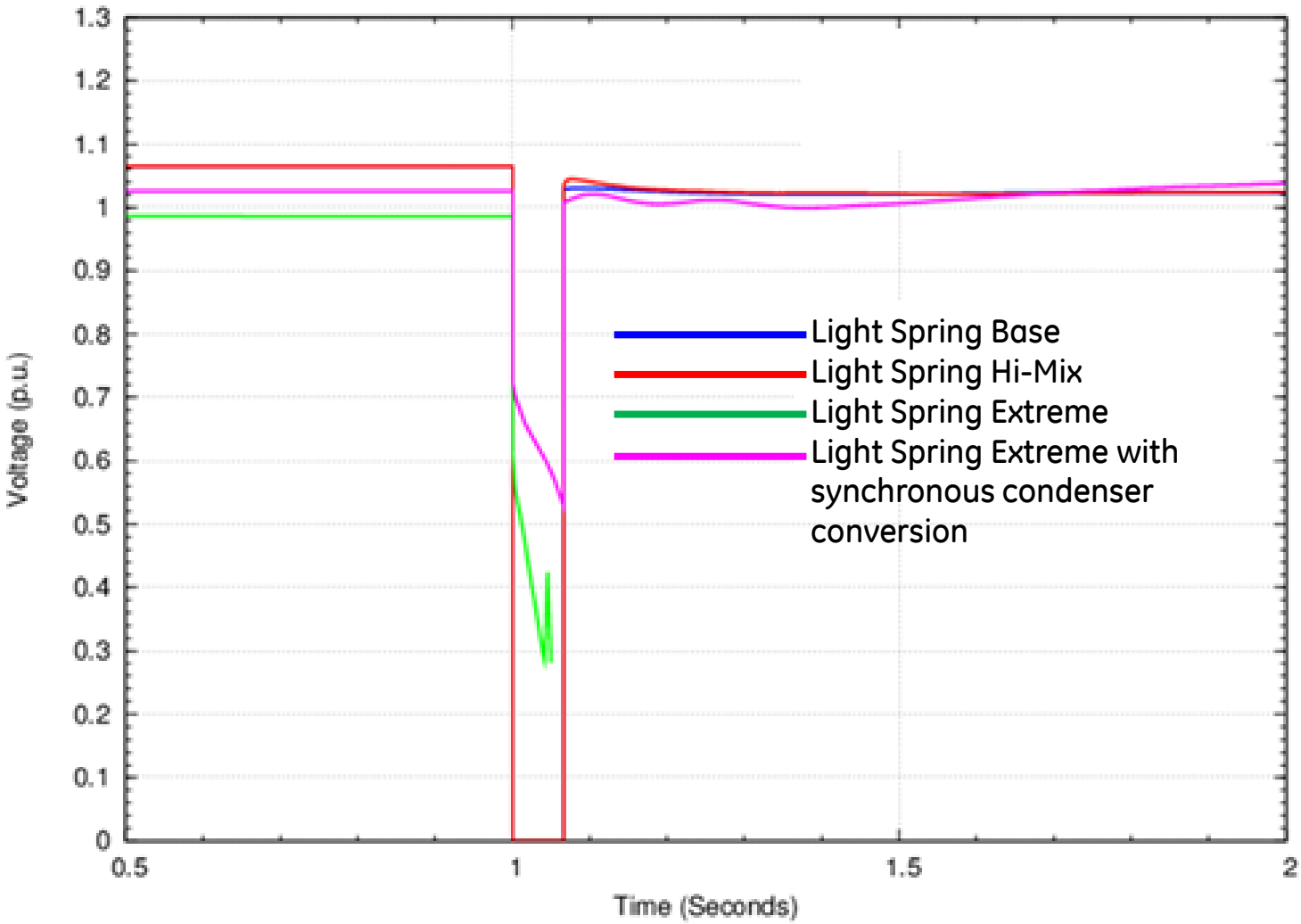
Transient Stability – Aeolus Fault



Synchronous condenser conversion at Dave Johnson 4 (400 MVA), Wyodak 1 (402.3 MVA), Laramie River 1 (690 MVA) plus ~500MVAr additional shunt capacitors

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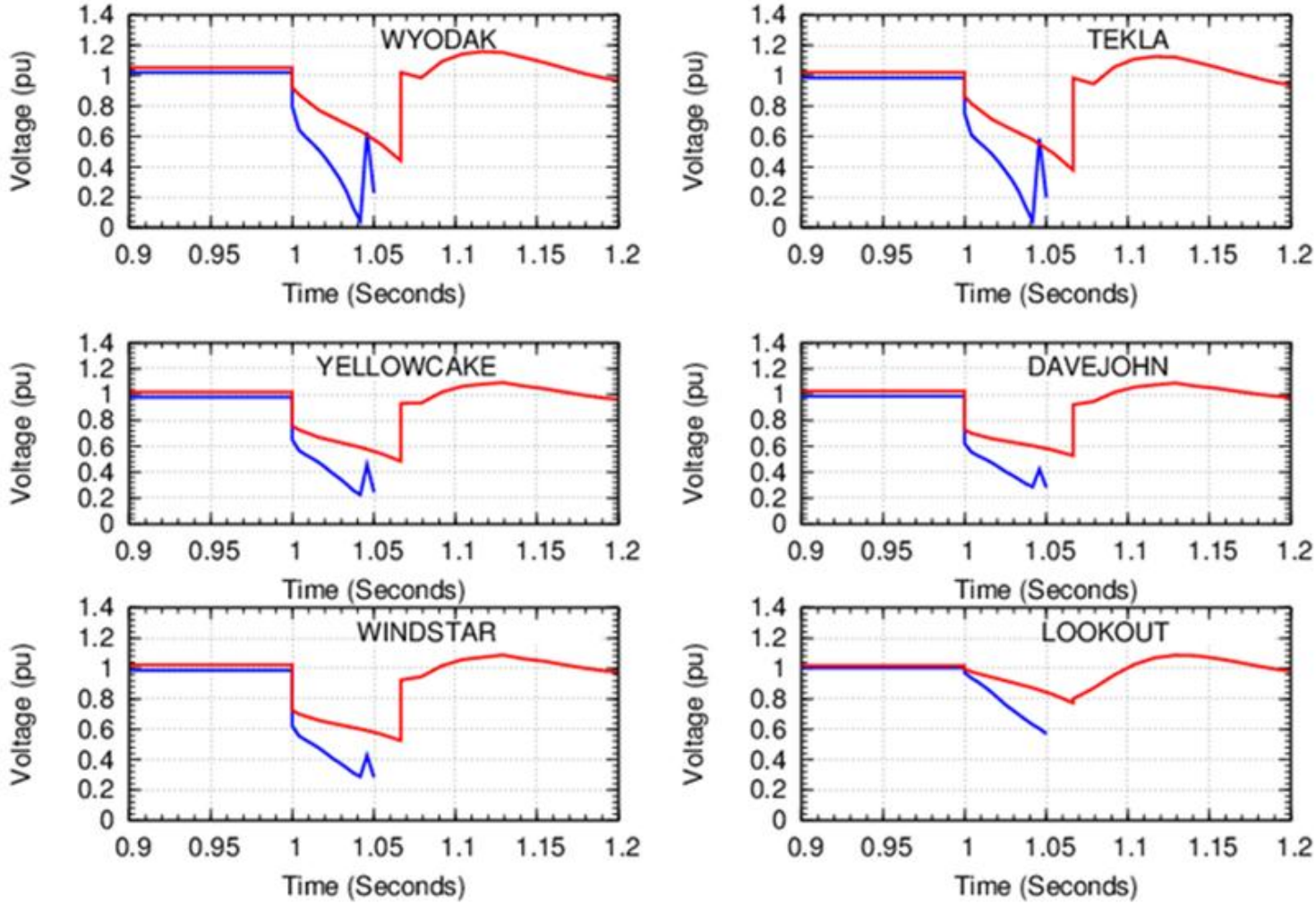
Aeolus Fault – Condenser Conversions

