WWSIS III: Western Frequency Response and Transient Stability Study

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TRC Review: Preliminary Results and Next Steps
October 10, 2013

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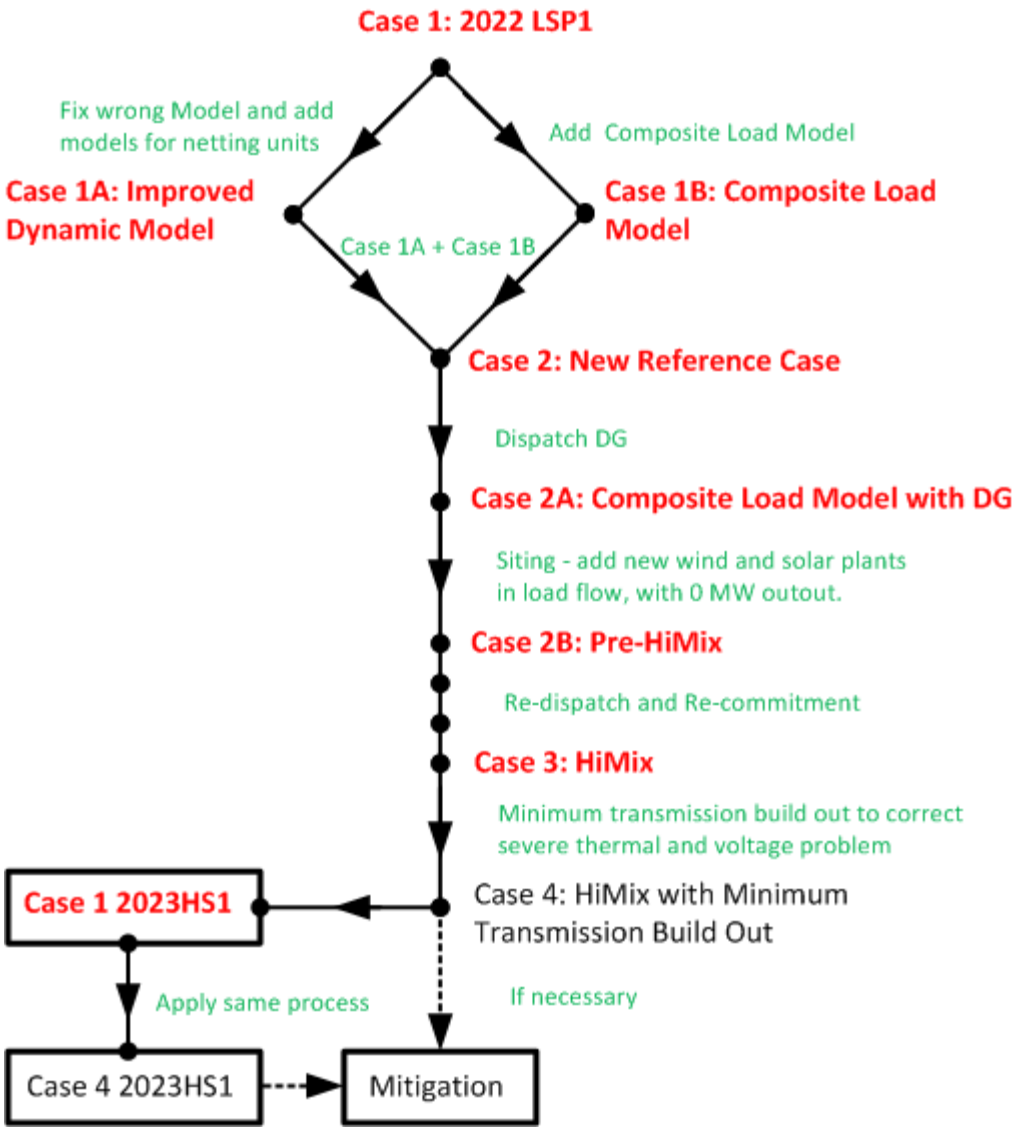
Outline

- Introduction
- De-commitment, re-dispatch and add renewables
- 2022LSP Case 3 (HiMix)
- 2022LSP Case 2A (Composite Load Model with DG)
- 2023 HS
- Plexos Hi-Mix Summer case
- Summary and Next Steps

Projected Evaluation of Study Cases



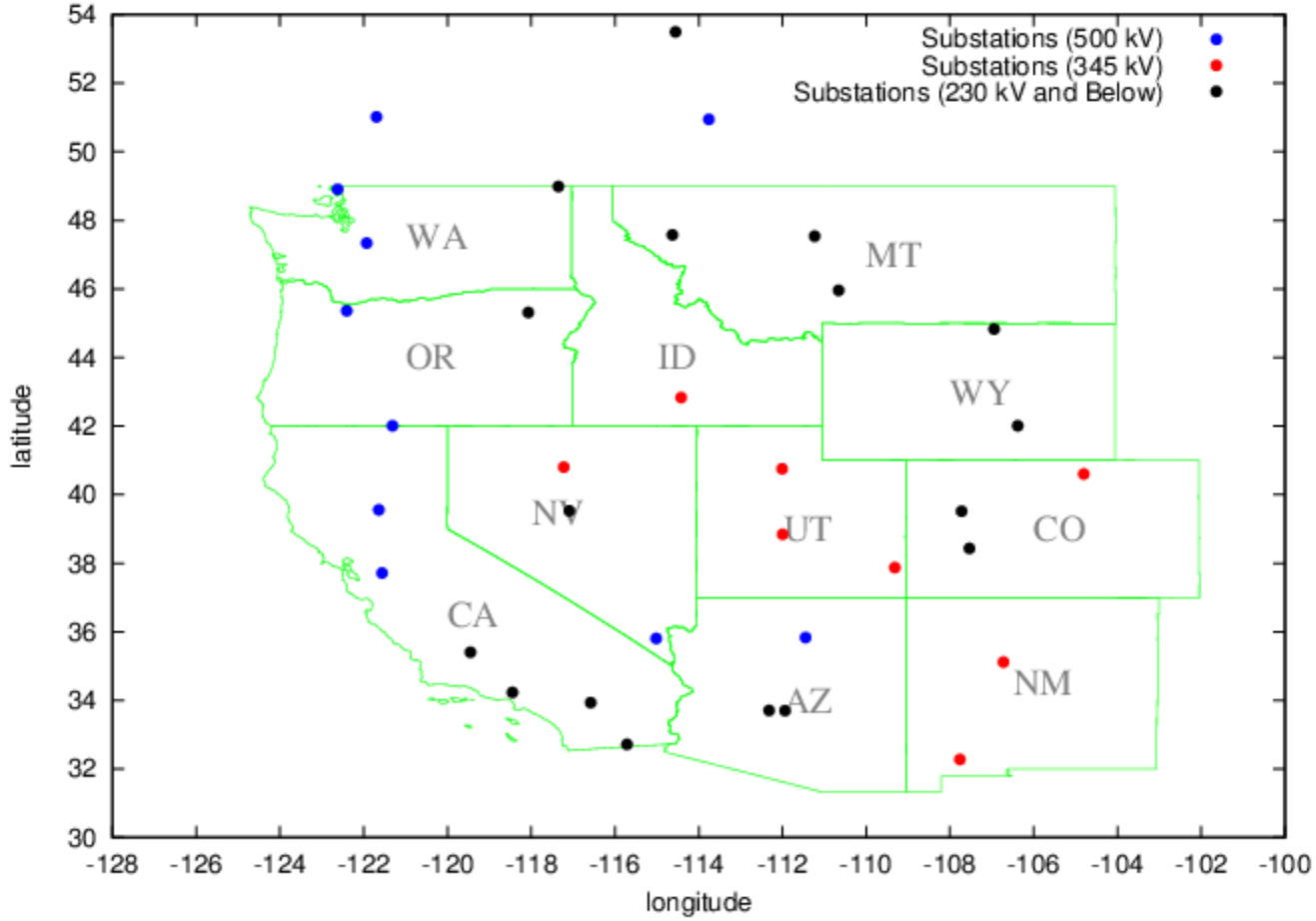
Performance Metrics: Area/Regional Monitoring

- New dynamic model (epcmod) to regional performance

Chan ID	Description
fr	Frequency (Hz) calculated from MVA weighted speed of synch machines
pg	Pgen of units with governors (GW)
mc	Capacity of units with governors (GW)
hr	Headroom on units with governors (GW)
nu	Number of units with governors
pm	Mechanical power of unit with governors (GW)
mv	MVA rating of unit with governors (GVA)
px	Pgen of units w/o governors (GW)
mx	Mechanical power of units w/o governors (GW)
nx	# units w/o governors
pq	Pgen of all synchronous generators (GW)
qg	Qgen of all synchronous generators (GVAr)
pl	P load (GW)
ql	Q load (GVAr)
pw	Pgen – Wind (GW)
qw	Qgen – Wind (GVAR)
pv	Pgen – Solar PV
qv	Qgen – Solar PV
pc	Pgen - CSP (GW)
dg	Pgen- DG (solar PV)

WECC Monitored Bus Locations

Frequency, voltage and angle at key WECC buses



25 Monitored Groups

- Each WECC area (21 total)
- Entire WECC System
- Desert Southwest
  - ARIZONA, EL PASO, NEVADA, NEW MEXICO, PSCOLORADO, WAPA R.M.
- Northeast
  - IDAHO, MONTANA, PACE, SIERRA, WAPA U.M.
- Northwest (area NORTHWEST)
- CALIFORNIA
  - IMPERIALCA, LADWP, PG&E, SANDIEGO, SOCALIF

2022LSP Case 2 – Initial Condition Metrics

		WECC	CALIFORNIA	DSW	NORTHEAST	NORTHWEST
Pgen of units with governors (GW)	pg	45.0	6.6	11.3	3.0	12.5
Capacity of units with governors (GW)	mc	67.7	12.8	16.2	4.4	17.8
Headroom on units with governors (GW)	**hr**	**22.7**	**6.1**	**4.9**	**1.3**	**5.2**
Number of units with governors	**nu**	**856.0**	**192.0**	**137.0**	**97.0**	**208.0**
Mechanical power of unit with governors (GW)	pm	45.1	6.7	11.3	3.0	12.6
MVA rating of unit with governors (GVA)	mv	69.0	13.3	17.9	4.6	16.5
Pgen of units w/o governors (GW)	px	53.0	14.7	14.4	9.8	2.1
Mechanical power of units w/o governors (GW)	mx	53.2	14.8	14.4	9.9	2.1
# units w/o governors	nx	823.0	326.0	82.0	132.0	68.0
Pgen of all synchronous generators (GW)	pq	98.0	21.3	25.7	12.8	14.7
Qgen of all synchronous generators (GVAr)	qg	5.3	-0.7	2.4	0.7	0.8
P load (GW)	pl	113.7	33.6	25.0	11.8	19.1
Q load (GVAr)	ql	32.1	8.2	7.2	3.3	4.3
Pgen – Wind (GW)	**pw**	**21.6**	**5.1**	**4.0**	**2.5**	**8.4**
Qgen – Wind (GVAR)	qw	-1.2	-0.6	0.4	-0.2	-0.7
Pgen – Solar PV	**pv**	**3.3**	**3.1**	**0.2**	**0.0**	**0.0**
Qgen – Solar PV	qv	0.1	0.1	0.0	0.0	0.0
Pgen - CSP (GW)	**pc**	**0.6**	**0.6**	**0.0**	**0.0**	**0.0**
Pgen- DG (solar PV)	**dg**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Kt	Kt	0.47	0.36	0.47	0.26	0.63

Kt definition important!

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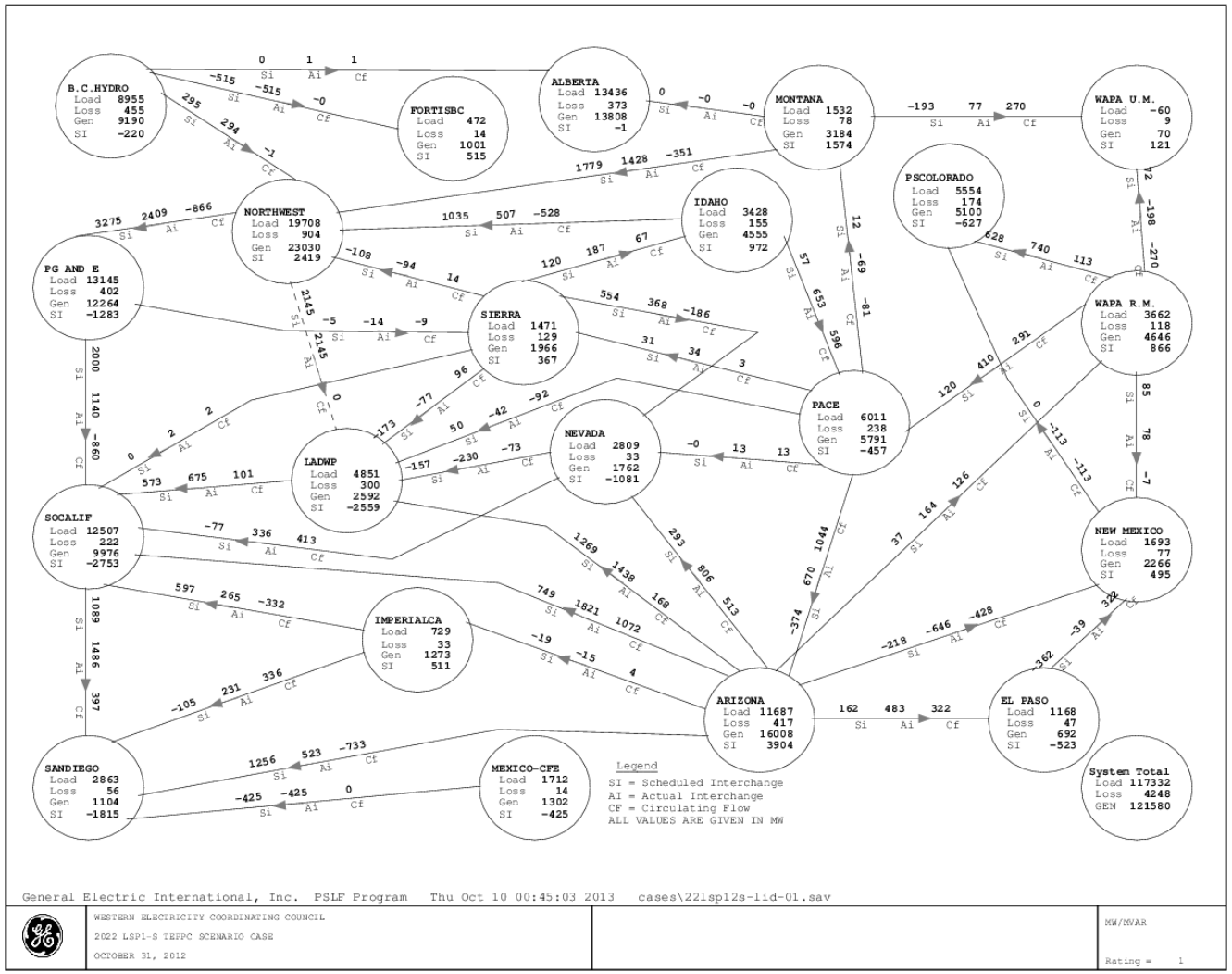
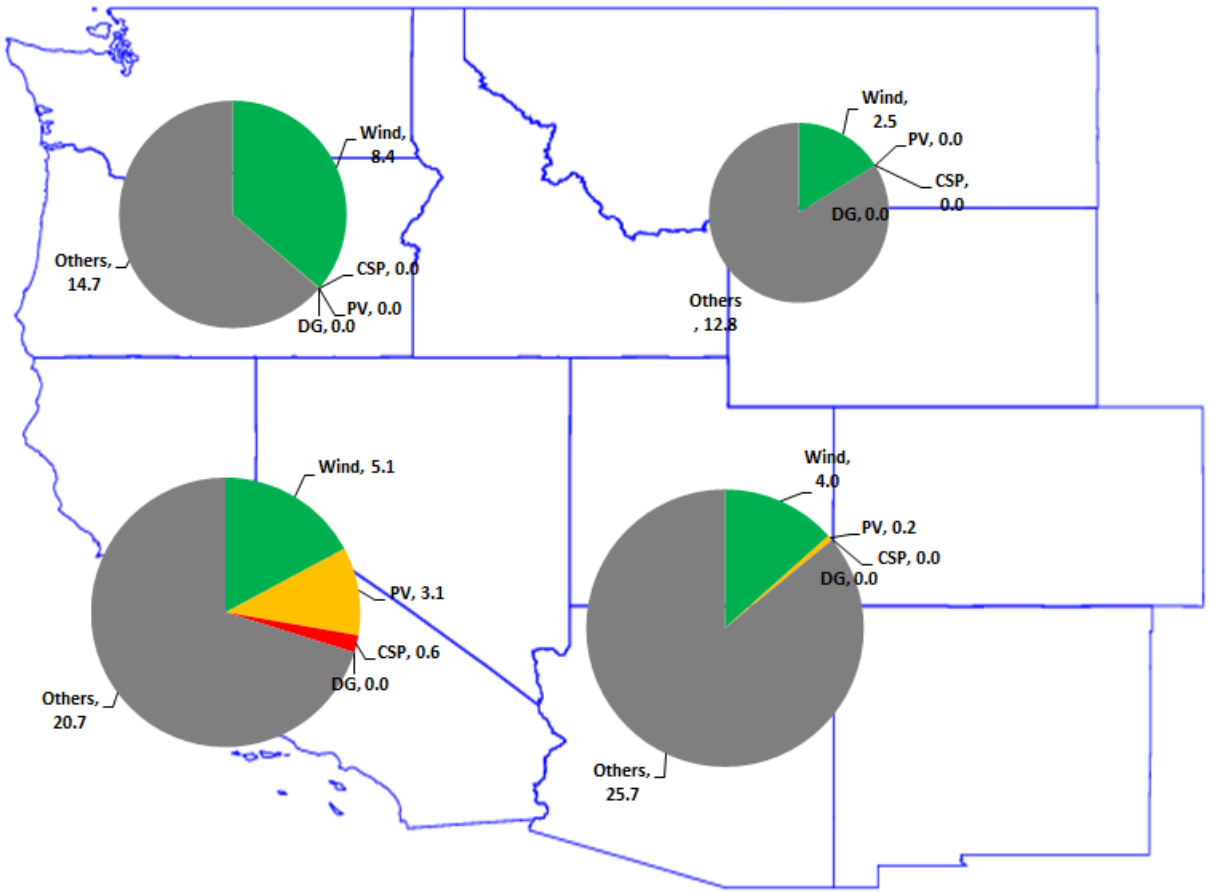
2022 LSP Case 2 – with Composite Load Model



