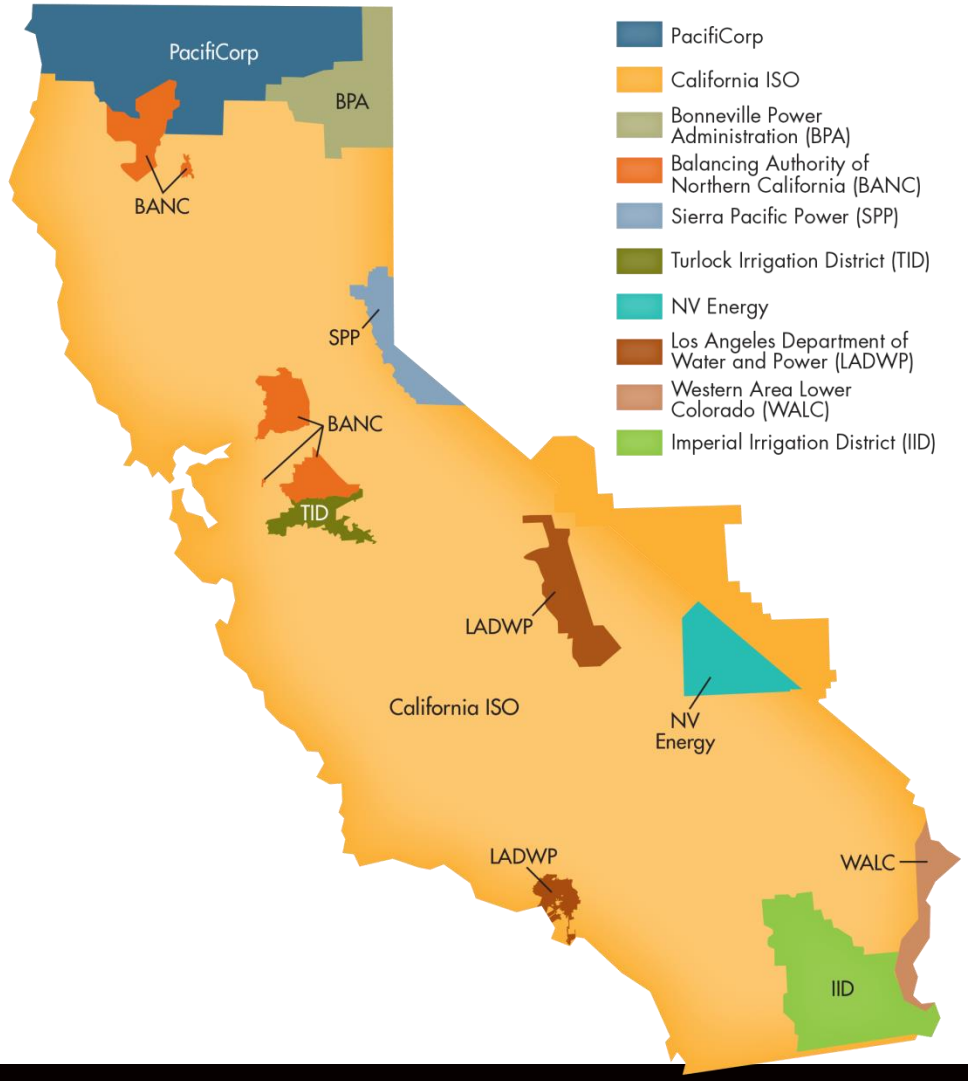
CAISO (California Independent System Operator)
Challenges and Solutions

Presented by:

Brian Cummins – Manager, CAISO

California ISO
Shaping a Renewed Future

California ISO by the numbers



- **60,703** MW of power plant capacity (net dependable capacity)
- **50,270** MW record peak demand (July 24, 2006)
- **27,589** market transactions per day
- **26,024** circuit-miles of transmission lines
- **30 million** people served
- **246 million** megawatt-hours of electricity delivered annually

California ISO in WECC

The ISO is the largest of about 38 balancing authorities in the Western Interconnection, handling an estimated 35 percent of the electric load in the West.

A balancing authority is responsible for operating a transmission control area.

It matches generation with load and maintains electric frequency of the grid.

CAISO new Building

CAISO new Building

LEED building

- Placing the east-west orientation to maximize natural light while reducing solar heat gain
- Creating a “cool down effect” with shade trees, building overhangs, and a reflective white cool roof
- Installing in the parking lot and roof top photovoltaic panels to generate 750 kilowatts
- Managing storm water runoff from hard surfaces through bioswales and retention basins.
- Using the highest rated energy efficient equipment possible and a sophisticated control system to manage them
- Using environmentally friendly refrigerants and fluorescent lamps with ultra low mercury levels to reduce future pollution
- Providing natural lighting, C02 sensors, and highly efficient air filters to deliver a large amount of outdoor air into the building