Light Spring Extreme, without condenser conversions
Light Spring Extreme, with condenser conversions



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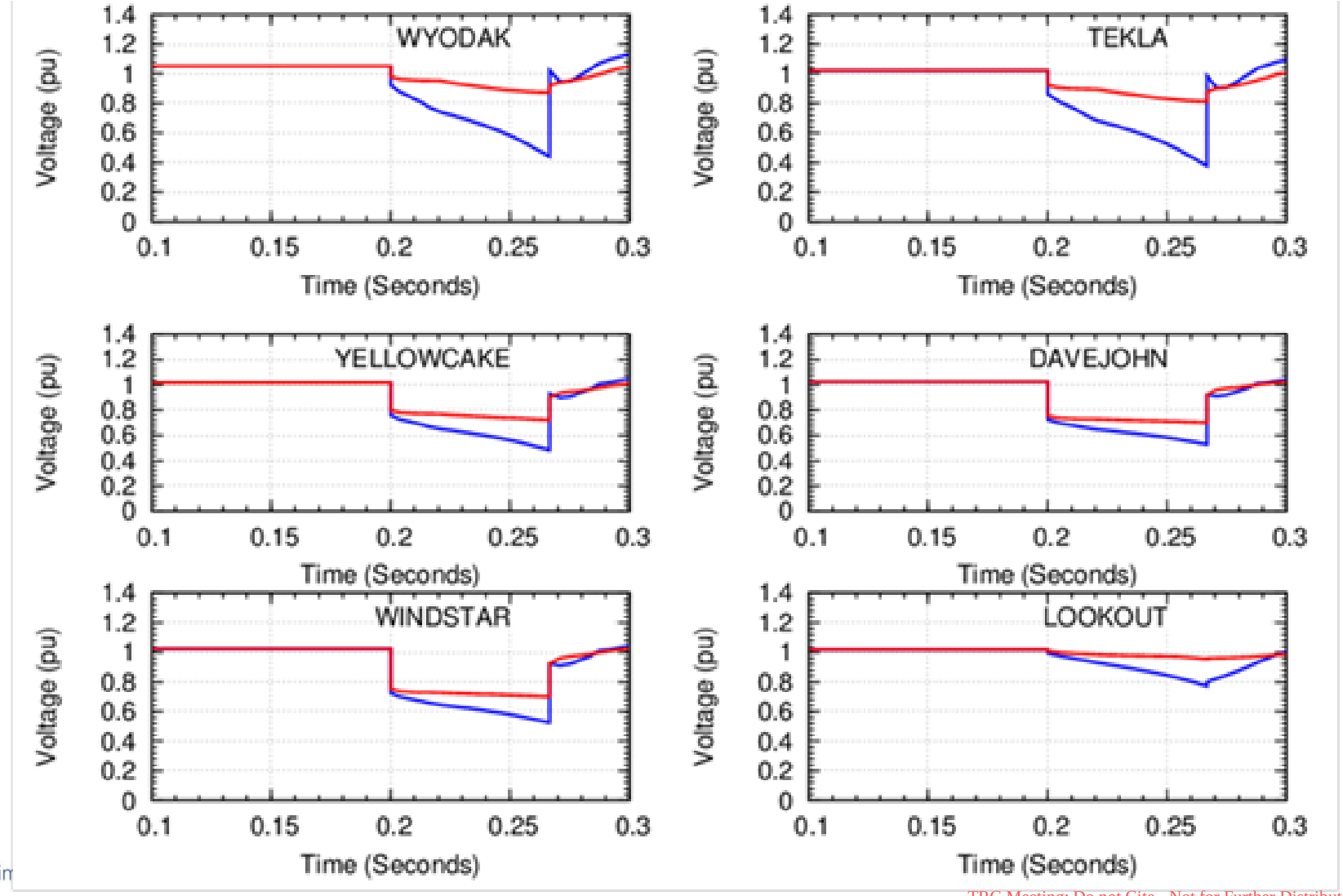
Aeolus Fault – Weak Grid WTG Controls

Light Spring Extreme, Standard WTG Controls and condenser conversions
Light Spring Extreme, Weak Grid WTG Controls and condenser conversions