2022LSP Case 2 – Renewable Conditions



~ 25 GW of wind and solar in US

	WECC	CALIFORNIA	DSW	NORTHEAST	NORTHWEST
Wind (GW)	21.6	5.1	4.0	2.5	8.4
PV (GW)	3.3	3.1	0.2	0.0	0.0
CSP (GW)	0.6	0.6	0.0	0.0	0.0
DG (GW)	0.0	0.0	0.0	0.0	0.0
Others (GW)	97.4	20.7	25.7	12.8	14.7

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Preliminary Results: Not for Further Distribution or Citation

Adding renewables, de-commitment and redispatch

A quick reminder of the core question we are addressing:

- The type, location, status and dispatch of *all* generation is critical to system frequency response and transient stability performance
- Unlike our earlier work, the new wind and solar is added at appropriate locations in the grid (rather than simply swapping out existing thermal plants, as we have done in some other work)
- As wind and solar generation picks up, other generation will be displaced….in a fashion that results in the lowest operating cost that satisfies the system physical and security constraints. Easy right?
- Economics drives the process…loadflow and stability programs are not, alone, economic tools.
- The economic evaluation of the WWSIS II work, using Plexos, is used here to provide an *economically rational* basis for the operational displacement of other generation by wind and solar power
- The next section describes the process in detail

Mining Plexos

Filtering the PLEXOS TEPCC results to capture periods of operation that are close to that of the WECC LSP'22 case:

Select/Filter:

- Day Time (PV $\neq$ 0.0)
- Spring (3/21-6/21)
- Load within 10GW of WECC LSP'22 case: 115GW
- Total W+S > 18GW in TEPPC: (WECC case has 21.6GW W+S in US)

Total: 1223 5-minute periods…about 1% of all year.

Average W+S : TEPPC = 20.6GW (compares well to 21.6 in WECC case)
Hi-Mix = 48.3GW

Max W+S: TEPPC = 26.5GW
Hi-Mix = 62.9GW (a sensitivity case?)

Look at impact on different classes of generation, vs. changes in W+S, and across TEPPC vs HiMix. Objective is to get clearer insight on the operation (dispatch & commitment) "rules" that apply **during periods like this** (LSP)

Mining Plexos Spring Samples

- PLEXOS TEPPC and Hi-Mix data used for 1st month of Spring (March 21-April 21, 2020)… this is results in:
- 487 5-minute samples
- Spread across 9 contiguous windows on 9 different days:

March 23	10:35 - 11:45	15 samples
April 1	9:10 - 15:40	79 samples
April 8	9:45 - 18:10	100 samples
April 9	6:50 – 13:45	84 samples
April 13	12:55	1 sample
April 16	10:55 – 14:10	17 samples
April 17	12:45 – 14:50	20 samples
April 20	7:10 – 17:35	126 samples
April 21	8:20 – 12:00	45 samples

Mining Plexos Spring Samples

- PLEXOS TEPPC and Hi-Mix data used for 1st month of Spring (March 21-April 21, 2020)… this is results in:
- 487 5-minute samples
- Sample that represent the mean of the sample space is sample # 31775 (April 4, 20120 at 7:50)
- Process of mapping Plexos TEPCC and HiMix cases with 2022 LSP case:
  - Map bus numbers, area and zone information for existing plants
  - Map bus numbers, area and zone information for added (WWSIS II) renewables
  - If Plexos TEPCC/HiMix bus number can't be found in 2022 LSP case, its area is set to -1 (so it is disregarded later)

Mining Plexos Case – Renewable Summary

Renewables summary for sample 31775

Fraction of PV that is distributed generation (DG)

Means "utility scale" PV

TEPCC (WWSIS II) @ 31775

Area #	CSP	WWSIS PV	WWSIS_wind
54			
14	515	1017	3261
50			
11	0	0	2
60		0	127
21	0	143	364
26	849	1123	0
20			
62	0	0	147
18	16	16	0
10	167	302	31
40	0	0	3960
65	0	0	1065
30	0	0	14
70	186	497	299
22	0	0	0
64	0	38	74
24	1098	2722	3421
52			
73	0	521	655
63		0	0
-1	34		
Total	2865	6379	13418

HiMix @ 31775

Area #	CSP	WWSIS PV	DG ratio	DG	PV	WWSIS_wind
54						
14	6375	3532	0.42	1471	2061	560
50						
11	143	428	0.47	202	227	2
60		0			0	150
21	124	309	0.10	32	277	337
26	493	1267	0.68	864	403	0
20						
62	0	5	0.44	2	3	1593
18	113	542	0.31	166	376	0
10	162	550	0.40	217	333	27
40	0	538	0.38	204	334	4551
65	0	326	0.73	239	87	2772
30	0	1274	0.46	584	690	30
70	178	962	0.37	355	608	594
22	0	205	0.57	116	89	0
64	0	936	0.22	208	728	661
24	1378	5238	0.44	2287	2951	2746
52						
73	0	792	0.46	364	428	3346
63		0	0.00	0	0	27
-1	644					
Total	9610	16905		7312	9592	17395

Difference

Area #	CSP	WWSIS PV	DG	PV	Wind
54					
14	5860	2515	1471	1044	-2701
50					
11	143	428	202	227	0
60	0	0	0	0	23
21	124	166	32	134	-26
26	-356	144	864	-720	0
20					
62	0	5	2	3	1446
18	97	526	166	360	0
10	-5	248	217	31	-4
40	0	538	204	334	591
65	0	326	239	87	1707
30	0	1274	584	690	16
70	-8	465	355	110	295
22	0	205	116	89	0
64	0	898	208	690	587
24	280	2516	2287	229	-676
52					
73	0	271	364	-93	2691
63	0	0	0	0	27
-1	609				
Total	6746	10526	7312	3214	3977

Remember these are from the Plexos case, NOT the WECC LSP base case

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Decommitment/Redispatch

Based on Plexos TEPCC and HiMix cases, develop rules for decommiting and redispatching generation, for periods of operation that look like the LSP'22 condition.

- Select Coal and Combined Cycle units, total 583 units
- For each of 583 units in 487 sample space look at pattern of its operation
- Develop rules for redispatch and decommitment of Coal and Combined cycle units and come up with list of units to be used in development of the Hi-Mix cases (Case 2A and Case 3)
- If short in redispatch capacity, consider redispatch of hydro units in Northwest and BC Hydro areas

Decommitment

- Develop rules for decomitment of generation for periods of operation that look like the LSP'22 condition.

- For each unit:
  - Set commitment flag for all units in sample space *{i.e. is the plant committed?}*

$$CF = \begin{cases} 1, & P>0 \\ 0, & P=0 \end{cases}$$

  - If $TEPCC_{CF}$ =1 and $HiMix_{CF}$=0, find set decommitment flag (DF) to 1 and calculate $\Delta P = P_{TEPCC} - P_{HiMix}$ *{i.e. does the plant get decommitted as wind & solar added?}*
  - Note: Δ P>0 means the unit is turned off
  - count # of times/percent DF=1 and $\Delta P <> 0$
  - count # of times/percent DF=1 $\Delta P>0$ (turned off)
  - count # of times/percent DF=1 $\Delta P<0$ (turned on)
- Decommitment rule: Take units that have DF<>0 for more than 30% of the time in the sample space *{i.e. plants that are often decommitted should be shutdown}*

Decommitment

Area summary of Coal and Combined Cycle units that have DF<>0 for more than 30% of the time in the sample space

Area name	Area #	# of units	average dP [MW]
ALBERTA	54	6	223
ARIZONA	14	20	1265
BC HYDRO	50		
EL PASO	11		
IDAHO	60	5	203
IMPERIALICA	21	1	37
LADWP	26	1	35
MEXICO-CFE	20	2	36
MONTANA	62	3	139
NEVADA	18		
NEW MEXICO	10	3	86
NORTHWEST	40	3	229
PACE	65	14	661
PG&E	30	6	497
PSCOLORADO	70	10	555
SAN DIEGO	22	1	35
SIERRA	64	3	156
SOCALIF	24	2	72
FORTISBC	52		
WAPA R.M.	73	21	1226
WAPA U.M.	63		
	-1		
Total		101	5455

So, for example, 20 specific INDIVIDUAL plants in Arizona are to be decommitted

Redispatch

- Develop rules for redispatching generation , for periods of operation that look like the LSP'22 condition.
  {i.e. need to further dispatch down plants to account for any displacement from renewables that wasn't covered by decommitting units}
- For each unit at every sample space:
  - Set commitment flag (CF) *{i.e. is the plant committed?}*

$$CF = \begin{cases} 1, & P>0 \\ 0, & P=0 \end{cases}$$

  - If $TEPCC_{CF}$ =1 and $HiMix_{CF}$=1, find $\Delta P = P_{TEPCC} - P_{HiMix}$
    {i.e. if the plant stayed committed, was is dispatched down?}
  - Note: Δ P>0 means dispatch back
  - count # of times/percent $\Delta P <> 0$
  - count # of times/percent $\Delta P > 0$ (dispatched back)
  - count # of times/percent $\Delta P < 0$ (ramped up)
- Redispatch rule (Coal and CC): Take units that have $\Delta P > 0$ for more than 50 times in the sample space *{i.e. plants that are often dispatched down are candidates}*
- Redispatch rule (Hydro): Take units that have $\Delta P > 0$ for more than 10 times in the sample space *{i.e. hydro plants that are often dispatched down are candidates, if we're short of thermal options}*

Redispatch

Area summary of Coal and Combined Cycle units that have ΔP>0 for more than 50 times in the sample space

Location matters! Displacement by wind and solar is NOT one-for-one in each area.

Coal and Combined cycle units

Area name	Area #	# of units	average dP [MW]
ALBERTA	54	3	102
ARIZONA	14	15	3645
BC HYDRO	50	1	90
EL PASO	11		
IDAHO	60	4	719
IMPERIALICA	21		
LADWP	26	3	1234
MEXICO-CFE	20	3	149
MONTANA	62	5	1113
NEVADA	18	2	164
NEW MEXICO	10	5	1071
NORTHWEST	40		
PACE	65	21	2254
PG&E	30	16	334
PSCOLORADO	70	6	715
SAN DIEGO	22	3	41
SIERRA	64	3	378
SOCALIF	24	7	253
FORTISBC	52		
WAPA R.M.	73	15	1847
WAPA U.M.	63		
	-1		
Total		112	14109

Hydro units

Area name	Area #	# of units	average dP [MW]
BC HYDRO	50	7	1072
NORTHWEST	40	126	1797
Total		133	2869

Area summary of Hydro units that have ΔP>0 for more than 10 times in sample space

Tendency is for more downward dispatch than for decommitment

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Decommitment and Redispatch

- Use decommitment to add DG (an intermediate step to Hi-Mix – Case 2A)
- Further decommit, and then use redispatch to add CSP, PV and Wind
- If short of options to decommit and redispatch thermal, then use hydro units for redispatch

Add Renewables – Capacity (nameplate rating)

Case 2

Case 3

	2022 LSP				WWSIS2-HiMix				2022 LSP HiMix			
Area #	CSP	DG	PV	Wind	CSP	DG	PV	Wind	CSP	DG	PV	Wind
54	0	0	0	2707	0	0	0	0	0		0	2707
14	0	0	971	175	7654	3655	5120	1440	6879		4923	1435
50	0	0	0	108	0	0	0	0	0		0	108
11	0	62	0	0	142	305	343	50	142		343	50
60	0	0	0	643	0	0	0	569	0		0	643
21	0	0	0	0	188	71	611	917	188		611	917
26	0	0	0	576	1043	1961	913	0	1043		913	576
20	0	0	0	0	0	15	0	294	0		0	0
62	0	0	0	707	0	21	27	3988	0		11	3975
18	0	0	64	0	229	285	642	0	229		556	0
10	0	0	100	1726	156	758	1160	3084	156		1260	3108
40	0	0	59	8680	0	500	817	11642	0		869	11655
65	0	0	0	2384	0	1126	409	4082	0		390	4111
30	0	0	3232	2399	0	1474	1740	1799	0		3232	2399
70	0	0	79	2134	169	547	937	1720	169		1016	2134
22	0	64	516	712	0	357	275	0	0		516	712
64	0	0	0	432	0	432	1511	821	0		1504	777
24	1436	0	2139	4497	2813	4741	6118	3149	2814		5913	4497
52	0	0	0	0	0	0	0	0	0		0	0
73	0	0	4	739	0	594	696	8149	0		690	8136
63	0	0	0	0	0	0	1	60	0		0	60
Total	1436	127	7164	28616	12393	16842	21322	41762	11618		22747	47999

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TRC Call: Do not Cite - Not for Further Distribution

Add Renewables – Total Dispatch

(MW instantaneous production)

Dispatch of existing renewables from case 2 not changed..so Yellow is the MAX of green and blue

Case 2

Target for Case 3

	2022LSP				WWSIS-HiMix				2022LSP-HiMix			
Area #	**CSP**	**DG**	**PV**	**Wind**	**CSP**	**DG**	**PV**	**Wind**	**CSP**	**DG**	**PV**	**Wind**
54	0	0	0	1665	0	0	0	0	0	0	0	1665
14	0	0	667	126	6375	1471	2061	560	6375	1471	2061	560
50	0	0	0	6	0	0	0	0	0	0	0	6
11	0	62	0	0	143	202	227	2	143	202	227	2
60	0	0	0	485	0	0	0	150	0	0	0	485
21	0	0	0	0	124	32	277	337	124	32	277	337
26	0	0	0	190	493	864	403	0	493	864	403	190
20	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	390	0	2	3	1593	0	2	3	1593
18	0	0	60	0	113	166	376	0	113	166	376	0
10	0	0	70	1078	162	217	333	27	162	217	333	1078
40	0	0	34	8341	0	204	334	4551	0	204	334	8341
65	0	0	0	1408	0	239	87	2772	0	239	87	2772
30	0	0	1928	733	0	584	690	30	0	584	1928	733
70	0	0	24	1822	178	355	608	594	178	355	608	1822
22	0	64	464	272	0	116	89	0	0	116	464	272
64	0	0	0	280	0	208	728	661	0	208	728	661
24	1451	0	1538	2937	1378	2287	2951	2746	1451	2287	2951	2937
52	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	3	736	0	364	428	3346	0	364	428	3346
63	0	0	0	0	0	0	0	27	0	0	0	27
Total	1451	127	4787	20469	8966	7311	9595	17396	9039	7311	11208	26827

This is WECC LSP base case

This is from the Plexos Hi-Mix cases

This is where we're trying to drive the LSP'22 Hi-Mix cases

Add Renewables – Dispatch Delta

Delta Renewable Generation Only				Delta Renewable Capacity Only				Target Capacity Factor of Added Renewable			
CSP	DG	PV	Wind	CSP	DG	PV	Wind	CSP	DG	PV	Wind
0	0	0	0	0		0	0	0%		0%	0%
6375	1471	1394	434	6879		3952	1260	93%		35%	34%
0	0	0	0	0		0	0	0%		0%	0%
143	140	227	2	142		343	50	101%		66%	4%
0	0	0	0	0		0	0	0%		0%	0%
124	32	277	337	188		611	917	66%		45%	37%
493	864	403	0	1043		913	0	47%		44%	0%
0	0	0	0	0		0	0	0%		0%	0%
0	2	3	1203	0		11	3268	0%		27%	37%
113	166	316	0	229		492	0	49%		64%	0%
162	217	263	0	156		1160	1383	104%		23%	0%
0	204	300	0	0		810	2975	0%		37%	0%
0	239	87	1364	0		390	1728	0%		22%	79%
0	584	0	0	0		0	0	0%		0%	0%
178	355	584	0	169		937	0	105%		62%	0%
0	52	0	0	0		0	0	0%		0%	0%
0	208	728	381	0		1504	345	0%		48%	110%
0	2287	1413	0	1378		3774	0	0%		37%	0%
0	0	0	0	0		0	0	0%		0%	0%
0	364	425	2610	0		686	7398	0%		62%	35%
0	0	0	27	0		0	60	0%		0%	45%
7588	7184	6420	6358	10182		15583	19383	75%		41%	33%

Trying to ADD ~27 GW more wind and solar to the LSP'22 case

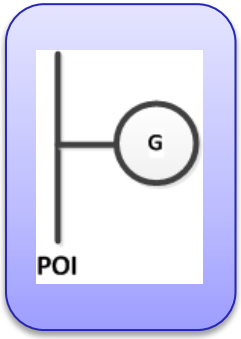
Area 64 wind dispatch only to 100%.