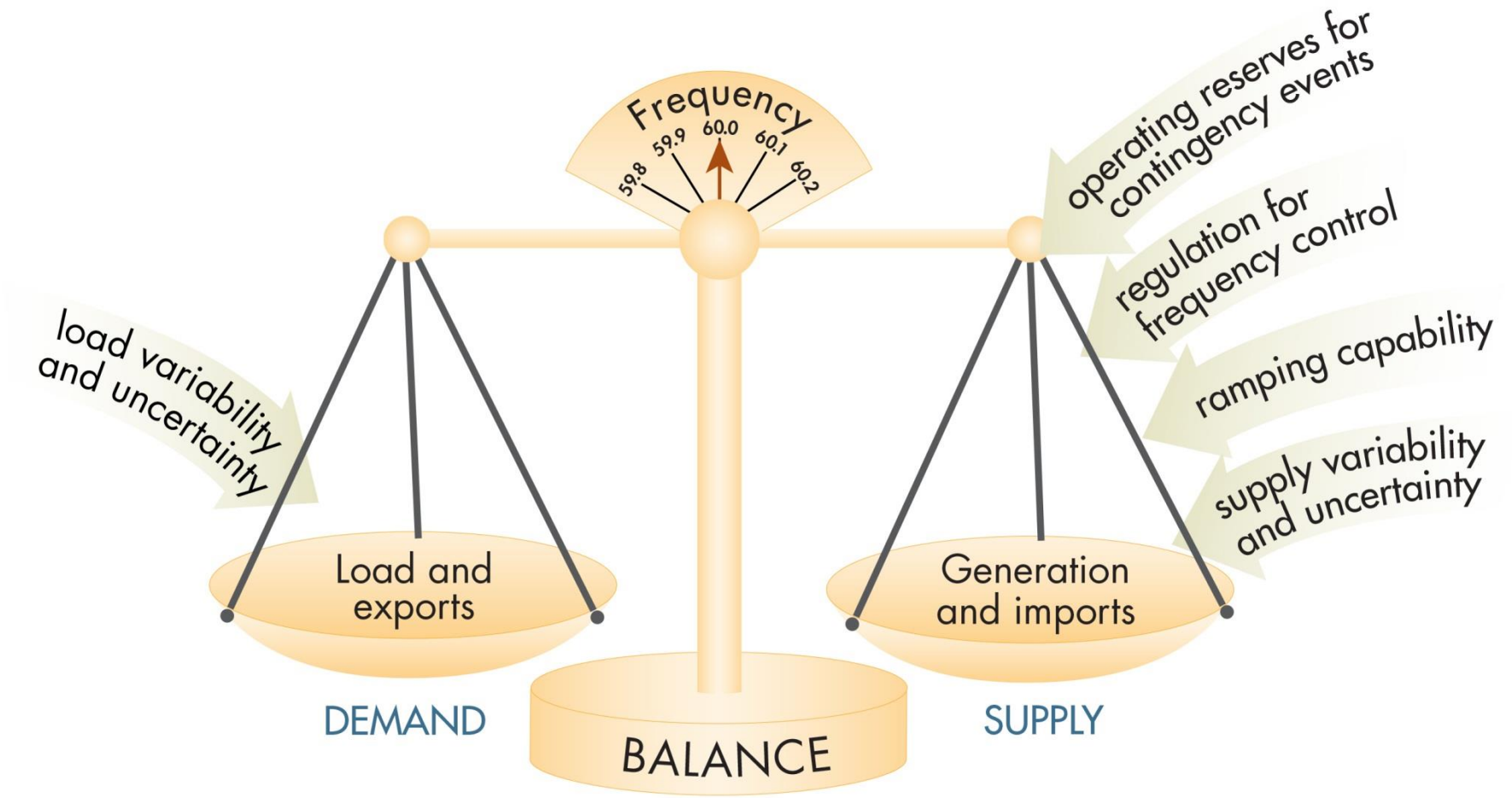
LEED building

Energy savings	
Facility	Electricity usage per sq. foot
previous leased space	65 kWh
new headquarters	27 kWh
reduction	**Almost 58%**