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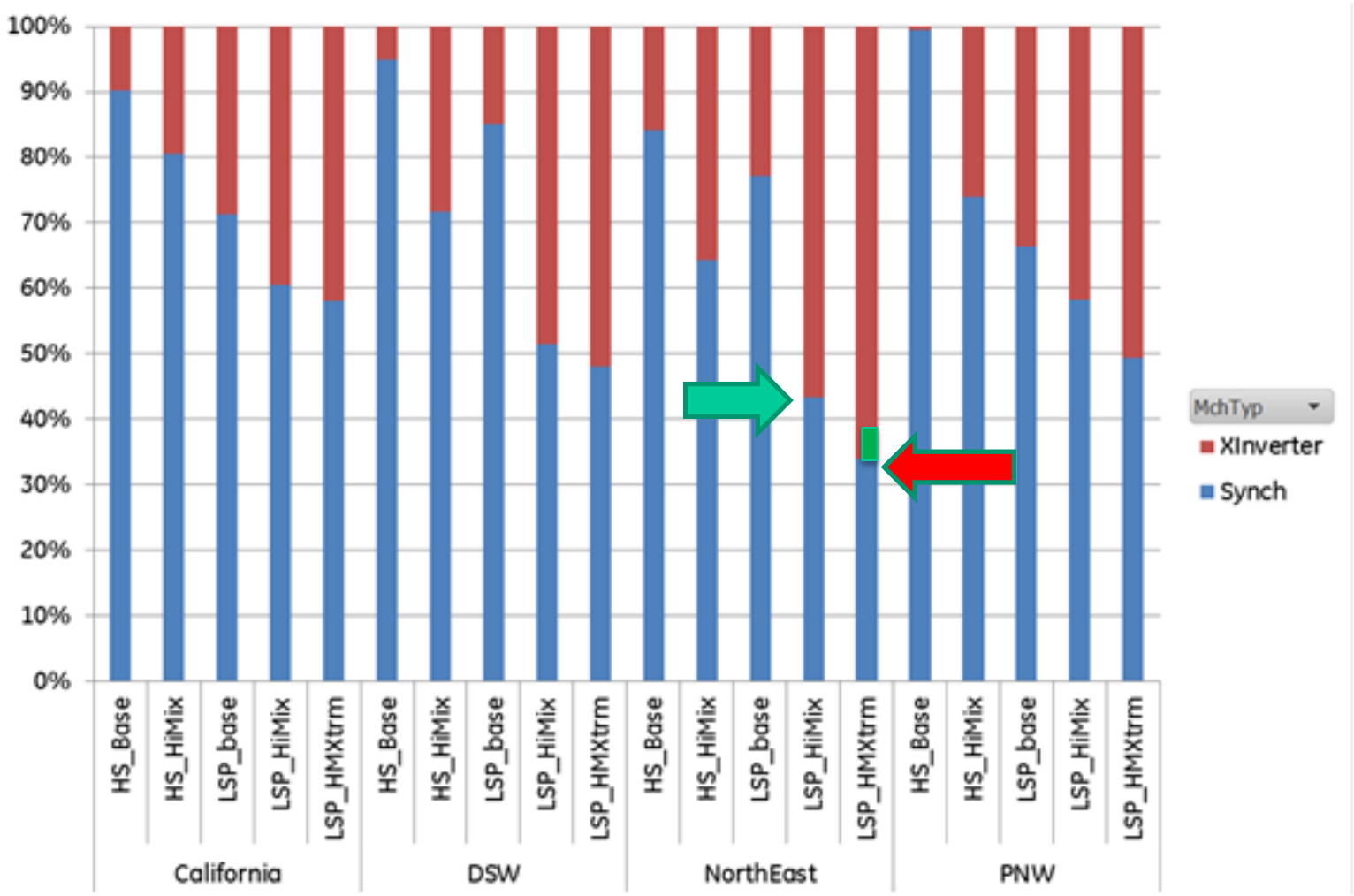
Synchronous vs. Non-synchronous



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Means to Improve Transient Stability

- Transmission additions
- Generation tripping RAS
- Frequency responsive controls on CSP plants

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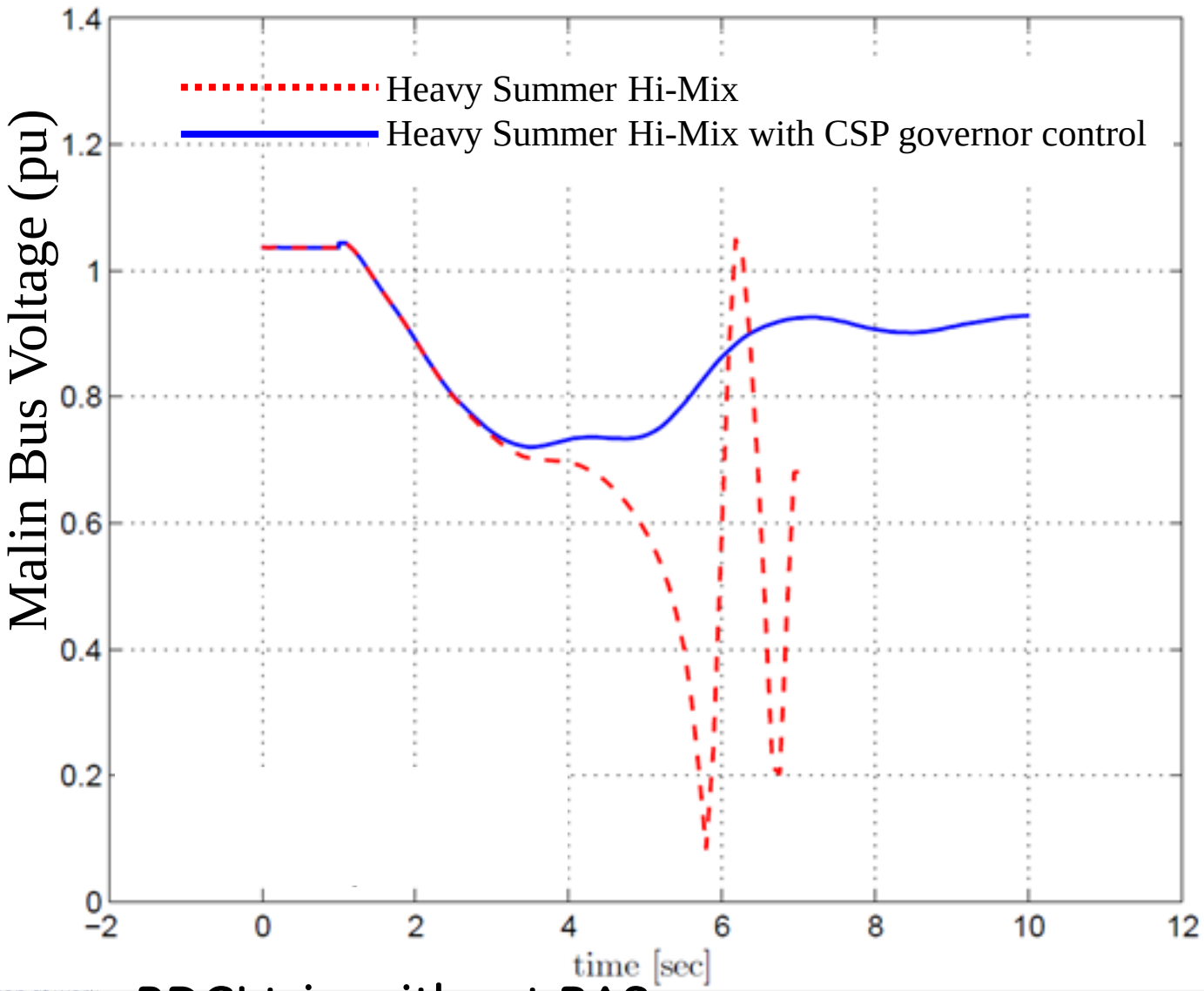
Frequency Control on CSP