Dispatch of existing renewables from case 2 not changed.
Largely meet the targets respecting capacity.

TRC Call: Do not Cite - Not for Further Distribution

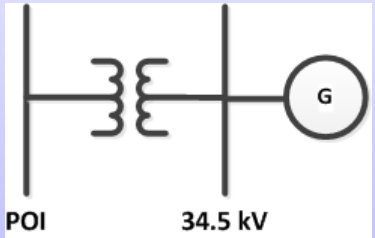
Renewable Modeling in Power Flow

Renewables in WWSIS-2 study

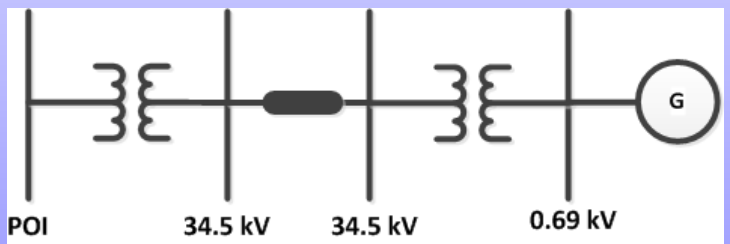


In load flow, newly added renewable were modeled as a single plant, with appropriate system build outs.

Renewables in PSLF



CSP

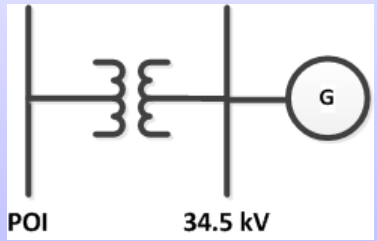


Utility Scale PV and Wind Turbine Generator

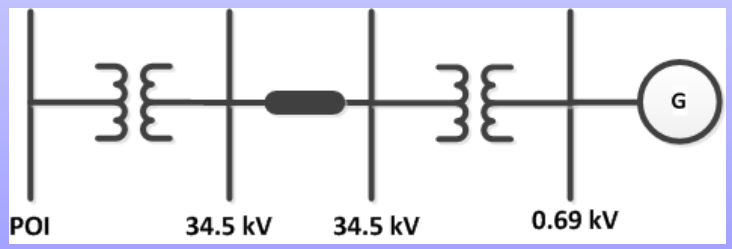
Renewable Modeling in Dynamics

- CSP – synchronous machine, standard WECC model without governor response
- Utilities scale PV – with voltage regulation and LVRT (gewtg and wtgfc)
- Wind turbine model – type 3 with voltage regulation and LVRT (gewtg, wtg, wndtge)

Renewables in PSLF



CSP



Utility Scale PV and Wind Turbine Generator

Outline

- Introduction
- De-commitment, re-dispatch and add renewables
- 2022LSP Case 3 (HiMix)
- 2022LSP Case 2A (Composite Load Model with DG)
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- Plexos Hi-Mix Summer case
- Summary and Next Steps

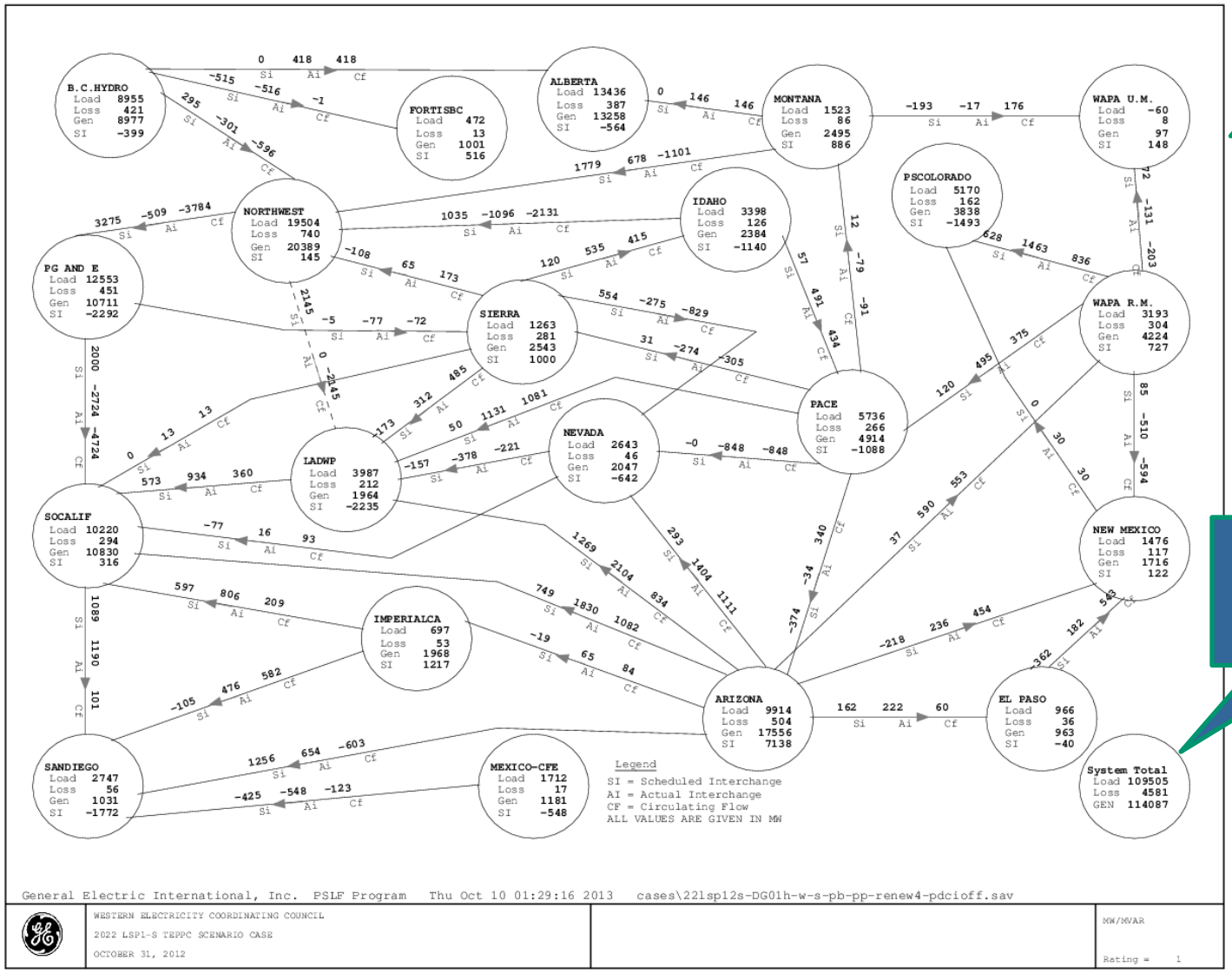
imagination at work

Preliminary Results: Not for Further Distribution or Citation

2022LSP Case 3 (Hi-Mix) – Initial Condition Metrics

		WECC	CALIFORNIA	DSW	NORTHEAST	NORTHWEST
Pgen of units with governors (GW)	pg	35.4	5.9	5.8	2.8	9.6
Capacity of units with governors (GW)	mc	61.0	12.8	10.1	4.0	17.7
Headroom on units with governors (GW)	**hr**	**25.5**	**6.9**	**4.3**	**1.2**	**8.0**
Number of units with governors	**nu**	**827**	**192**	**113**	**95**	**206**
Mechanical power of unit with governors (GW)	pm	35.5	5.9	5.8	2.8	9.7
MVA rating of unit with governors (GVA)	mv	61.4	13.3	11.0	4.3	16.4
Pgen of units w/o governors (GW)	px	42.5	12.3	13.6	3.2	2.1
Mechanical power of units w/o governors (GW)	mx	42.9	12.5	13.9	3.2	2.1
# units w/o governors	nx	832	336	104	111	68
Pgen of all synchronous generators (GW)	pq	77.9	18.2	19.3	6.0	11.7
Qgen of all synchronous generators (GVAr)	qg	5.3	0.2	3.8	0.6	-1.2
P load (GW)	pl	113.2	33.6	24.6	11.7	19.2
Q load (GVAr)	ql	31.5	8.1	6.7	3.3	4.3
Pgen – Wind (GW)	**pw**	**27.9**	**5.4**	**7.0**	**5.4**	**8.4**
Qgen – Wind (GVAR)	qw	-2.1	-0.2	0.4	-0.6	-1.3
Pgen – Solar PV	**pv**	**9.7**	**5.2**	**3.4**	**0.8**	**0.3**
Qgen – Solar PV	qv	-1.0	-0.1	-0.9	0.1	-0.2
Pgen - CSP (GW)	**pc**	**8.2**	**1.2**	**7.0**	**0.0**	**0.0**
Pgen- DG (solar PV)	**dg**	**7.0**	**3.7**	**2.6**	**0.4**	**0.2**
Kt	Kt	0.41	0.32	0.27	0.29	0.62

2022 LSP Case 3 (Hi-Mix)



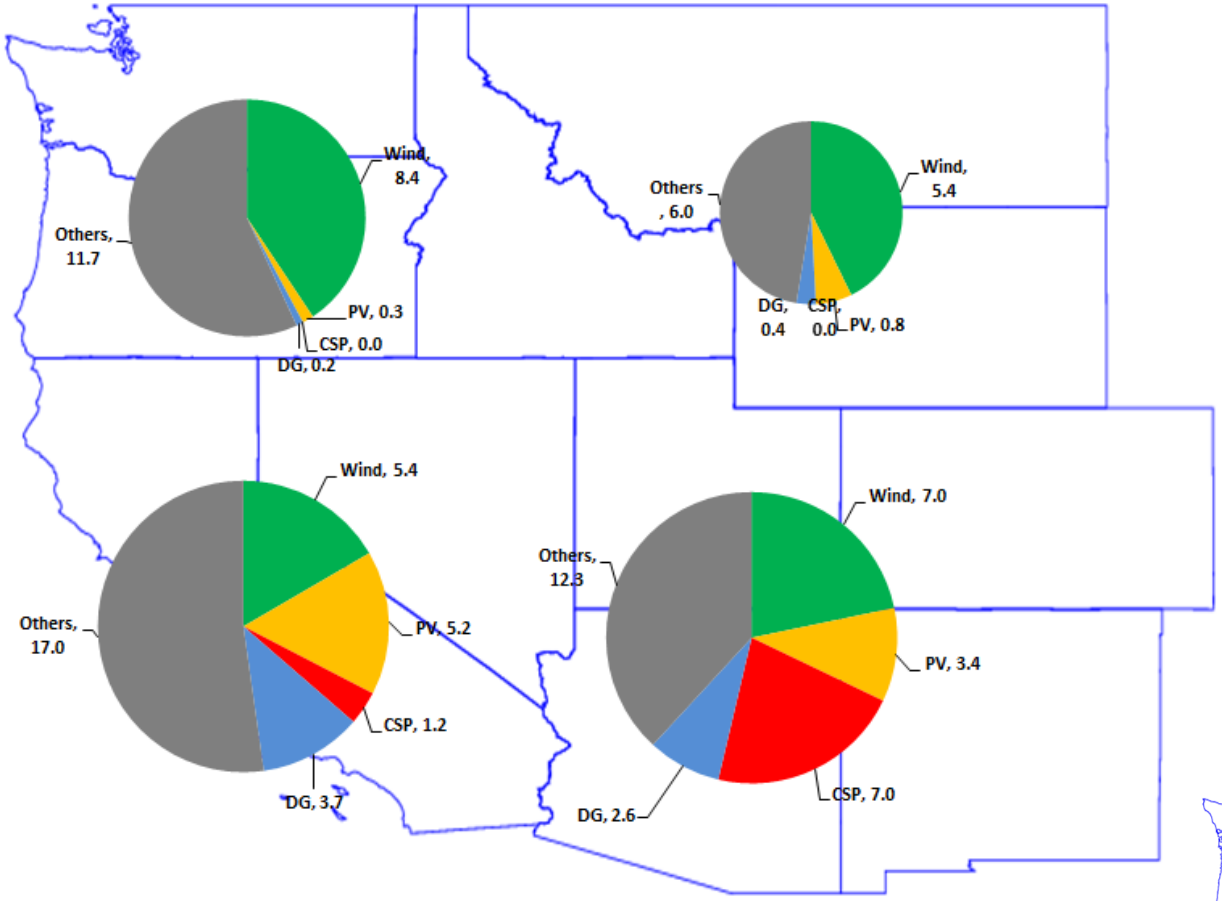
PDCI and Intermountain HVDC off

Total system load reduced due to composite load model with DG

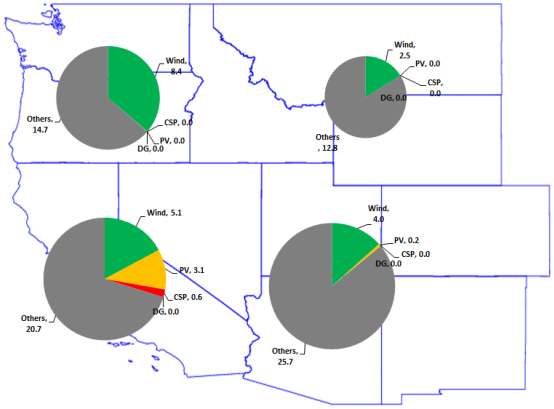
imagination at work

Preliminary Results: Not for Further Distribution or Citation

2022LSP Case 3 (Hi-Mix)– Renewables Condition



	WECC	CALIFORNIA	DSW	NORTHEAST	NORTHWEST
Wind (GW)	27.9	5.4	7.0	5.4	8.4
PV (GW)	9.7	5.2	3.4	0.8	0.3
CSP (GW)	8.2	1.2	7.0	0.0	0.0
DG (GW)	7.0	3.7	2.6	0.4	0.2
Others (GW)	69.7	17.0	12.3	6.0	11.7