Folsom, CA – Control Room

Alhambra, CA – Control Room

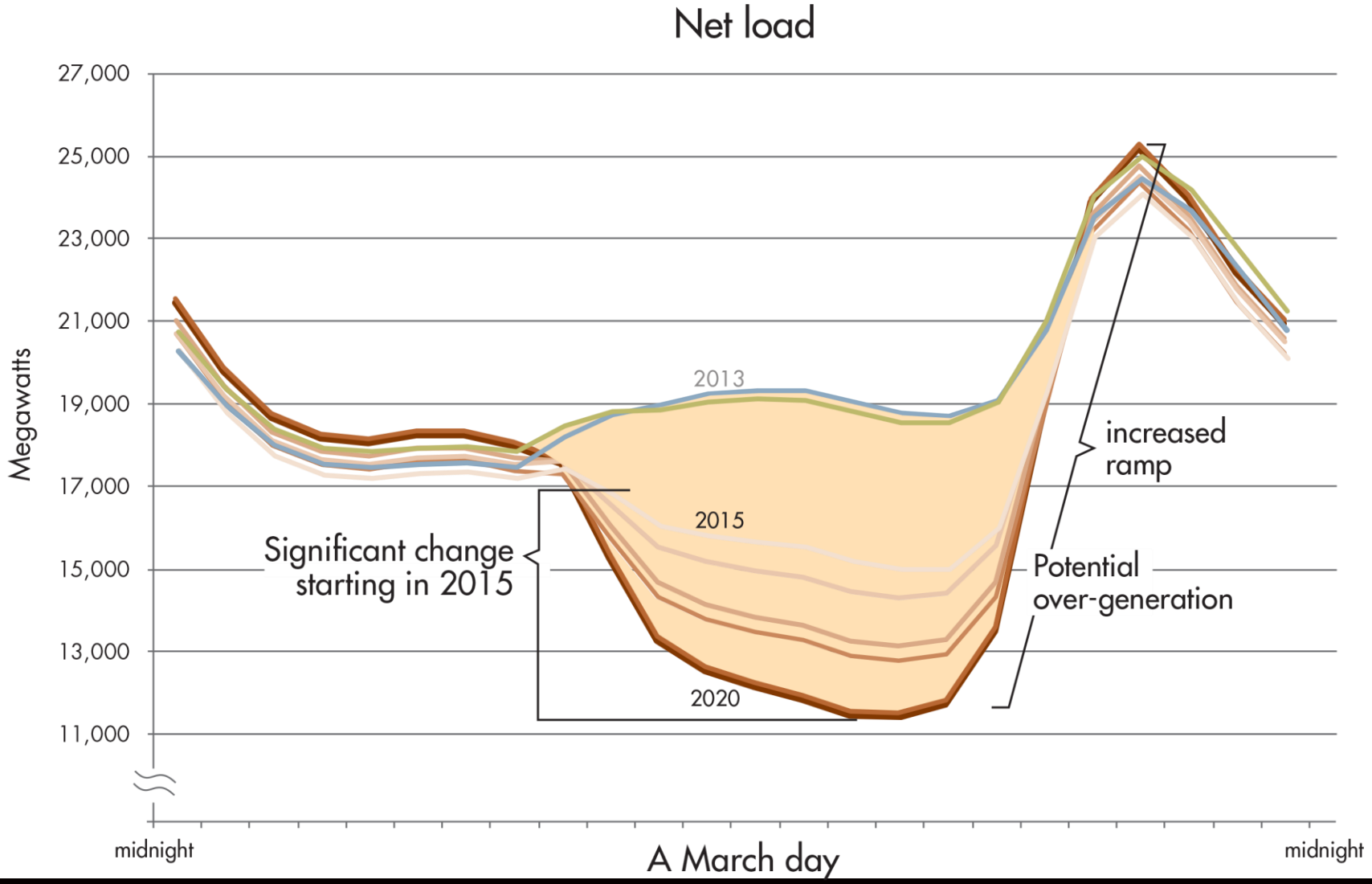
Balancing Supply and Demand



Changes in the Electric Industry affecting us

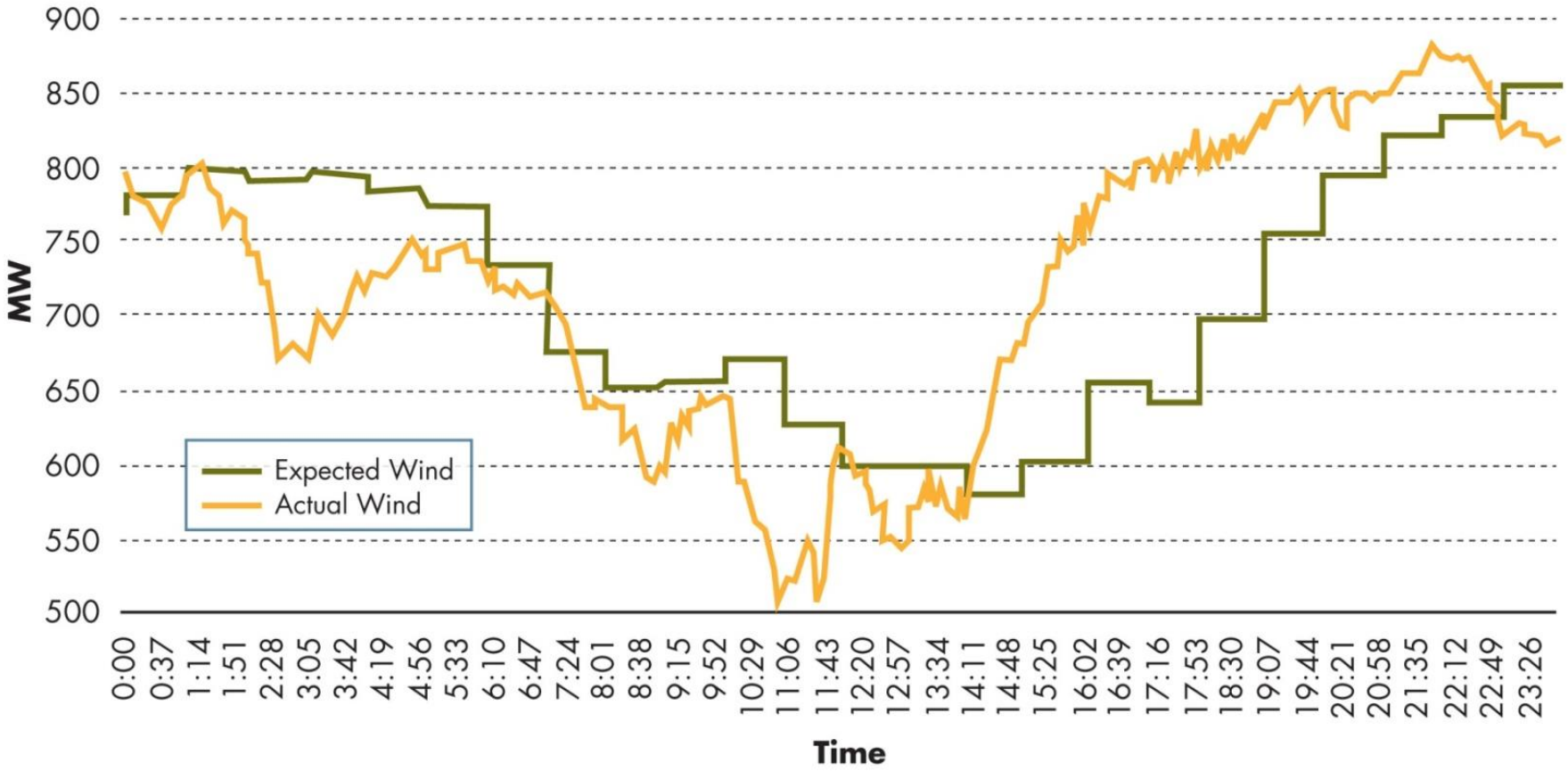
- Renewable Generation – Setting new peaks on a weekly base
  - Wind unpredictable output (3300 MW peak)
  - Solar unpredictable output for telemetry generation (1100 MW peak)
  - Photo Voltaic (PV) on roof tops without telemetry (1500 MW Estimate)
- Higher expectation of reliability
- Higher expectation of security
- SmartGrid
- Immediate answers
- Situational awareness through Visualization