PDCI trip without RAS

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Transient Stability Conclusions

For the conditions studied:

- System-wide transient stability can be maintained with high levels of wind and solar generation. An 80% reduction in coal plant commitment resulted in acceptable transient stability performance. Local stability, voltage and thermal problems will need to be addressed with straightforward transmission system reinforcements. (ExSum Sections 1.4 & 1.5, Report Sections 4, 6 & 8.3)

- With further reinforcements, a 90% reduction in coal plant commitment resulted in acceptable transient stability performance. (ExSum Sections 1.4 & 1.5, Report Sections 4, 6, 7.2, 7.5 & 8.4)

- Additional transmission, and CSP generation with frequency responsive controls are effective at improving transient stability. (ExSum Section 1.3, Report Sections 7.2, 7.5 & 8.4)

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Frequency Response Analysis

- System conditions
  - Primarily light spring Base and Hi-Mix
  - Plus Extreme renewables light load sensitivity
  - Plus heavy summer Base and Hi-Mix
- Outages
  - Loss of 2 Palo Verde
  - Loss of DG ~equivalent to 2 Palo Verde
  - Loss of 3 Palo Verde
  - Loss of 3 Palo Verde and sympathetic DG trip

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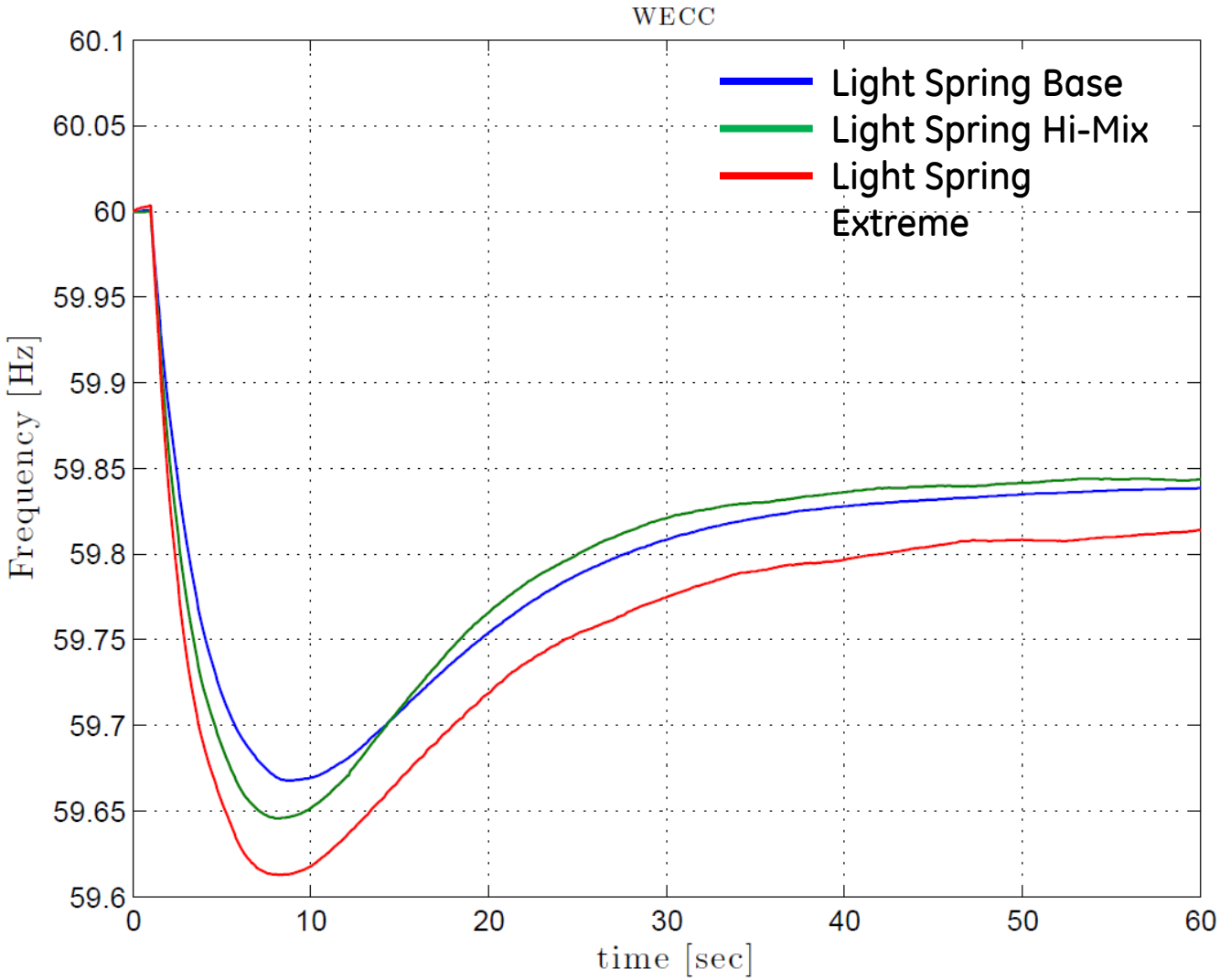
Frequency Response – Increasing VG