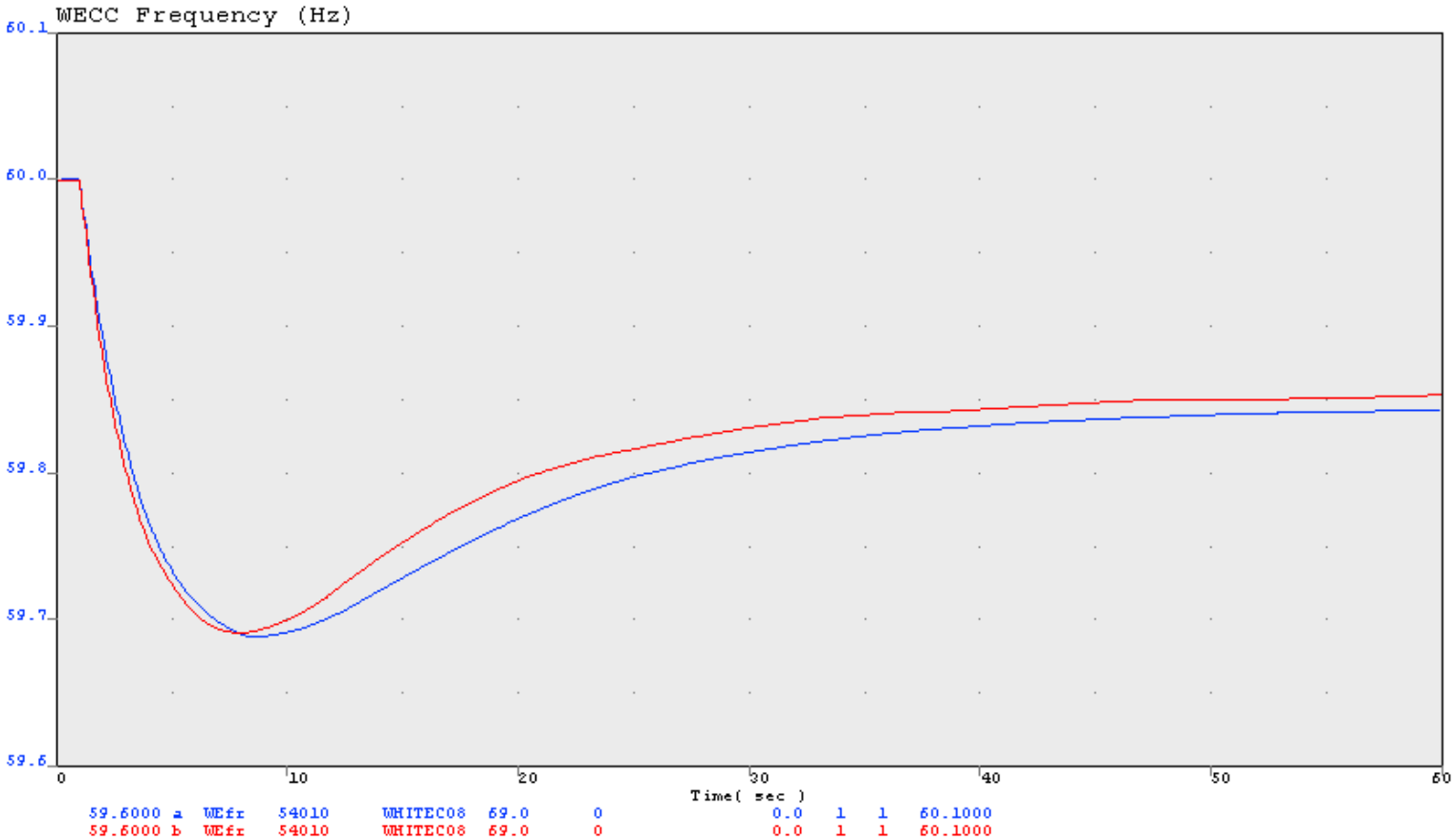
imagination at work

LSP'22 Stability Results

The next section will present:

- A few results from Case 2: the new Light Spring reference case….largely as presented at last TRC (with minor corrections)
- Introduction of new Case 3 (LSP Hi-Mix) results compared to Case 2
- An interesting look at effect of decommitment vs. redispatch from an intermediate run (Case 2A).

WECC Response to Loss of 2 Palo Verde Units – Case 2 (Blue) and Case 3 (Red)

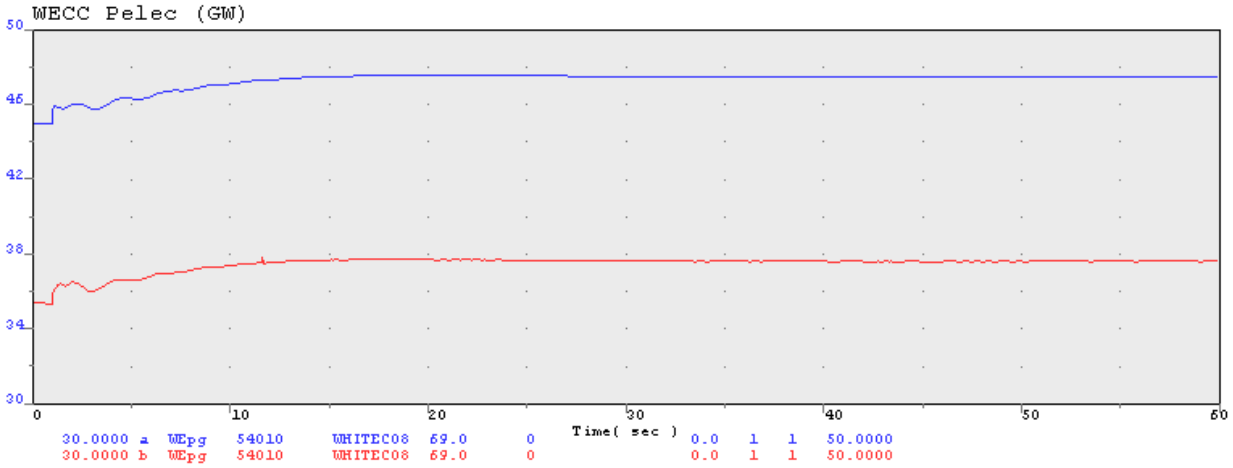


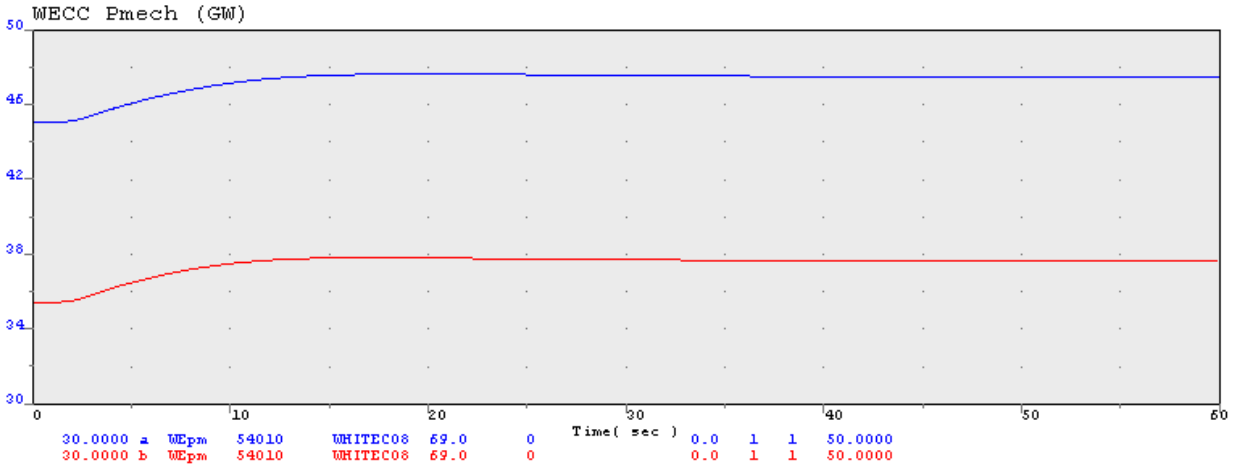
imagination at work

Preliminary Results: Do not Cite - Not for Further Distribution

WECC Generation Response to Loss of 2 Palo Verde Units – Case 2 (Blue) and Case 3 (Red)

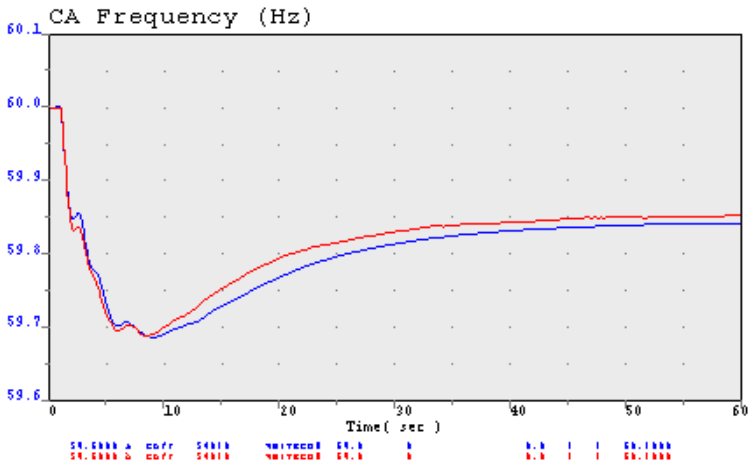
Governor response units only

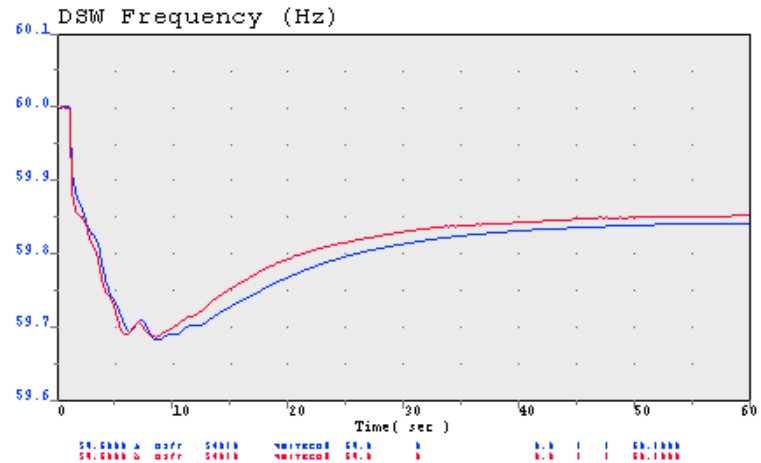


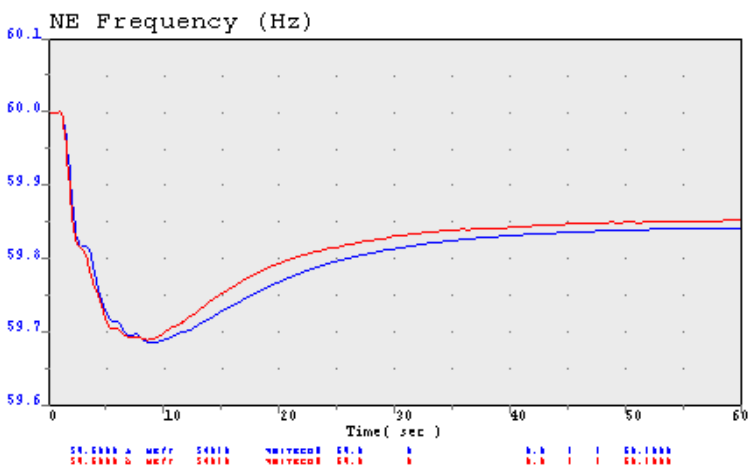


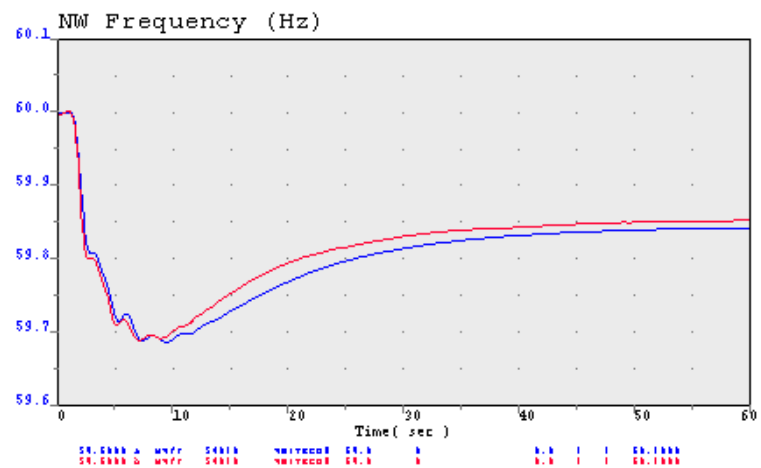
imagination at work

Area Response to Loss of 2 Palo Verde Units – Case 2 (Blue) and Case 3 (Red)

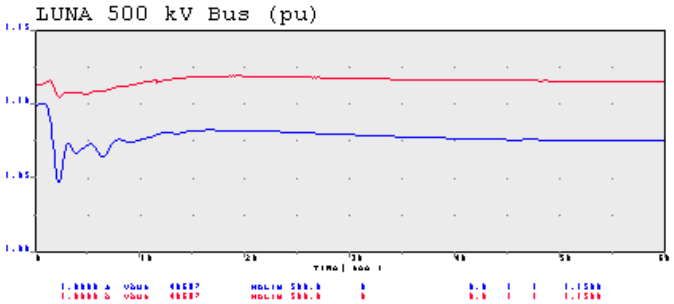


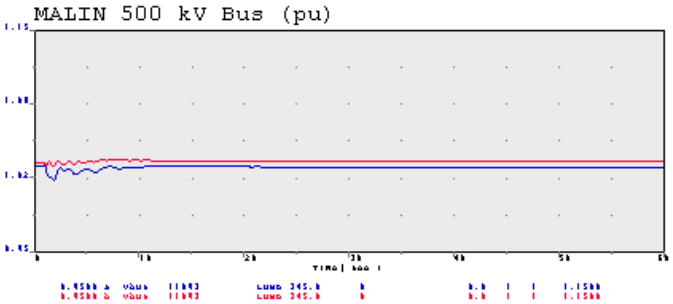


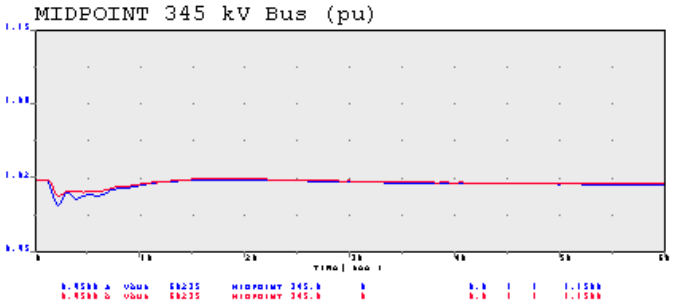


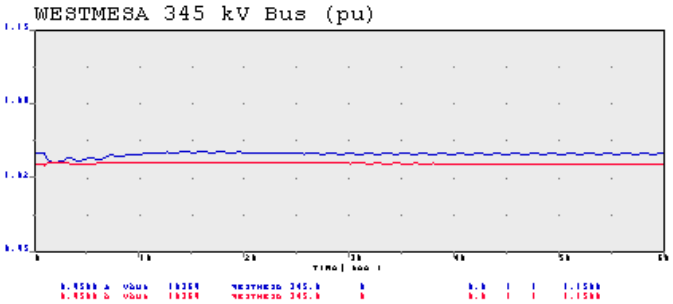


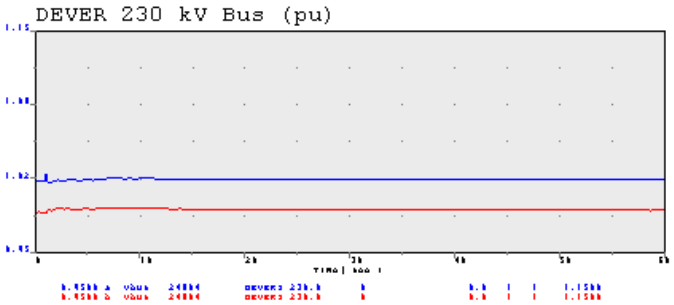
Bus Response to Loss of 2 Palo Verde Units – Case 2 (Blue) and Case 3 (Red)