Operational needs are significantly changing between 2013 and 2020 the “Duck” Curve



Forecasted vs. actual wind output

Simulated spring day in 2012

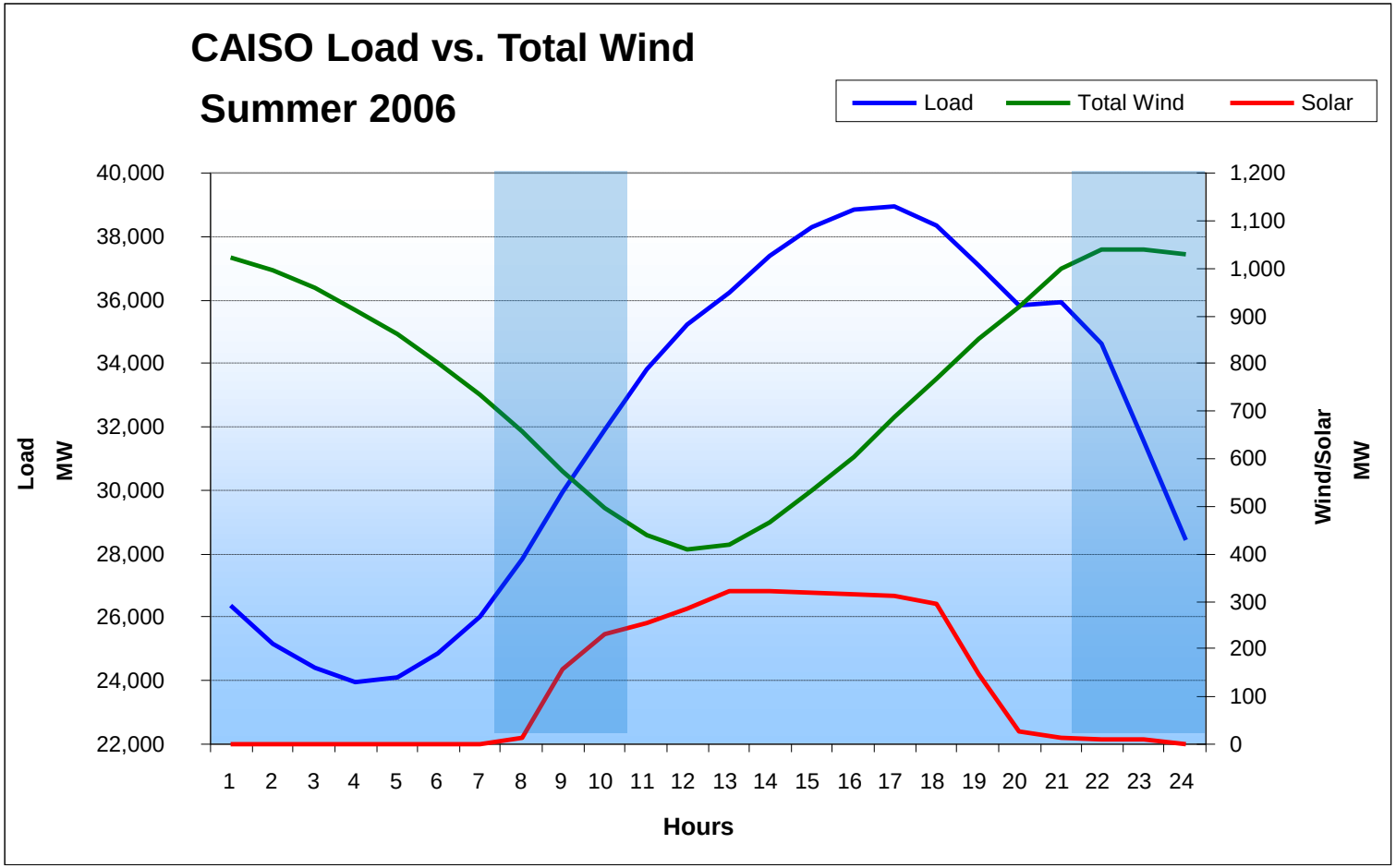


Source: 2010 Integration of Renewable Resources Operational Requirements and Generation Fleet Capability at 20% RPS