Trip 2 Palo Verde units (~2,750MW)

imagination at work

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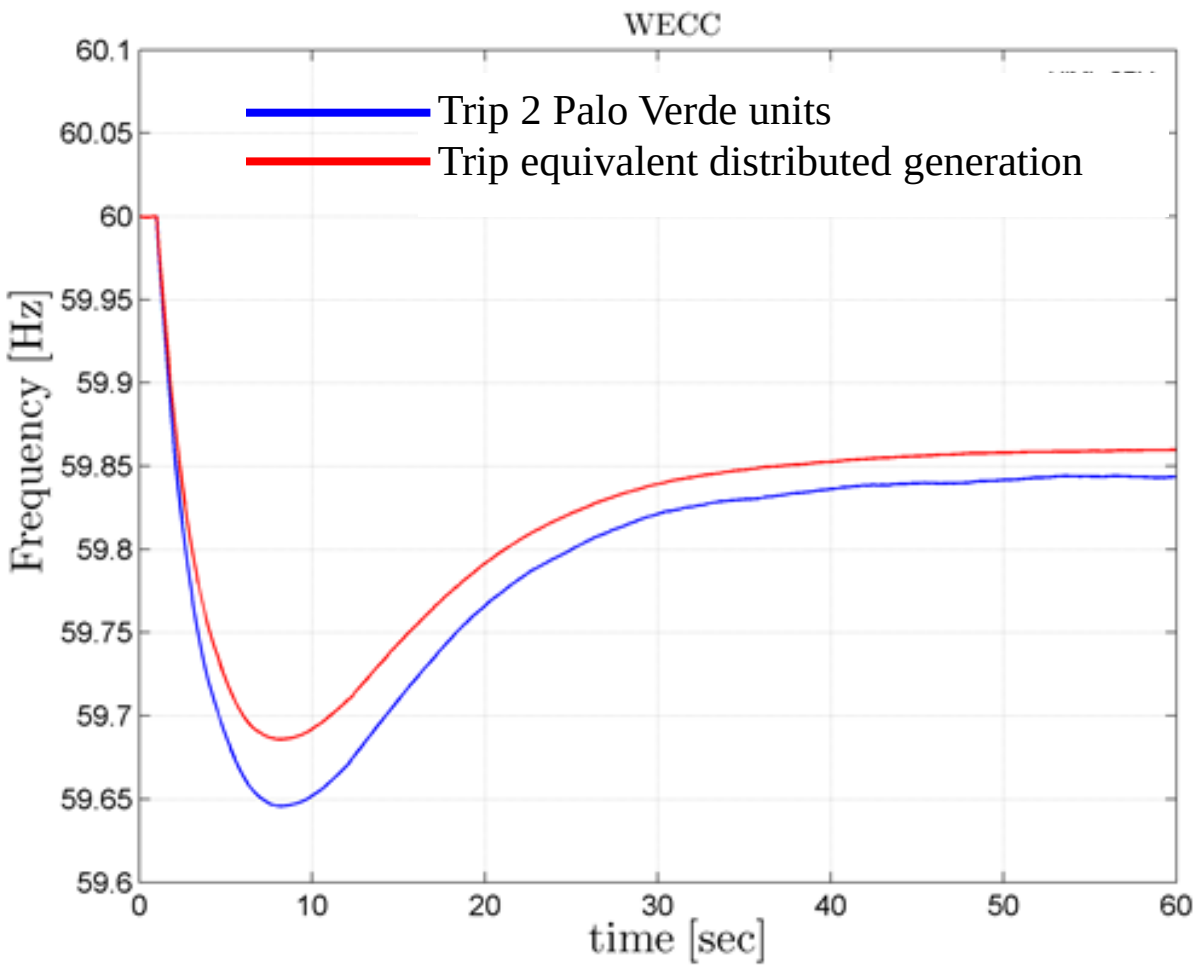
Frequency Response – Big Plant vs. Distributed Gen Trip



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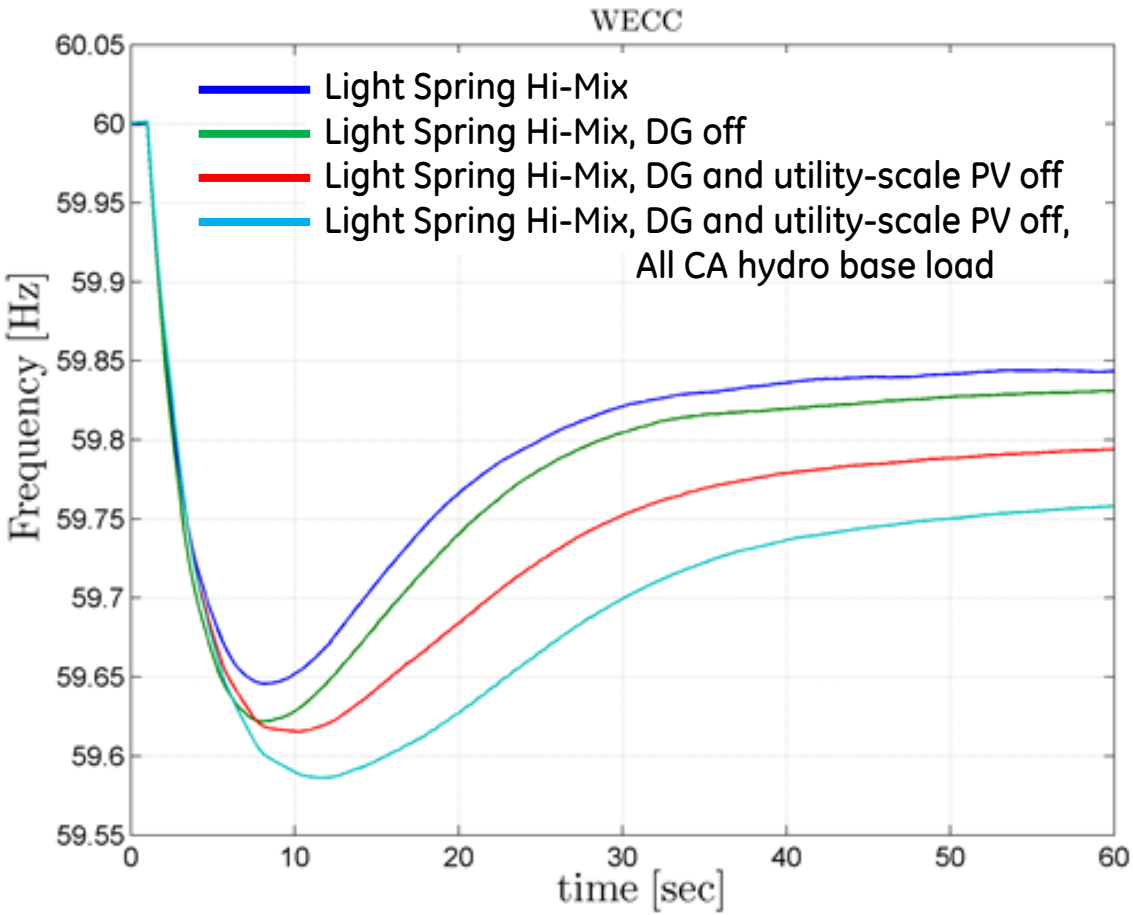
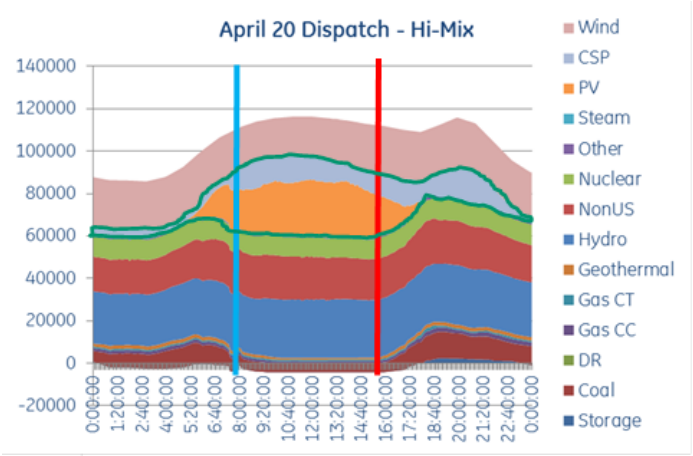
Frequency Response – Headroom Depletion