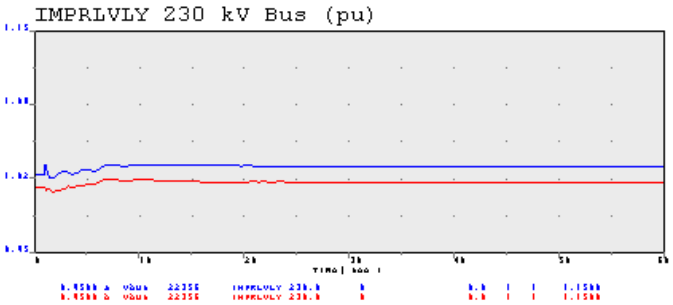




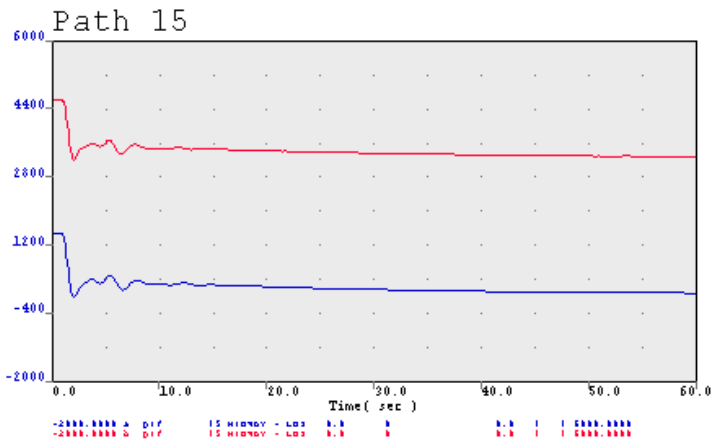


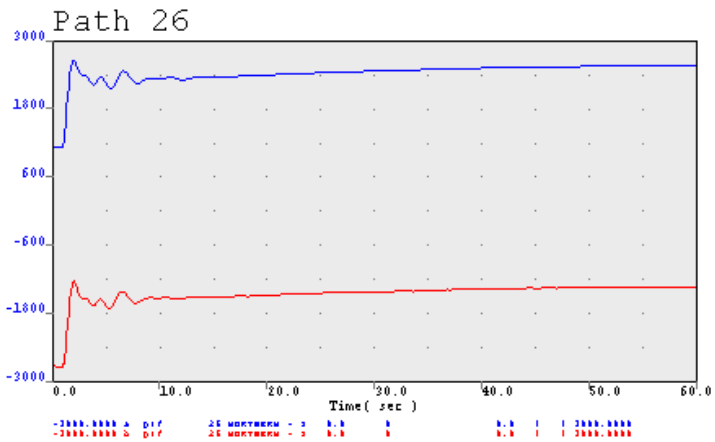


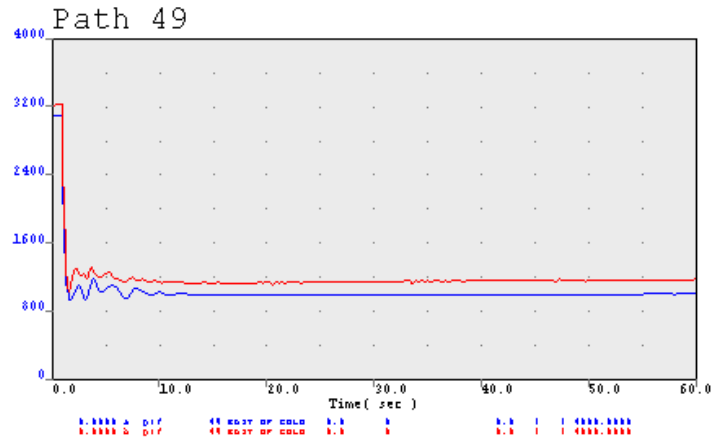


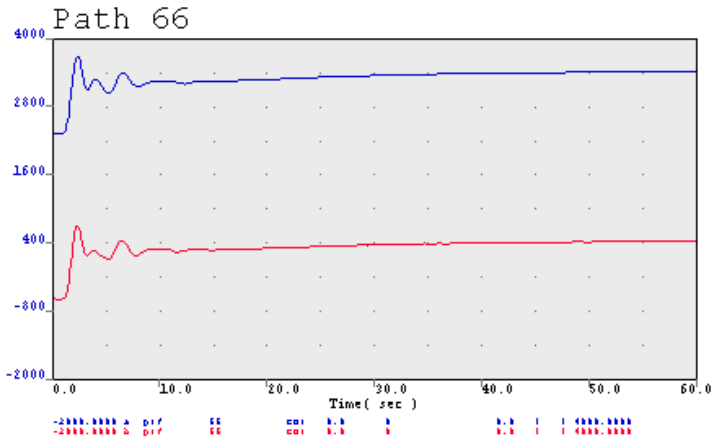


Interface Response to Loss of 2 Palo Verde Units – Case 2 (Blue) and Case 3 (Red)



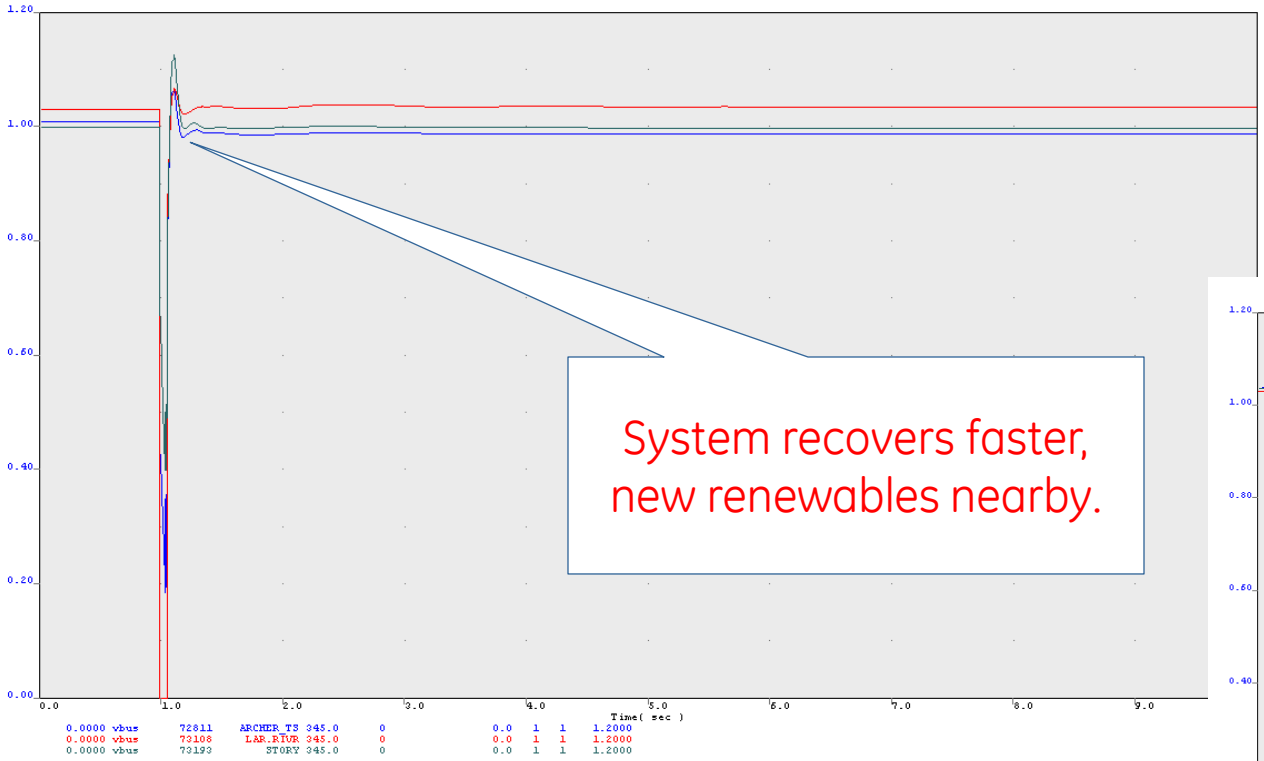


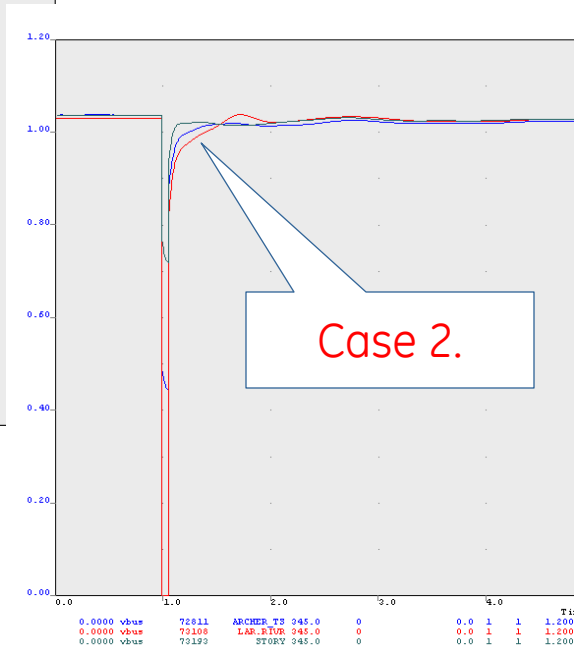




2022LSP Case 3 (Hi-Mix) Contingency - Laramie River Station 345-kV

3-phase 4 cycle fault
Fault clear after 4 cycle
Criteria is to look for Vswing no less than 0.7 p.u.





imagination at work

Outline

- Introduction
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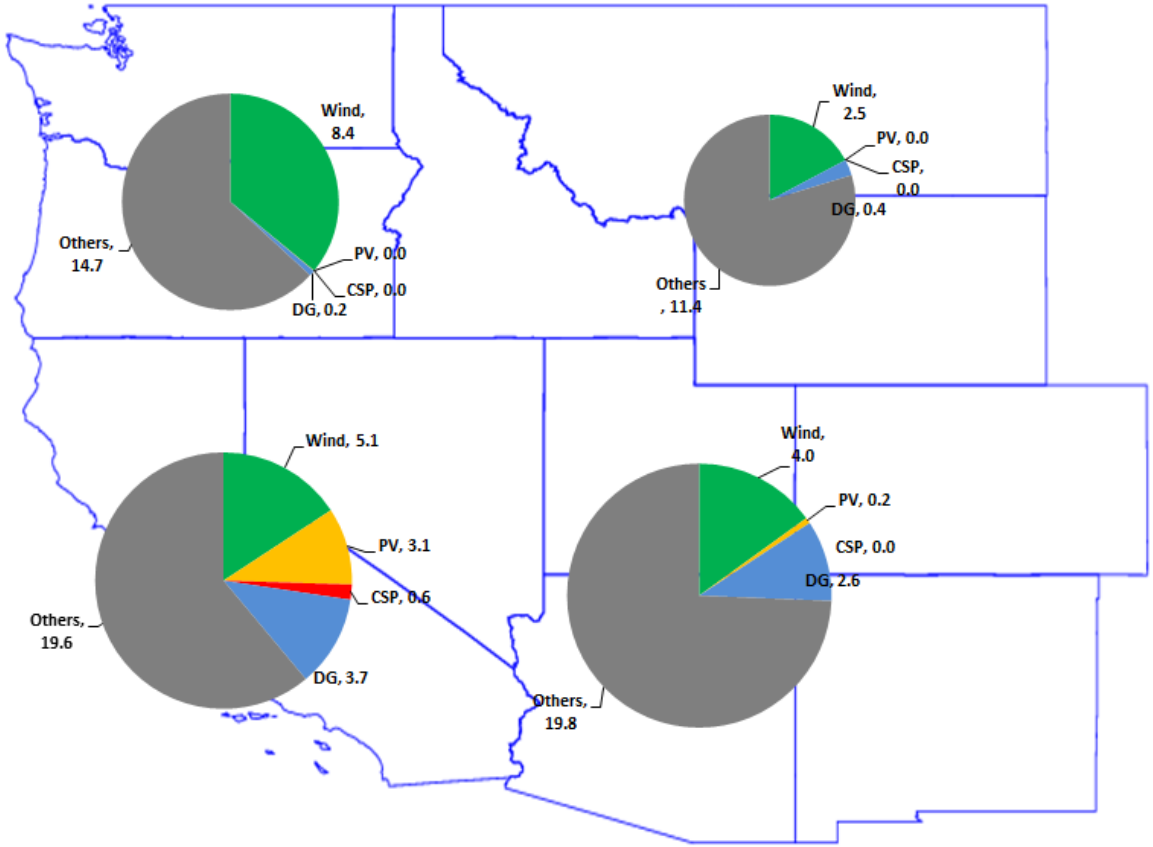
2022 LSP Case 2A - DG portion of Hi-Mix only

- As noted above, as an intermediate step to creating Case 3, LSP'22 Hi-Mix, only the distributed PV were added. This is a substantially different model, which embeds the PV with the load (as DG).
- In order to test this step, a case in which only the DG is added, was run.
- To balance the added DG, candidate thermal units were decommited. Only. No units were dispatched down.
- The net result is a case in which Kt drops, and headroom does not increase. This is un realistic, in the sense that the economics are unlikely to cause only decommitments.
- However, the stability results are of some interest

2022LSP Case 2A (Composite Load Model with DG) – Initial Condition Metrics

		WECC	CALIFORNIA	DSW	NORTHEAST	NORTHWEST
Pgen of units with governors (GW)	pg	42.9	6.6	9.3	2.8	12.5
Capacity of units with governors (GW)	mc	65.3	12.8	14.0	4.0	17.8
Headroom on units with governors (GW)	**hr**	**22.3**	**6.1**	**4.7**	**1.2**	**5.2**
Number of units with governors	**nu**	**843**	**192**	**126**	**95**	**208**
Mechanical power of unit with governors (GW)	pm	42.9	6.7	9.4	2.9	12.6
MVA rating of unit with governors (GVA)	mv	66.2	13.3	15.5	4.3	16.5
Pgen of units w/o governors (GW)	px	46.8	13.6	10.5	8.6	2.1
Mechanical power of units w/o governors (GW)	mx	47.0	13.7	10.5	8.6	2.1
# units w/o governors	nx	787	315	65	124	68
Pgen of all synchronous generators (GW)	pq	89.7	20.2	19.8	11.4	14.7
Qgen of all synchronous generators (GVAr)	qg	-1.2	-2.4	-1.0	-0.1	0.2
P load (GW)	pl	113.2	33.6	24.6	11.7	19.1
Q load (GVAr)	ql	31.9	8.2	6.9	3.3	4.3
Pgen – Wind (GW)	**pw**	**21.6**	**5.1**	**4.0**	**2.5**	**8.4**
Qgen – Wind (GVAR)	qw	-1.8	-1.1	0.3	-0.2	-0.7
Pgen – Solar PV	**pv**	**3.3**	**3.1**	**0.2**	**0.0**	**0.0**
Qgen – Solar PV	qv	-0.3	-0.3	0.0	0.0	0.0
Pgen - CSP (GW)	**pc**	**0.6**	**0.6**	**0.0**	**0.0**	**0.0**
Pgen- DG (solar PV)	**dg**	**7.0**	**3.7**	**2.6**	**0.4**	**0.2**
Kt	Kt	0.45	0.33	0.45	0.26	0.62

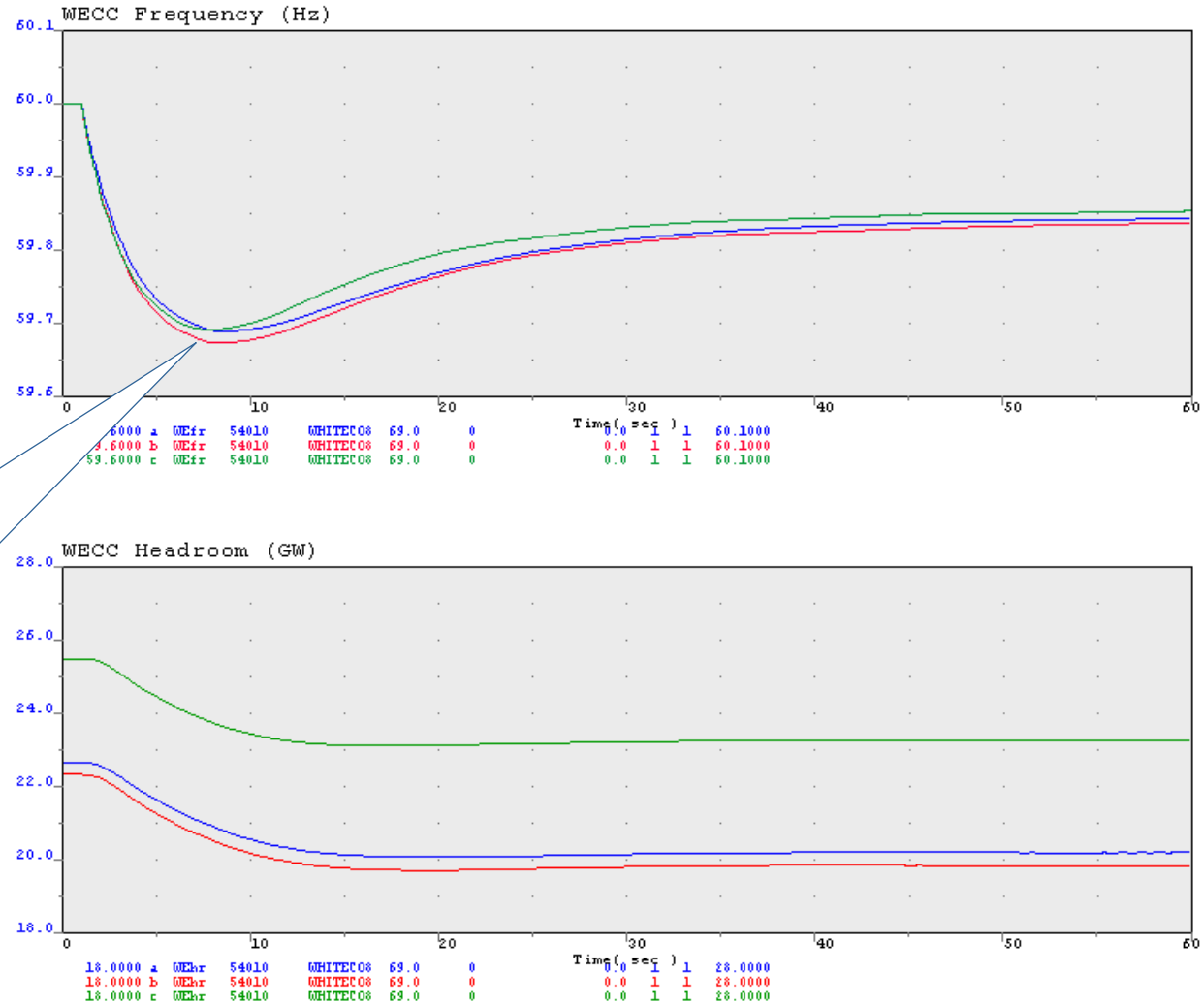
2022LSP Case 2A - Renewable Conditions



DG is new

	WECC	CALIFORNIA	DSW	NORTHEAST	NORTHWEST
Wind (GW)	21.6	5.1	4.0	2.5	8.4
PV (GW)	3.3	3.1	0.2	0.0	0.0
CSP (GW)	0.6	0.6	0.0	0.0	0.0
DG (GW)	7.0	3.7	2.6	0.4	0.2
Others (GW)	57.2	7.7	13.0	8.5	6.1