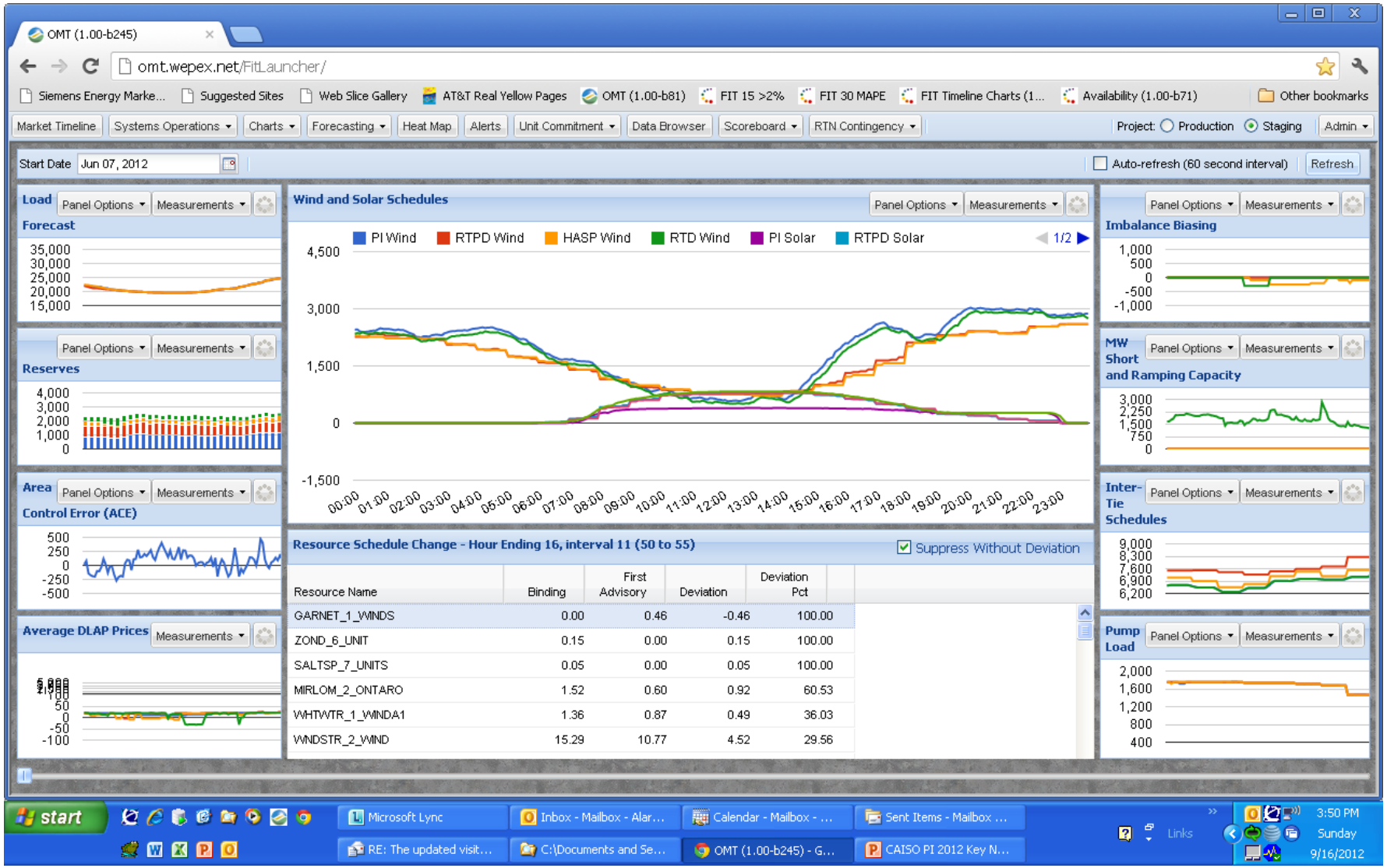
Challenges in the Horizon

- Unpredictable generation in the horizon depending on weather forecast
- More ramp rate is required to meet sudden changes in weather
- True actual load is deformed by PV roof tops
- Need to know accurate and immediate power flow as it is becoming more dynamic
- Inter-ties schedule needs to go to 15 minutes instead of hourly
- Need to know the Sequence of event immediately during important events (Sep 8, 2011 outage)

Wind generation tends to be inversely correlated to daily load curve, creating ramping impacts



Renewable challenges



Resources required for renewables integration

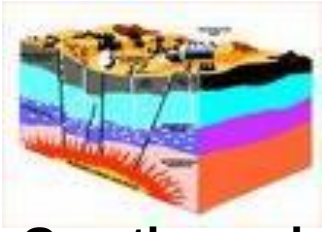
Wind Generation

Solar Generation

“Partners in Success”

Generation Portfolio	Storage	Demand Response
Quick Start Units	Shift Energy from off-peak to on-peak	Price sensitive load
Fast Ramping	Mitigate Over Generation	Responsive to ISO dispatches
Wider Operating Range (lower P_{min})	Voltage Support	Frequency Responsive
Regulation capability	Regulation capability	Responsive to Wind Generation Production