Trip 2 Palo Verde units (~2,750MW)

imagination at work

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Means to Improve Frequency Response

- Frequency responsive controls on wind plants
- Frequency responsive controls on solar plants
- Frequency responsive controls on energy storage

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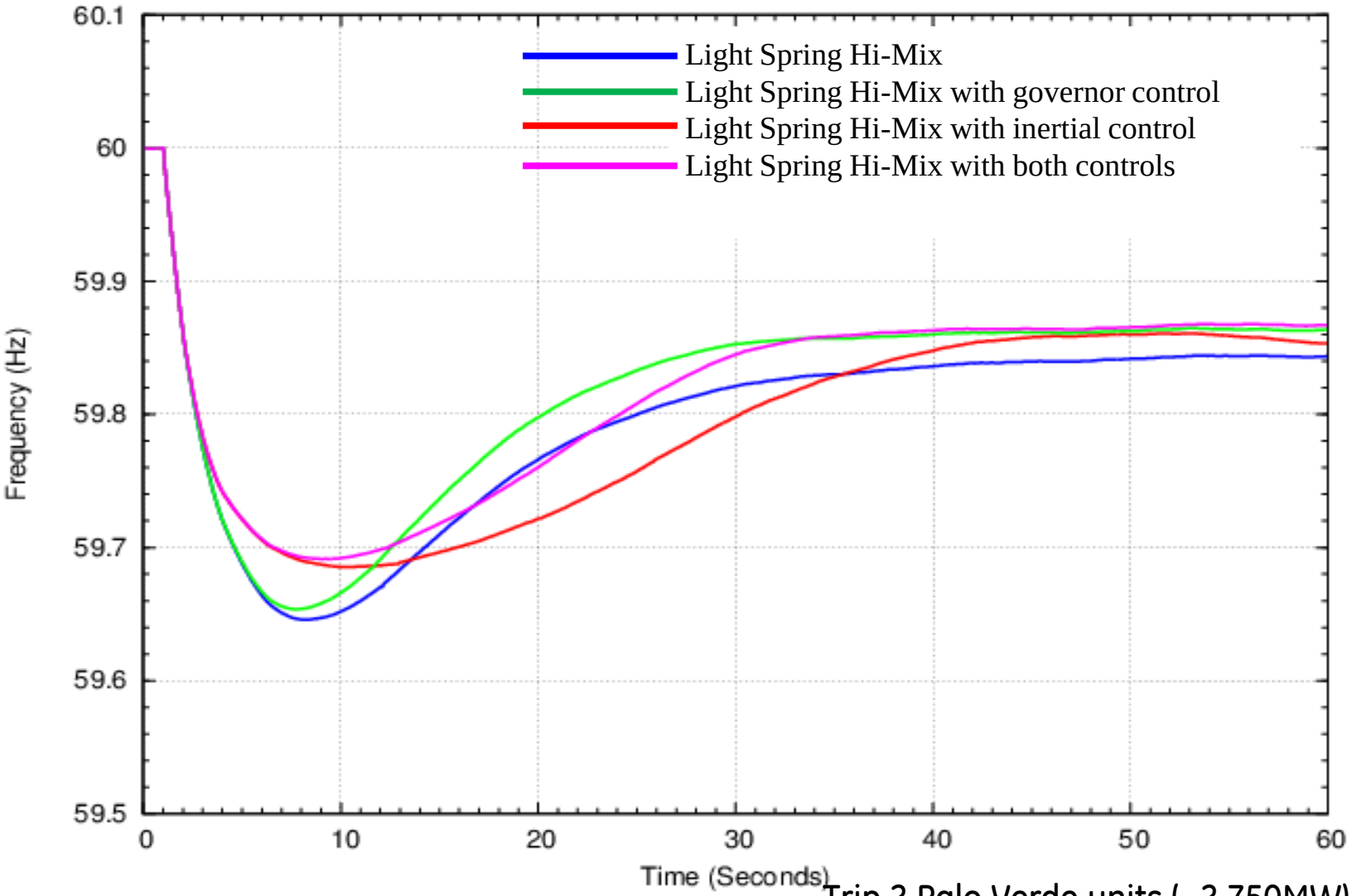
Frequency Control on Wind Plants



Trip 2 Palo Verde units (~2,750MW)