2022LSP-Case 2 (Blue) vs 2A (Red) vs 3 (Green) – for Loss of 2 Palo Verde Units



Decommitment of governor responsive units causes slight degradation of frequency nadir

imagination at work

Outline

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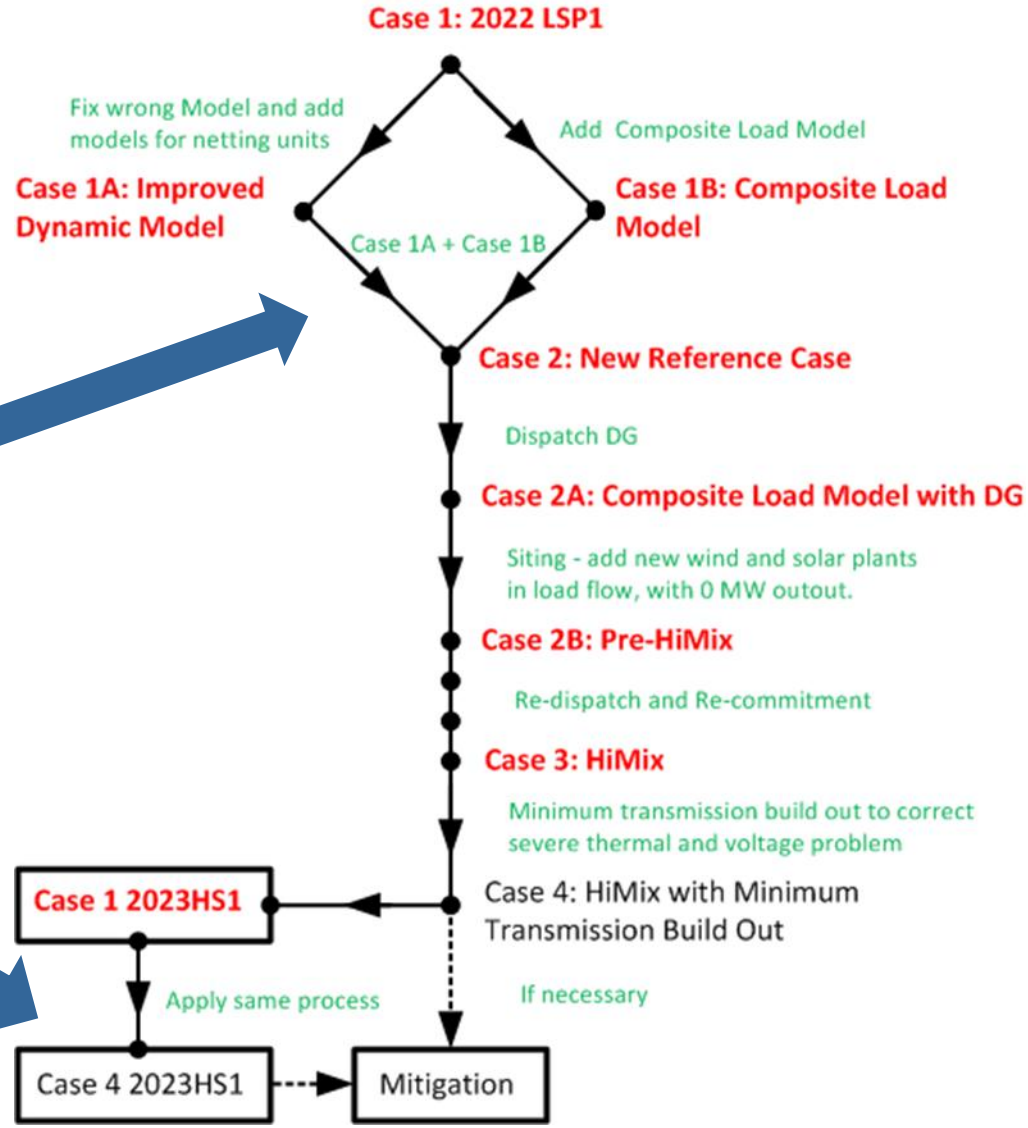
imagination at work

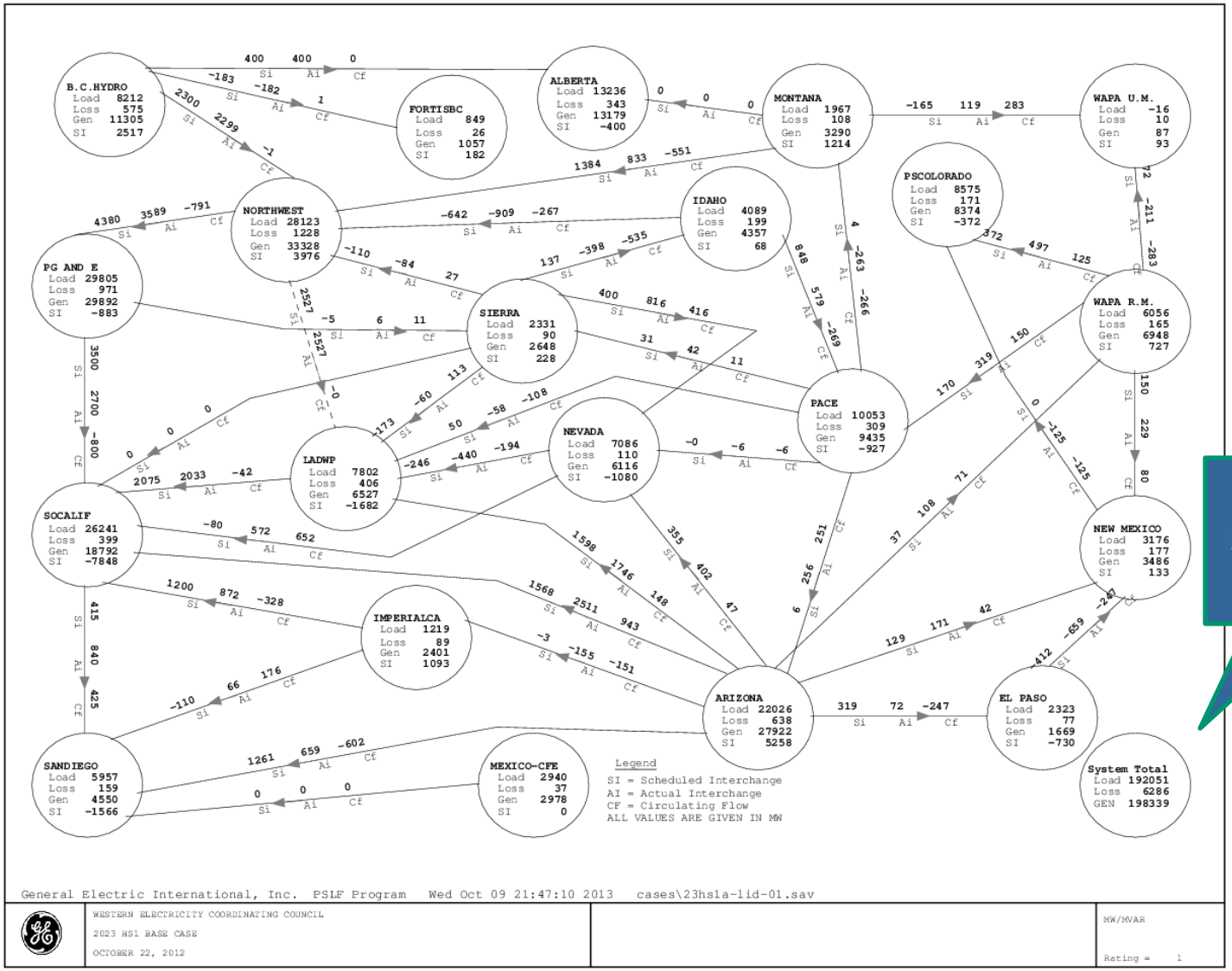
Preliminary Results: Not for Further Distribution or Citation

2023HS …Heavy Summer Cases

- Progress in parallel
- HS'23 has substantial topological differences from LSP'22…not just different load and dispatch.
- Clean-up process for HS'23 (fixing models, netting , etc) complete.
- Composite loads added
- Development of Hi-Mix HS'23 underway



2023 HS1 Base Case

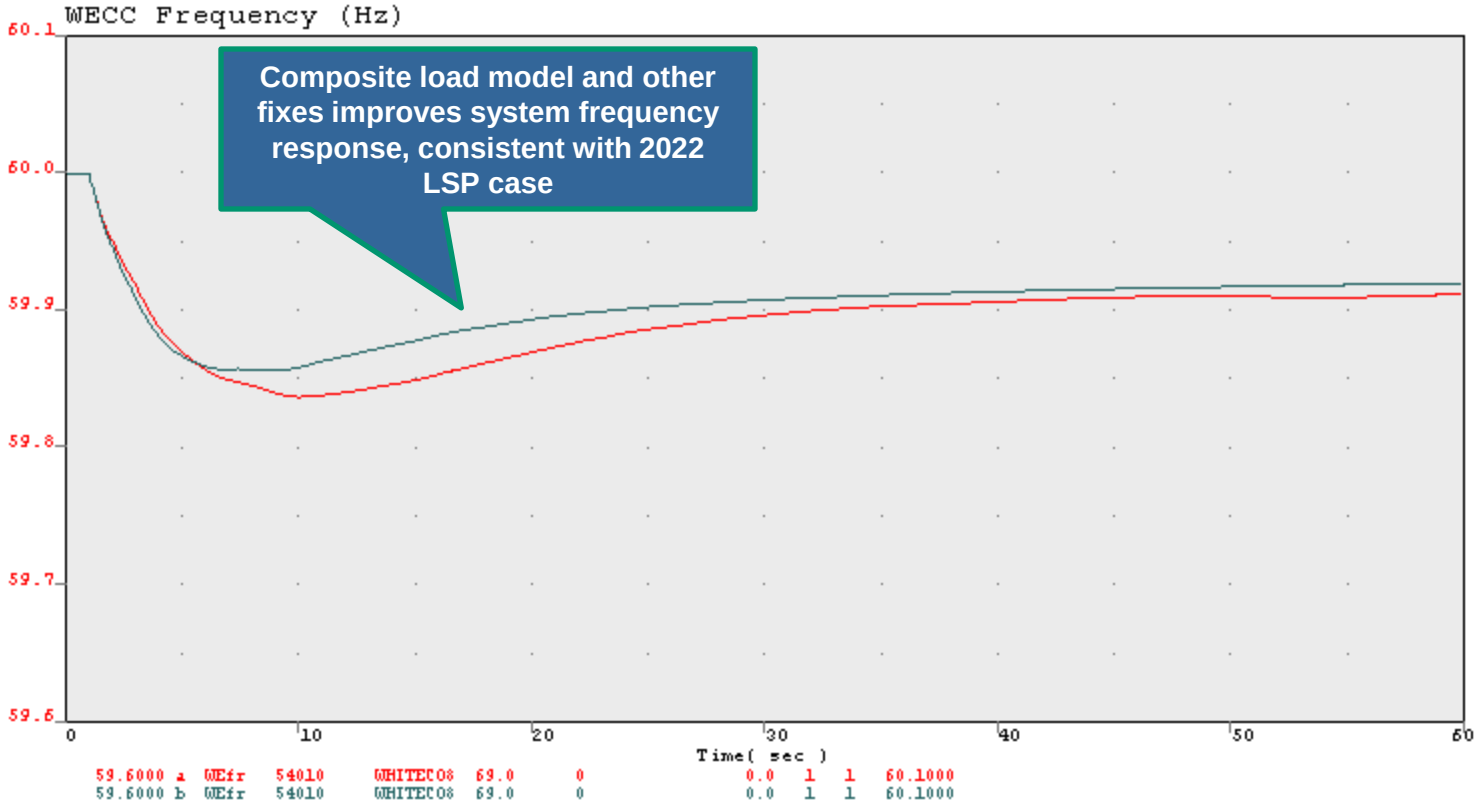


192 GW Load
vs
117 GW in 2022 LSP case

imagination at work

TRC Call: Do not Cite - Not for Further Distribution

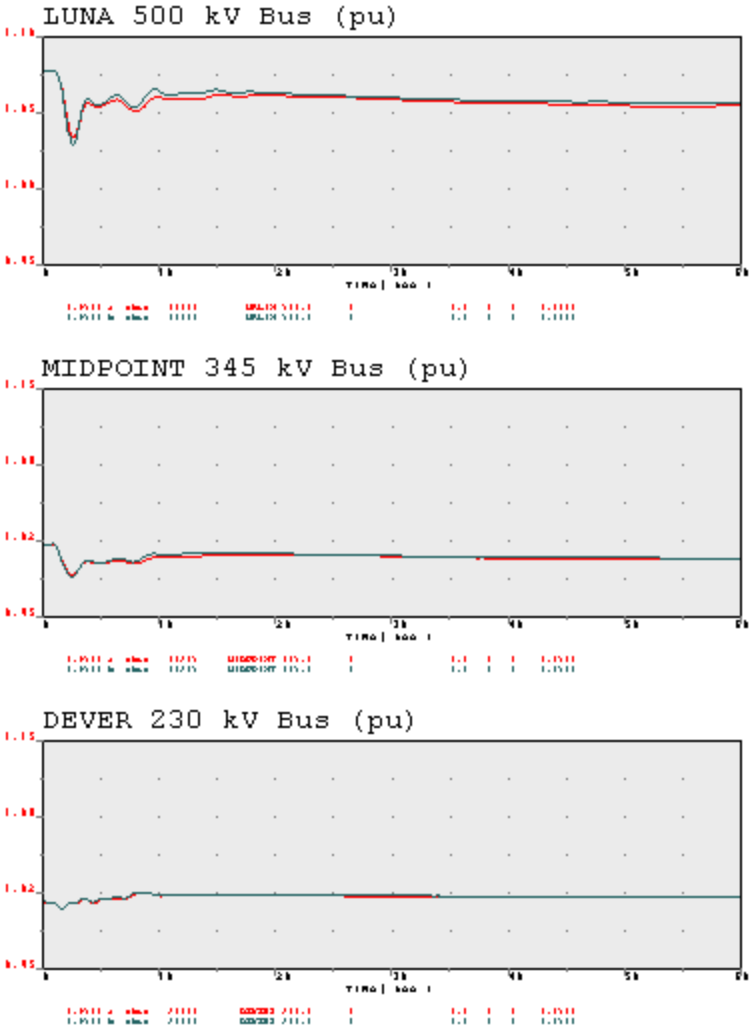
WECC Frequency Response to Loss of 2 PV – 2023HS Case 1 (red) vs 2023HS Case 2 (green)