Hydro Generation



Geo-thermal Generation

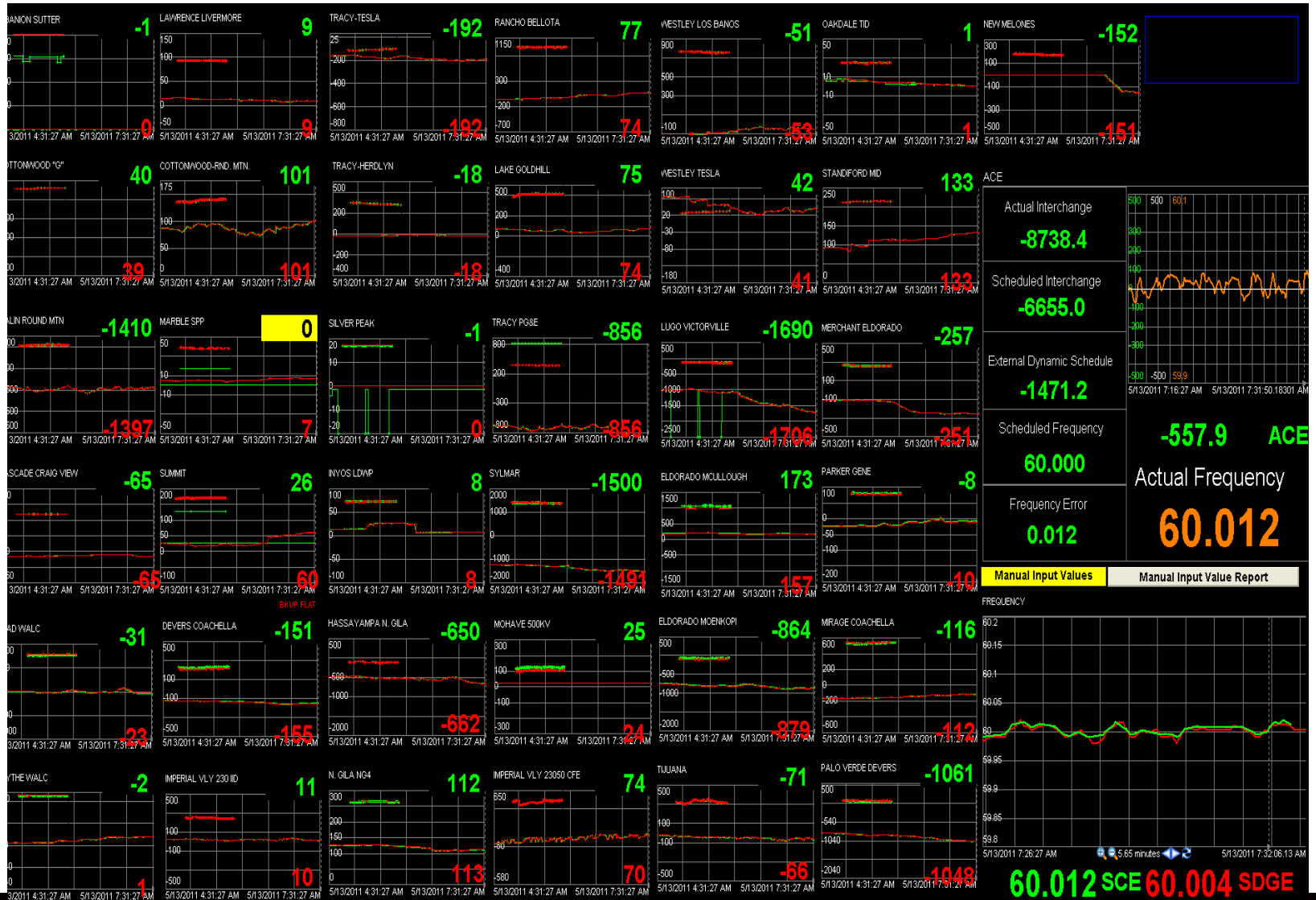
Solution helps if you think this way

- EMS provides reality and a way to operate reality
- The market is the forecast of the reality to come
- We need to provide operators visualization to tie the past, current, and the future
- Operators' confidence is increased as you provide the visualizations and accuracy of the forecast

PI is the continuum for operators to see and analyze the past, operate the current, and proactively make decisions to prevent a negative future

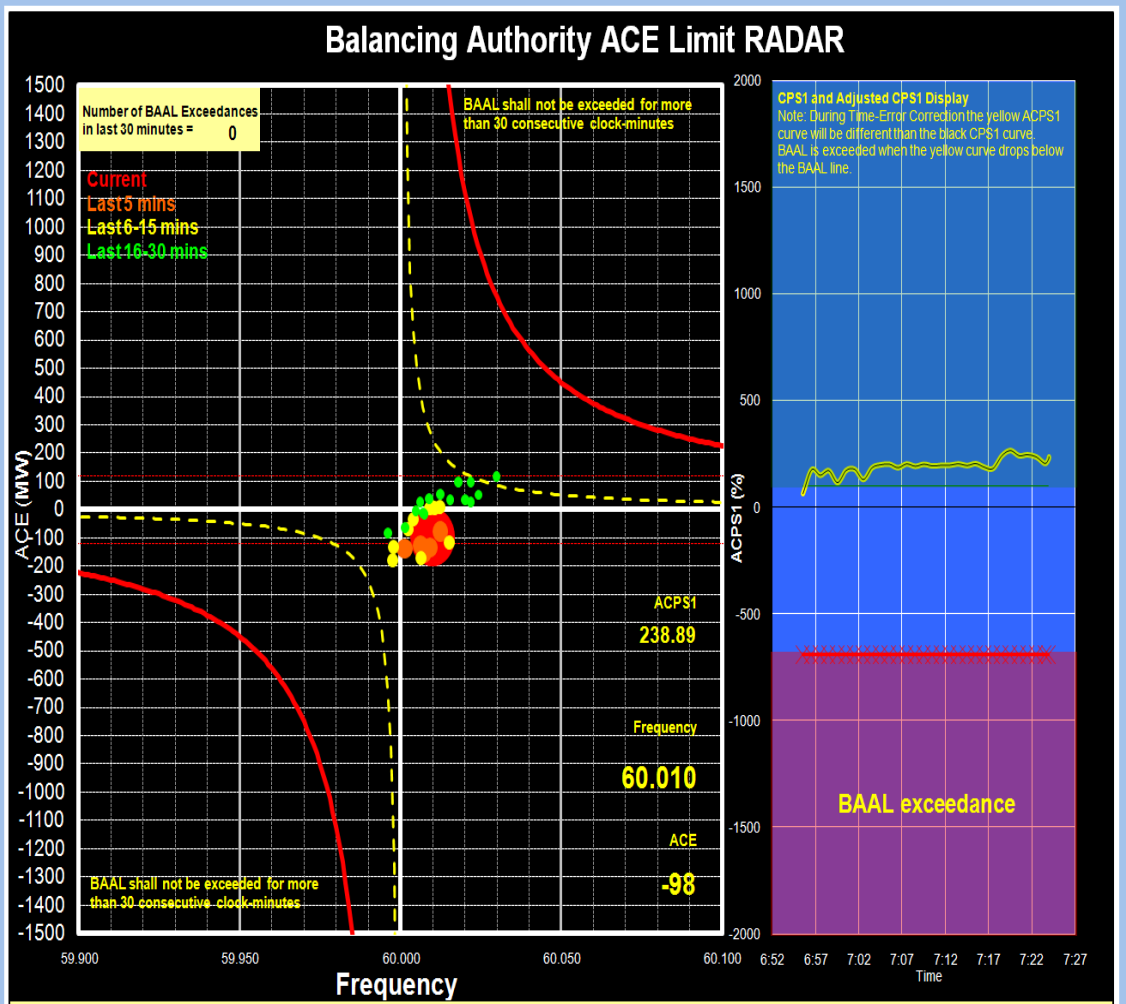
PI for Reliability

CAISO PI Display – reliability back-up tie line display with ACE-Area Control Error/FREQ