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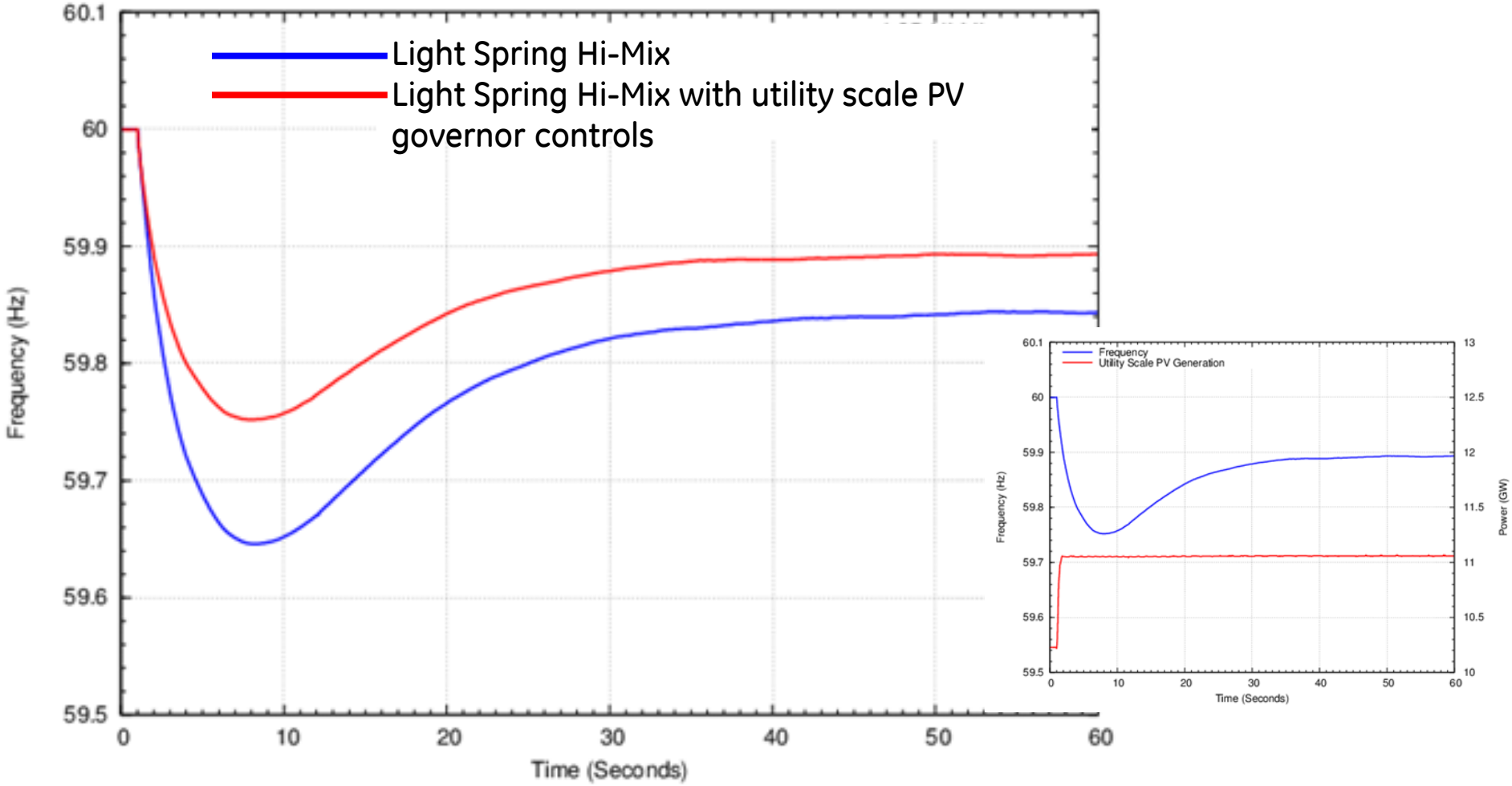
Frequency Control on Utility-scale PV



Trip 2 Palo Verde units (~2,750MW)

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FR vs. FRO

Key:
>110% of FRO
90%<FRO<110%
<90% of FRO

		Light Spring Frequency Response (MW/0.1Hz)							
	FRO	Base	Hi-Mix	Wind Governor Control	Wind Inertial Control	Wind Governor and Inertial Controls	Utility-scale PV Governor Control	Energy Storage	Extreme Hi-Mix
WECC	840	1352	1311	1610	1323	1571	2065	1513	1055
By Region									
CALIFORNIA	296	305	312	335	315	334	562	369	295
DSW	220	215	119	240	111	215	475	224	97
NORTHEAST	82	61	47	140	40	129	135	85	51
NORTHWEST	131	434	483	528	507	528	537	487	280
By Area									
ARIZONA	104	69	50	67	48	63	237	105	45
EL PASO	9	4	4	5	3	4	21	9	3
IDAHO	18	21	22	23	22	23	23	22	21
IMPERIALCA	4	14	14	27	13	24	42	14	14
LADWP	29	31	30	31	30	31	71	30	29
MONTANA	11	10	10	53	5	44	9	10	11
NEVADA	28	44	34	34	34	35	56	34	19
NEW MEXICO	14	50	2	9	8	9	55	14	2
PACE	42	23	8	58	6	55	26	40	11
PG AND E	133	190	197	205	198	205	202	197	189
PSCOLORADO	36	-14	6	6	6	6	49	33	6
SANDIEGO	21	7	7	7	7	7	7	21	7
SIERRA	11	7	7	7	7	7	76	10	7
SOCALIF	108	63	63	64	65	66	240	103	56
WAPA R.M.	27	63	24	118	11	98	56	26	23
WAPA U.M.	0	3	3	4	3	4	3	3	3

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Frequency Response Conclusions

For the conditions studied:

- System-wide frequency response can be maintained with high levels of wind and solar generation. (ExSum Sections 1.2 & 1.3, Report Sections 3, 5.2, 5.4, 5.6, 5.7 & 8.1)

- Individual balancing area frequency response may not meet its obligation without additional frequency response from resources both inside and outside the particular area. (ExSum Sections 1.2 & 1.3, Report Sections 3, 7 & 8.2)

- For California, adequate frequency response was maintained during acute depletion of headroom from afternoon drop in solar. Ability of California hydro to provide frequency response is required. (ExSum Section 1.2 , Report Section 5.4)

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Frequency Response Conclusions, pt 2

For the conditions studied:

- Frequency responsive controls on wind, solar PV, CSP plants, and energy storage are effective at improving both frequency nadir and settling frequency, and thus frequency response. (ExSum Section 1.3, Report Sections 7.1, 7.2, 7.3, 7.4 & 8.2)

- Using new, fast responding resources to ensure adequate frequency response adds complexity, but also flexibility, with high levels of wind and solar generation. Practice will need to evolve to take advantage of easily adjustable speed of response, as well as location, and size of the generation trip. (ExSum Section 1.6, Report Sections 7.2, 7.3, 7.4 & 8.5)