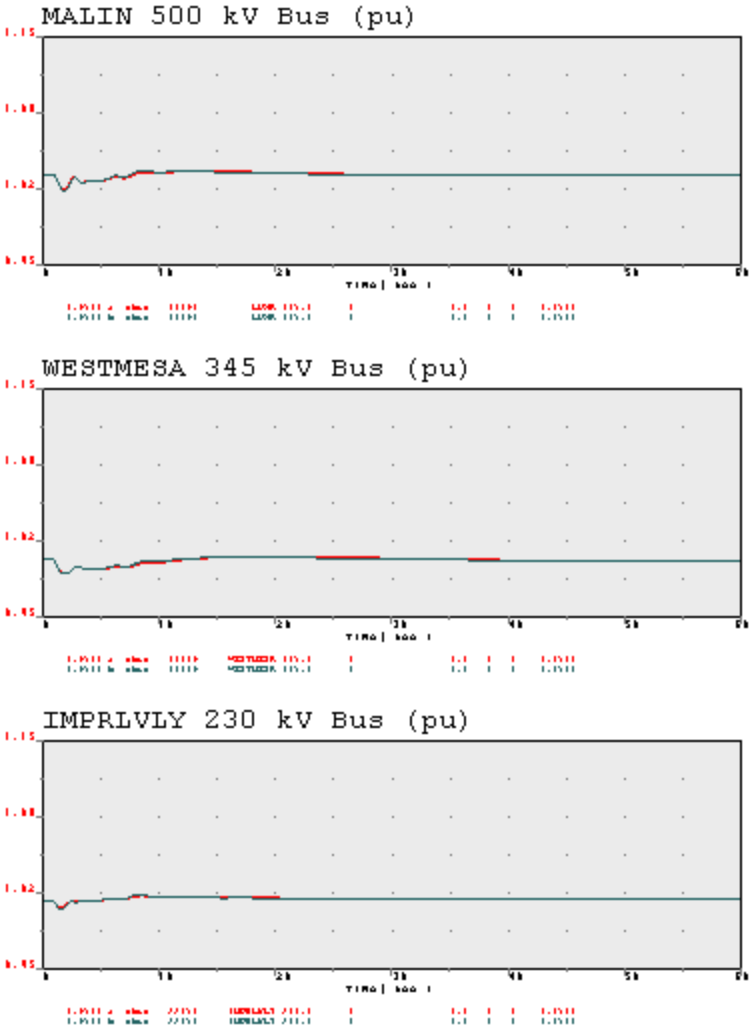


imagination at work

TRC Call: Do not Cite - Not for Further Distribution

Bus Voltage Response to Loss of 2 PV – 2023HS Case 1 (red) vs 2023HS Case 2 (green)

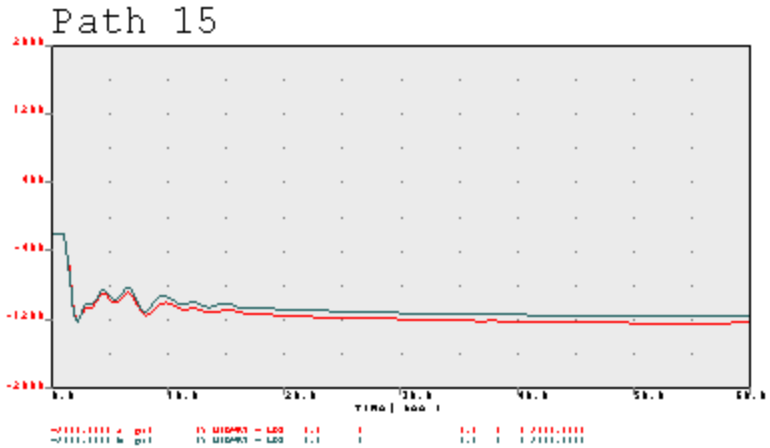


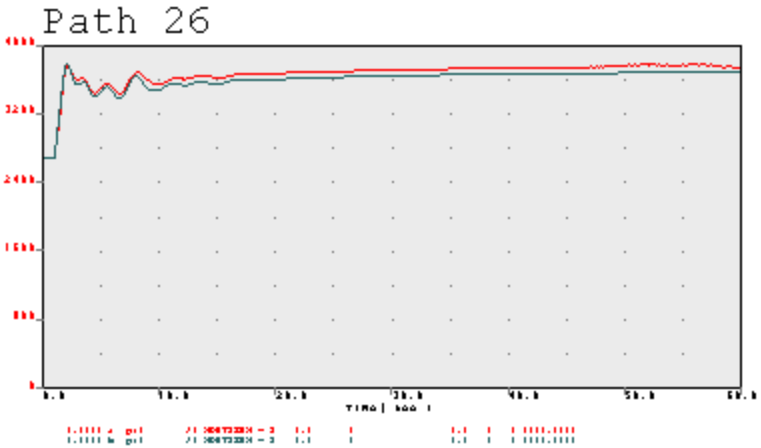


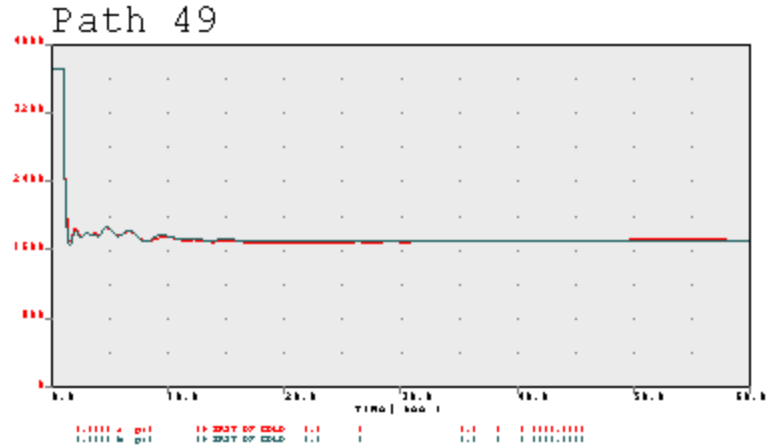
imagination at work

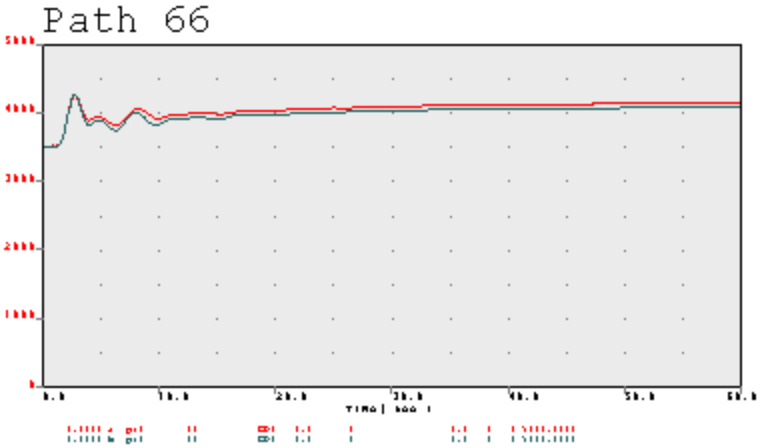
TRC Call: Do not Cite - Not for Further Distribution

Interface Response to Loss of 2 PV – 2023HS Case 1 (red) vs 2023HS Case 2 (green)



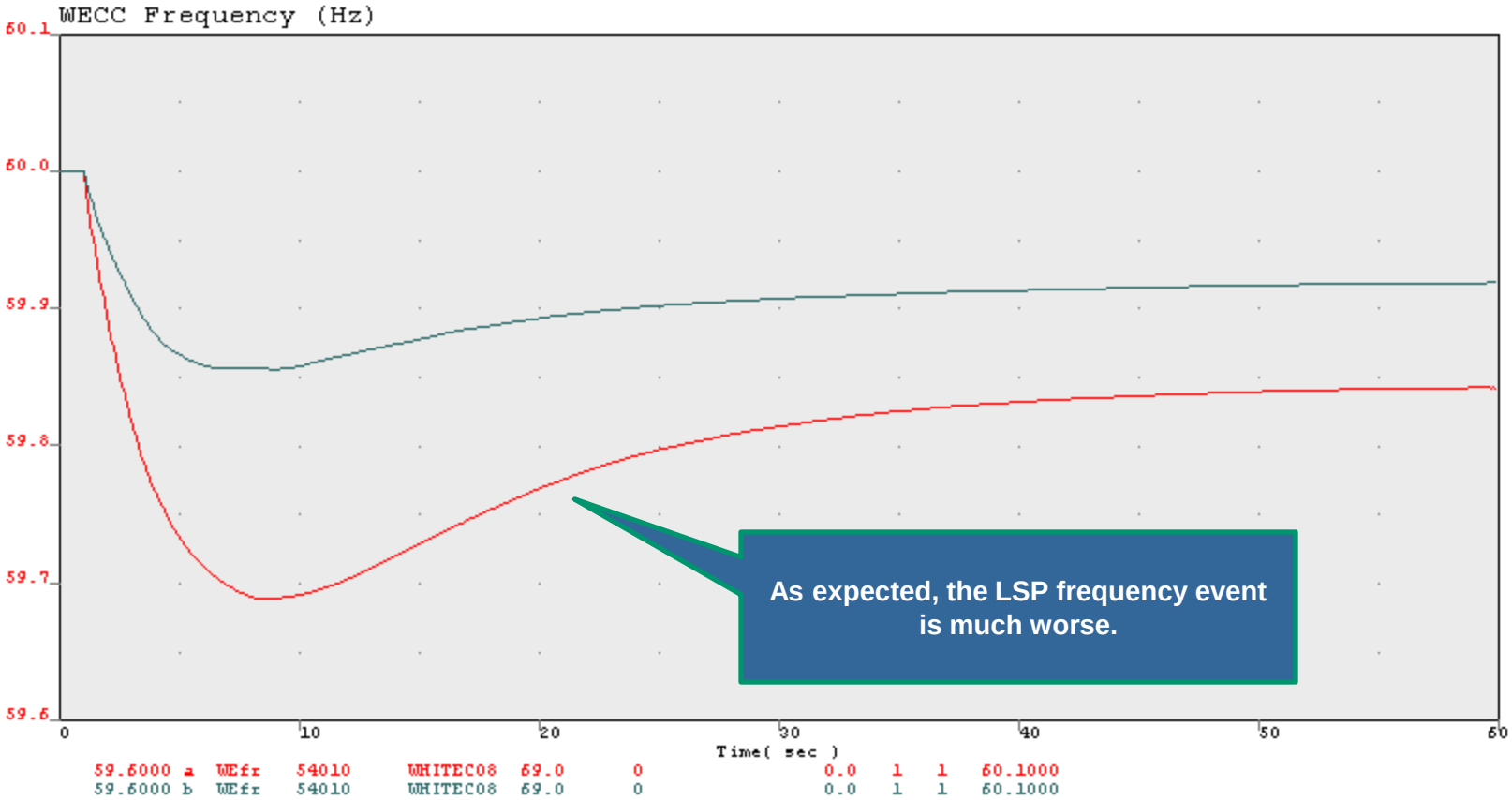






TRC Call: Do not Cite - Not for Further Distribution

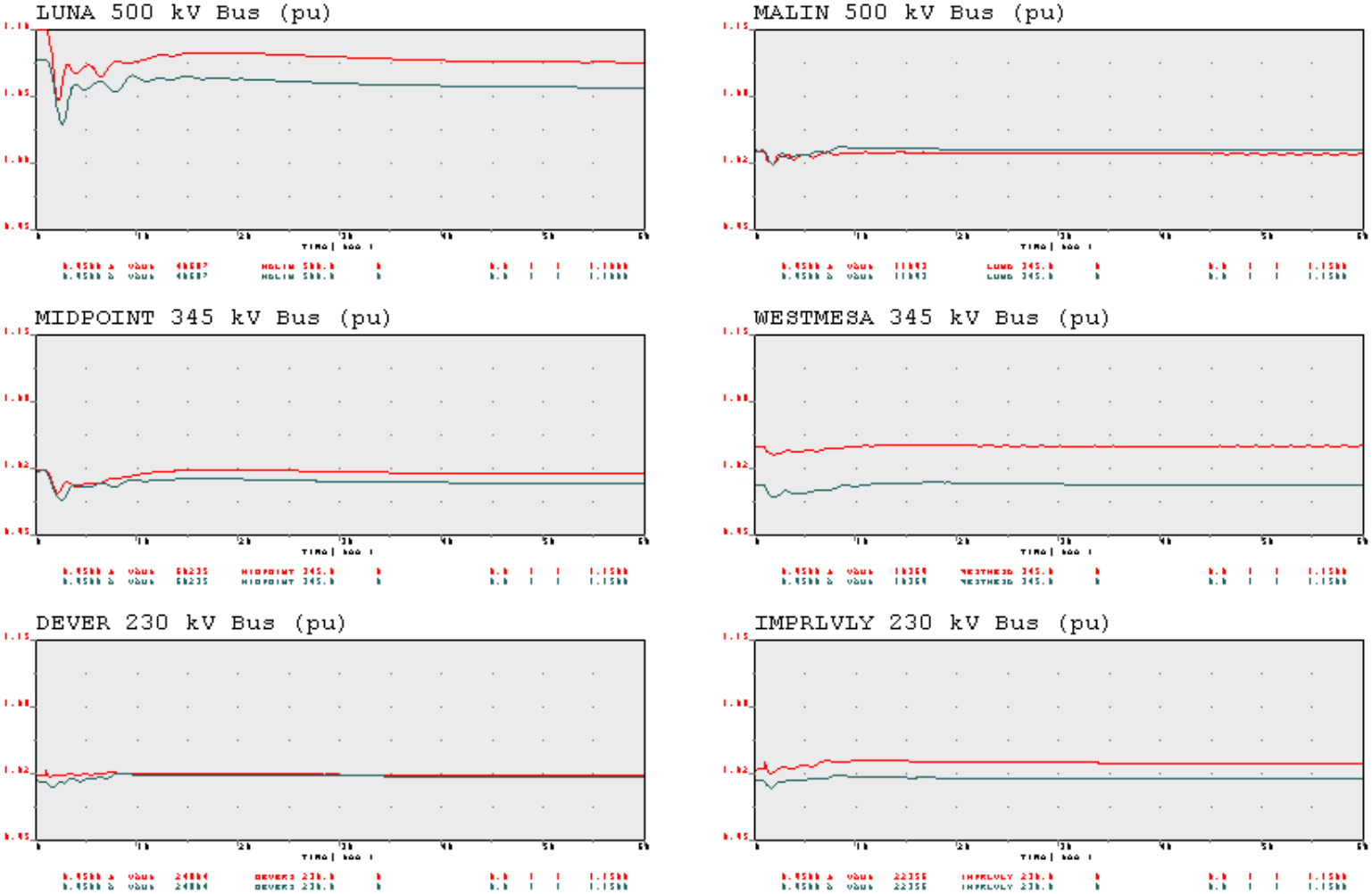
WECC Frequency Response to Loss of 2 PV – 2022LSP Case 2 (red) vs 2023HS Case 2 (green)



imagination at work

TRC Call: Do not Cite - Not for Further Distribution

Bus Voltage Response to Loss of 2 PV – 2022LSP Case 2 (red) vs 2023HS Case 2 (green)