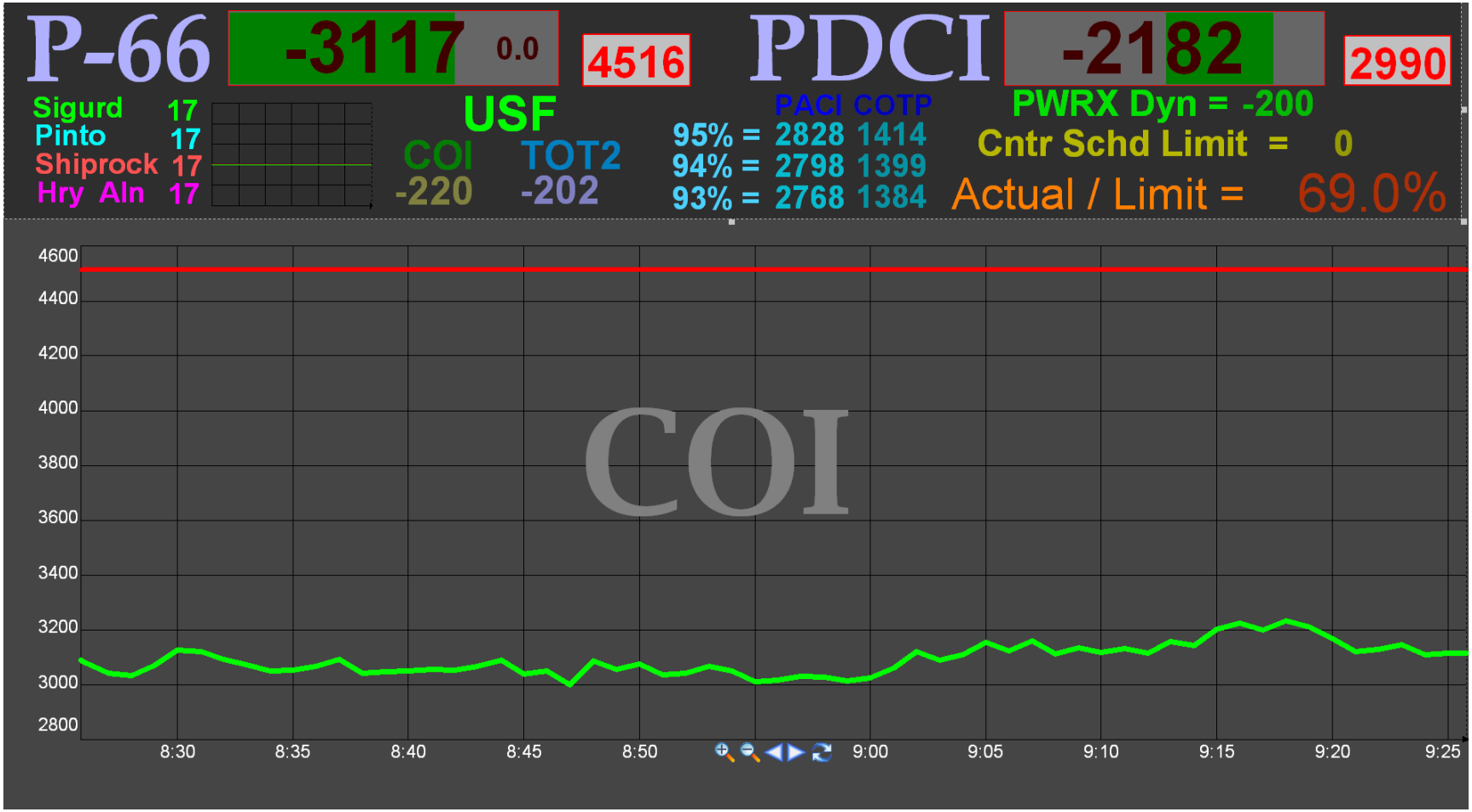
CAISO PI Display – reliability CAISO AGC summary

CAISO PI Display – reliability balancing authority ACE (Area Control Error) limit radar