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Model Improvement

- Load model
- Wind and solar models
- Frequency responsive control philosophy

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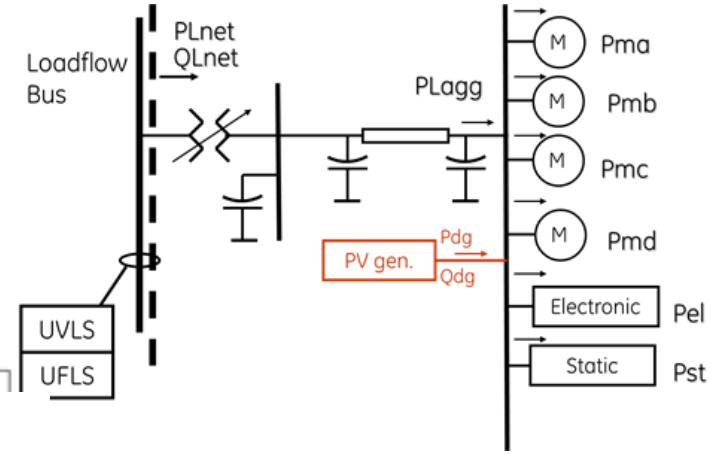
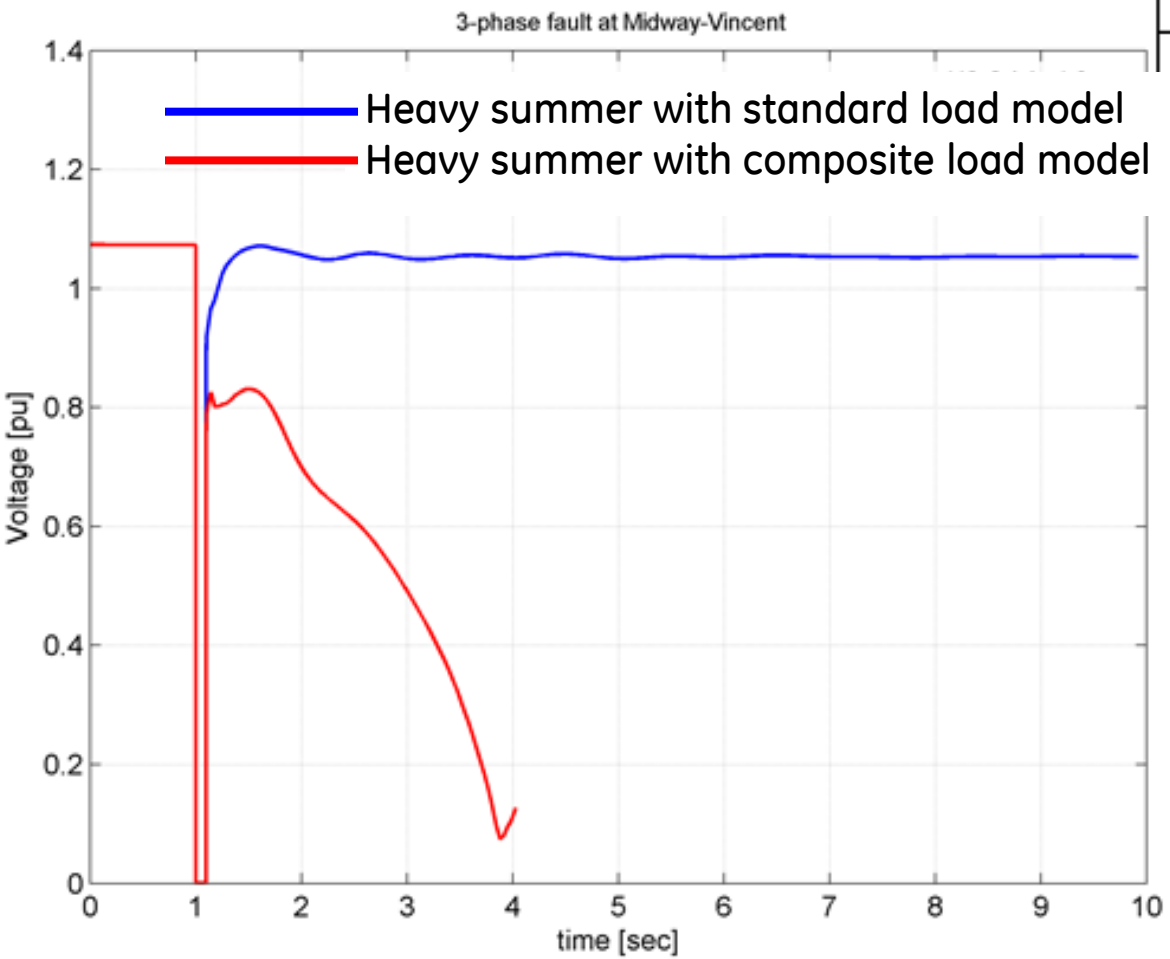
Impact of Load Model





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Other Conclusions

- Accurate modeling is extremely important when analyzing high stress conditions – solar PV, CSP, wind and load models all had an impact on system performance. (ExSum Section 1.6, Report Sections 5.1, 6.1, 6.4 & 8.5)

- Attention to detail is important. Local and locational issues may drive constraints on both frequency response and transient stability. (ExSum Section 1.4, Report Sections 2.2, 2.6, 4.2 & 8.3)

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Other Conclusions

- The location of generation tripping, e.g., DG vs. central station, is not as important as the amount of generation that is tripped. However, widespread deliberate or sympathetic DG tripping after a large disturbance had an adverse impact on system performance. (ExSum Section 1.2, 1.4 & 1.6 , Report Sections 5.1, 5.2, 5.3, 8.1, 8.3 & 8.5)

- Further analysis is needed. (ExSum Section 1.6, Report Section 8.5)
  - High coal displacement/Weak grid/Low levels of synchronous generation
  - Path ratings and associated remedial action schemes
  - DG impact on transmission system performance
  - Costs and benefits of constraining commitment and dispatch to reserve FR

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Schedule & Next Steps

- October 16, 2014 – final comments due on draft final report and draft executive summary
- December 31, 2014 – final report published
- Some FY15 funding for dissemination of study results – venue suggestions welcome
- Some FY15 funding for follow-on work to explore system performance with high penetration wind, and subsequent low levels of synchronous generation