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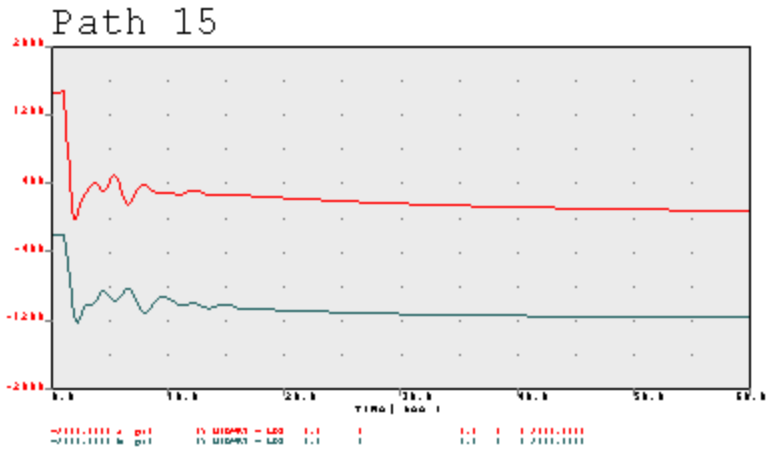
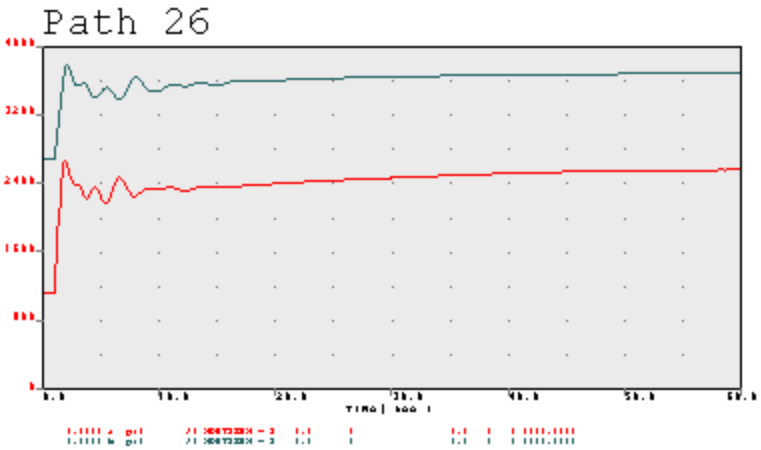
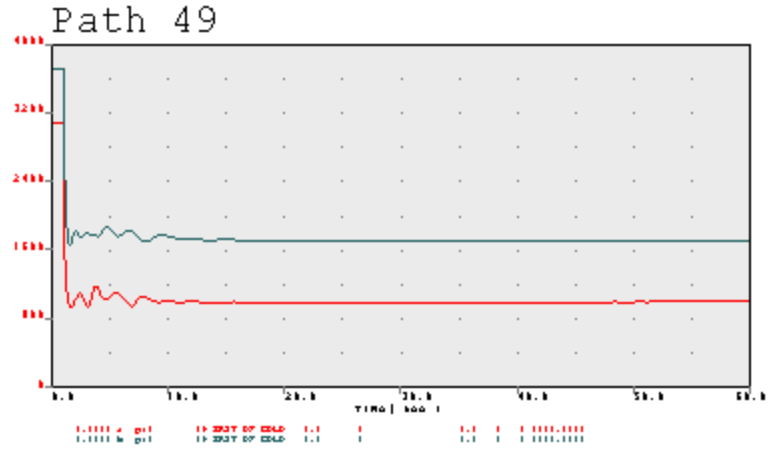
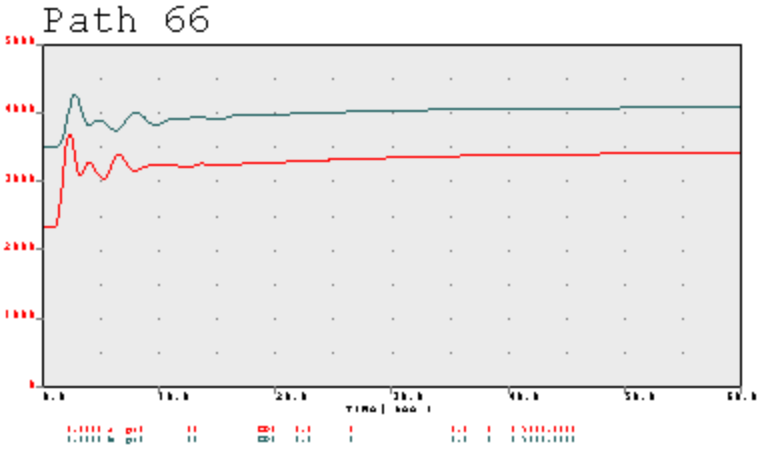
Interface Response to Loss of 2 PV – 2022LSP Case 2 (red) vs 2023HS Case 2 (green)









TRC Call: Do not Cite - Not for Further Distribution

Outline

- Introduction
- De-commitment, re-dispatch and add renewables
- 2022LSP Case 3 (HiMix)
- 2022LSP Case 2A (Composite Load Model with DG)
- 2023 HS
- Plexos Hi-Mix Summer case
- Summary and Next Steps

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Preliminary Results: Not for Further Distribution or Citation

Plexos Hi-Mix Summer case

- PLEXOS TEPPC and Hi-Mix data used for Summer (July 16-August 26, 2020)… this is results in:
- 95 5-minute samples
- Spread across 10 contiguous windows on 10 different days:
  - July 16 13:45 - 14:40 12 samples
  - July 17 13:55 - 14:30 8 samples
  - July 21 13:25 - 13:30 2 samples
  - July 30 13:20 – 13:30 3 samples
  - August 11 14:05 - 14:15 3 sample
  - August 12 12:20 – 13:10 8 samples
  - August 13 11:35 – 12:55 17 samples
  - August 14 13:00 – 14:20 16 samples
  - August 25 12:55 – 13:25 7 samples
  - August 26 12:05 – 13:35 19 samples
- Period 68417, August 25 13:20 closest to mean of samples

Mining Plexos

Filtering the PLEXOS TEPCC results to capture periods of operation that are close to that of the WECC HS'23 case:

Idea is to use the same approach as we did with the LSP'22
Details/reality says "not so fast".

WECC HS'23 case has load of ~192GW. Highest load ever in Plexos study as 169GW.
Mapping is slightly lower fidelity.

Filter:

- Day Time (PV ≠ 0.0)
- Summer: July and August Only (that's what we have detailed Plexos results for)
- CSP > 4000 -- average: 4568MW 9745MW – Hi-Mix
- PV > 4000 -- average: 4201MW 24887MW – Hi-Mix
- Load > 150GW -- average: 152.8GW 9745MW – Hi-Mix
- Wind > 3000 -- average: 4513MW 9362MW – Hi-Mix

Total: 96 5-minute periods.

Average W+S : TEPPC = 13.3GW – compares 6.4GW in WECC HS'22 (US only)
Hi-Mix = 44.0GW

Max W+S: TEPPC = 16.2GW
Hi-Mix = 51.4 GW – a sensitivity or the main Hi-Mix case?

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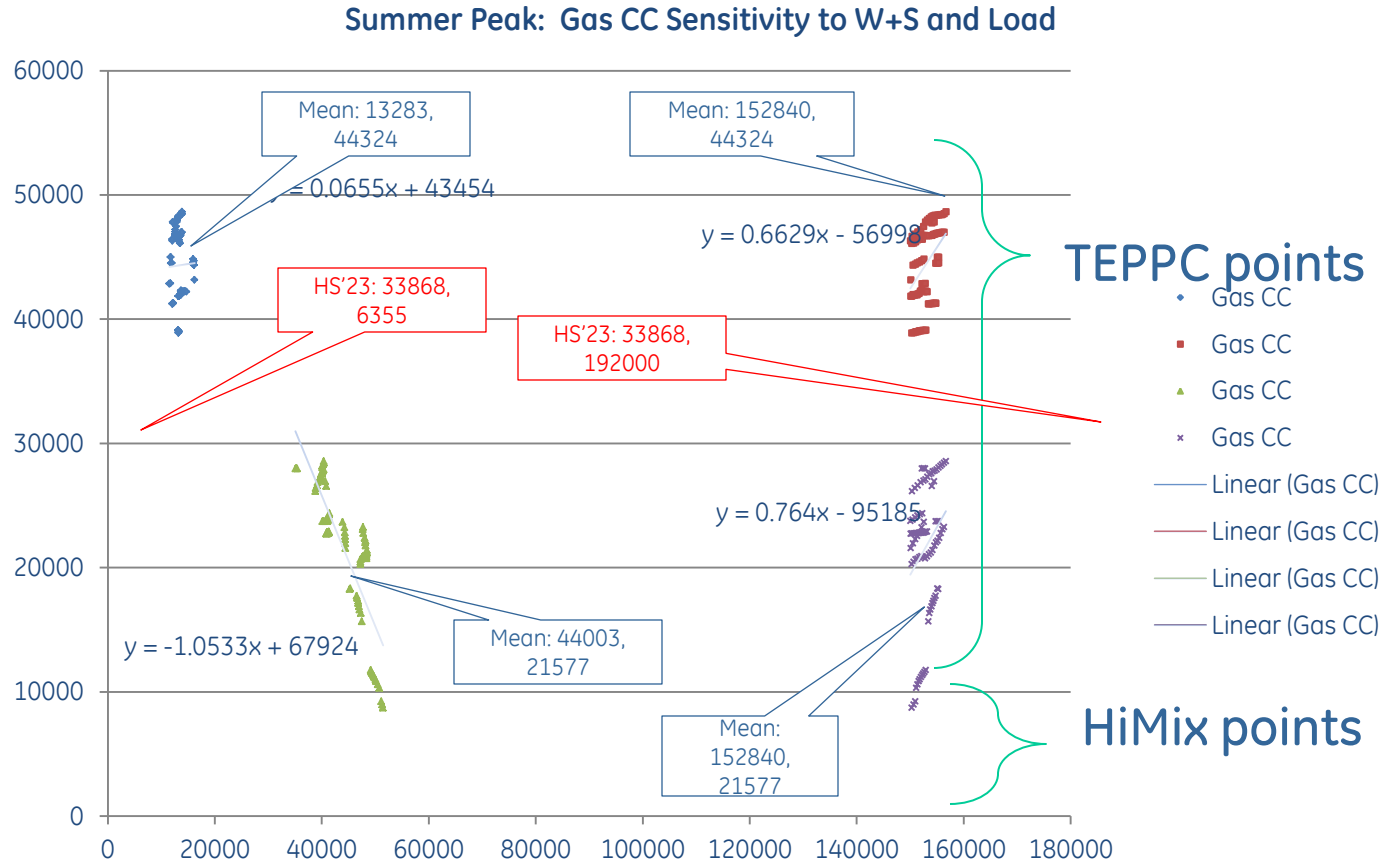
Mining Plexos: Combined Cycle Plants (part 1: What is this?)

- TEPPC vs HiMix
- CC dispatch vs. W+S AND vs. Load
- So 4 clusters of 5 minute periods…total of 96 of them
- CC plants



CC Dispatch vs W+S

CC Dispatch vs System Load

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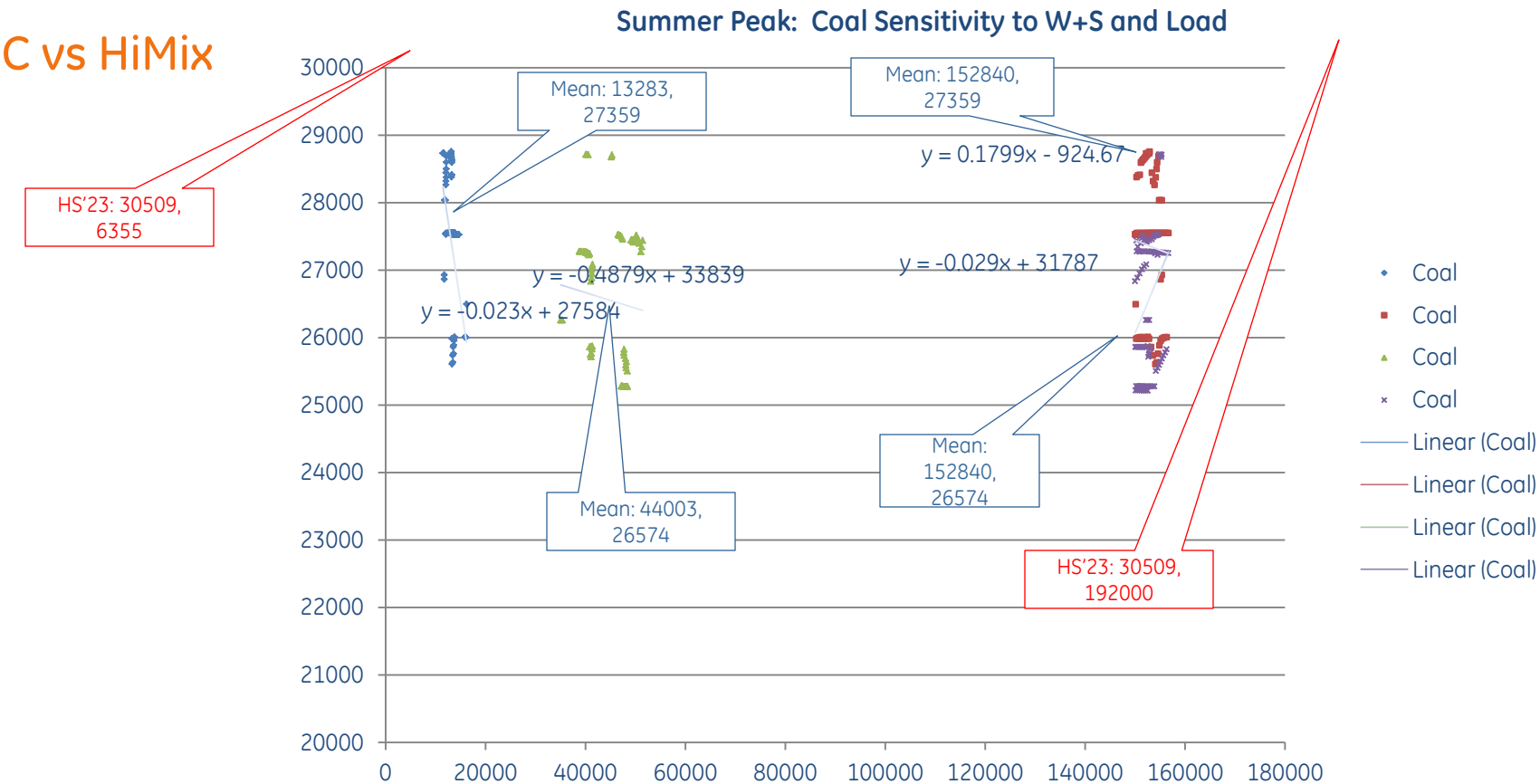
Mining Plexos: Coal Plants

TEPPC vs HiMix



- Essentially no change in the coal plants at peak.

Plexos Case – Renewable Summary – for HS'23 Hi-Mix

Renewables summary for sample 68417

TEPCC WWSIS II @ 68417

Area name	Area #	CSP	WWSIS PV	WWSIS_wind
ALBERTA	54			
ARIZONA	14	351	389	326
BC HYDRO	50			
EL PASO	11			21
IDAHO	60			120
IMPERIALICA	21		155	32
LADWP	26	1147	259	
MEXICO-CFE	20			5
MONTANA	62			64
NEVADA	18	116		
NEW MEXICO	10	53	92	4
NORTHWEST	40			6064
PACE	65			226
PG&E	30			28
PSCOLORADO	70	186	265	37
SAN DIEGO	22			
SIERRA	64		119	31
SOCALIF	24	2396	1825	89
FORTISBC	52			
WAPA R.M.	73		480	363
WAPA U.M.	63			
-1	-1	251	506	72
Total		4500	4090	7480

HiMix @ 68417

Fraction of PV that is distributed generation (DG)

Area #	CSP	WWSIS PV	DG ratio	DG	PV	WWSIS_wind
54						
14	3182	4608	0.42	1919	2689	111
50						
11		359	0.47	169	190	21
60		0			0	167
21	187	432	0.10	45	387	27
26	1147	1770	0.68	1207	563	
20		10				5
62		25	0.44	11	14	762
18	197	464	0.31	142	321	
10		631	0.40	249	382	106
40		770	0.38	292	477	6908
65		838	0.73	615	223	1448
30		2175	0.46	997	1177	102
70	186	827	0.37	305	522	60
22		437	0.57	247	190	
64		1372	0.22	305	1067	95
24	3095	6963	0.44	3040	3923	73
52						
73		720	0.46	331	389	873
63		1	0.00	0	1	0
-1	1508	1476				132
	9502	23877		9875	12516	10890

Difference

Means "utility scale" PV

Area #	CSP	WWSIS PV	DG	PV	Wind
54					
14	2831	4219	1919	2300	-215
50					
11	0	359	169	190	0
60	0	0	0	0	47
21	187	277	45	232	-5
26	0	1510	1207	304	0
20		10			
62	0	25	11	14	698
18	81	464	142	321	0
10	-53	540	249	290	102
40	0	770	292	477	844
65	0	838	615	223	1222
30	0	2175	997	1177	74
70	0	562	305	257	23
22	0	437	247	190	0
64	0	1253	305	948	64
24	698	5137	3040	2097	-16
52					
73	0	240	331	-92	510
63	0	1	0	1	0
-1	1256				
Total	5001	18817	9875	8932	3349

Remember these are from the Plexos case, NOT the WECC LSP base case

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Preliminary Results: Not for Further Distribution or Citation

Summary/Observations

- Frequency response is not significantly affected for this case
  - Changes in Kt, headroom, and post-disturbance flow patterns tended to balance out
  - Intermediate point, with *only* unit decommitments, degraded response slightly. As expected. Not necessarily realistic case
- Light spring weekend morning case results in massive solar generation in DSW and southern CA:
  - drives S to N flow, somewhat like winter
  - PDCI off (could also be scheduled S to N). Didn't run PDCI case.
- No apparent negative impact on transient stability
- Decommitment and redispatch used most candidates…
  - to get to extreme hi renewable sensitivity (~62GW) will be "interesting"

TRC Call: Do not Cite - Not for Further Distribution

Next steps/Discussion

- More work on LSP'22 Hi-Mix
  - No obvious stability problems so far, but substantial changes in flow patterns could result in stability issues for other disturbances… suggestions welcome from TRC
- Consider extreme LSP'22 Hi-Mix.
  - Highest instantaneous production of LSP samples…~62GW (vs. ~48GW for case shown in this meeting. Does TRC agree this is of interest?
- Continue toward HS'23 Hi-Mix
  - Average renewable ~44GW (up from ~6GW in bases case)
  - Extreme renewable for Hi-Mix (for this window) ~51GW
- What are we missing?!! (if anything)

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