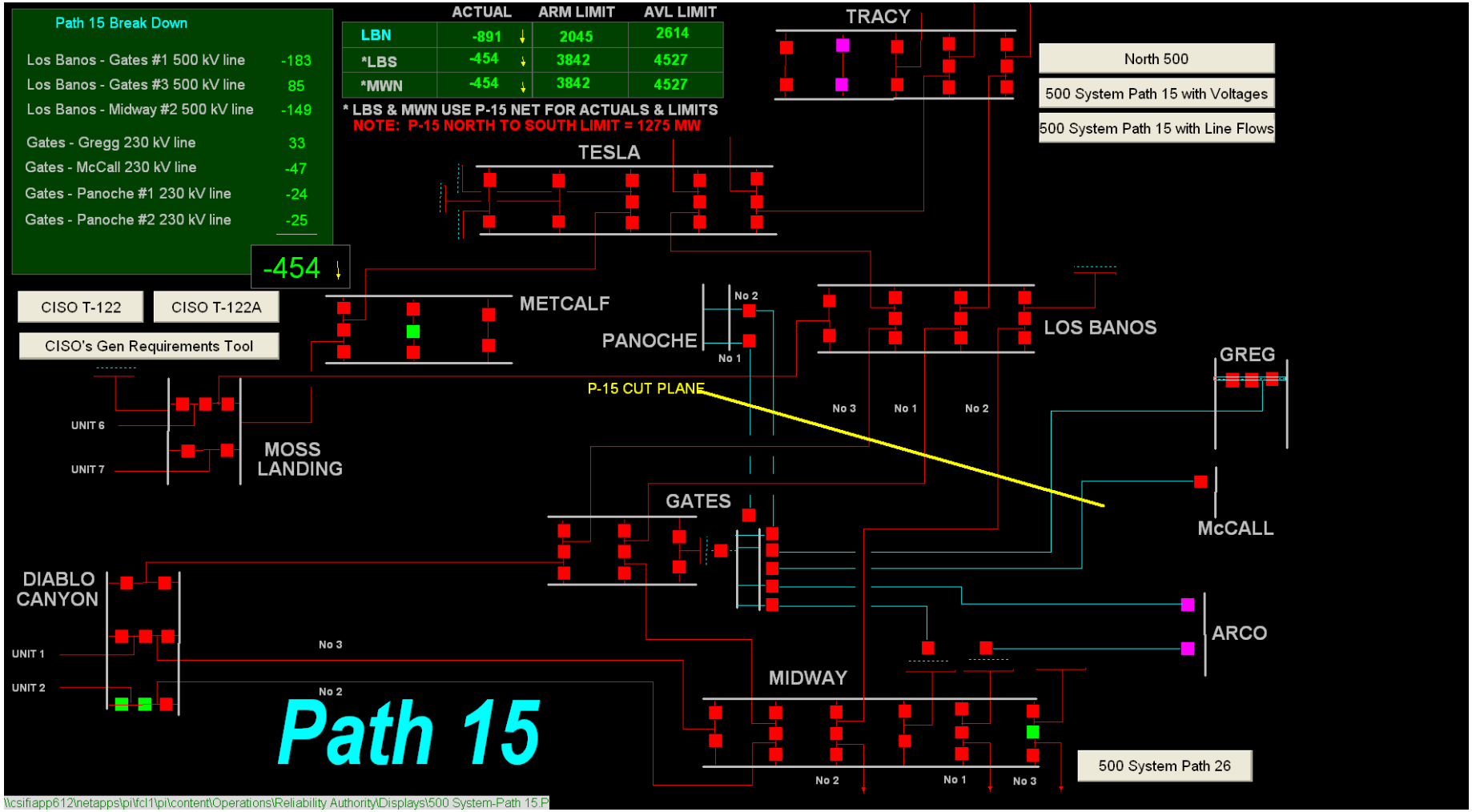


PI for Transmission

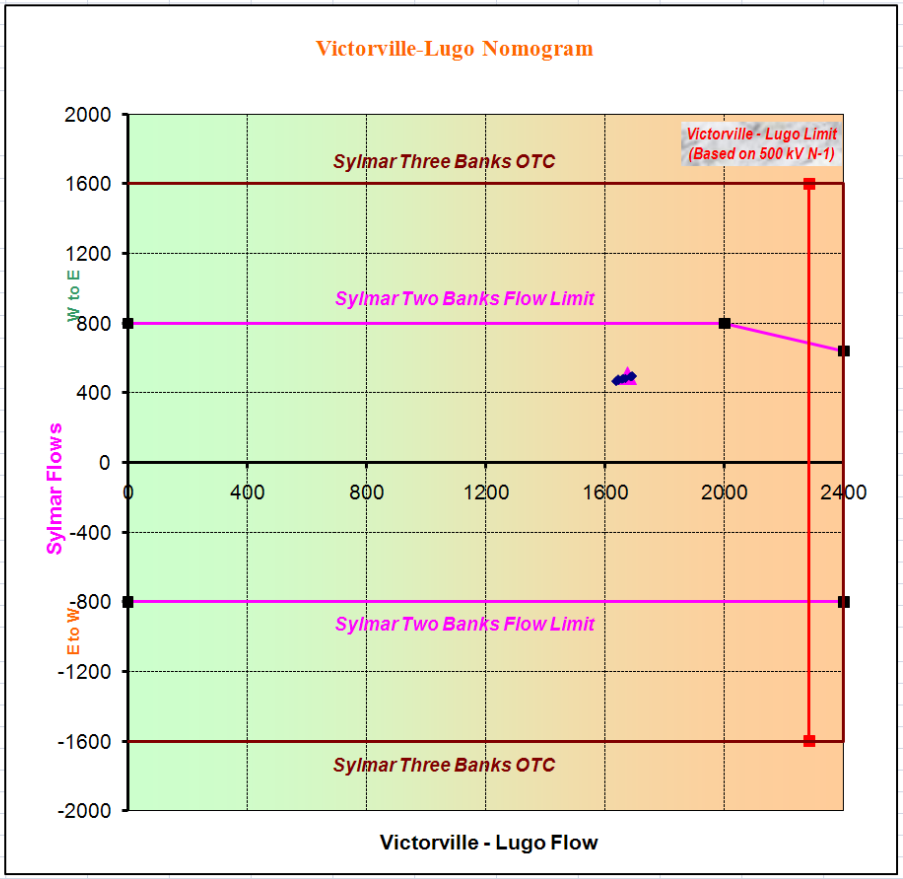
CAISO PI Display – transmission California-Oregon Intertie (COI) summary



CAISO PI Display – transmission path 15 summary



CAISO PI Display – transmission nomogram



5/13/2011 7:22

Vic-Lugo Flow	Eldorado-Lugo Flow	Mohave-Lugo Flow	Palo Verde - Devers Flow	Hassayampa - North Gila Flow
	756 MW	-3 MW	1048 MW	648 MW
1675 MW	Sylmar Bank Flows 499 MW			
			SCE Load	11567 MW

Victorville - Lugo Limit	Victorville-Lugo Margin
2284 MW	609 MW

Sylmar Transformer Banks ratings

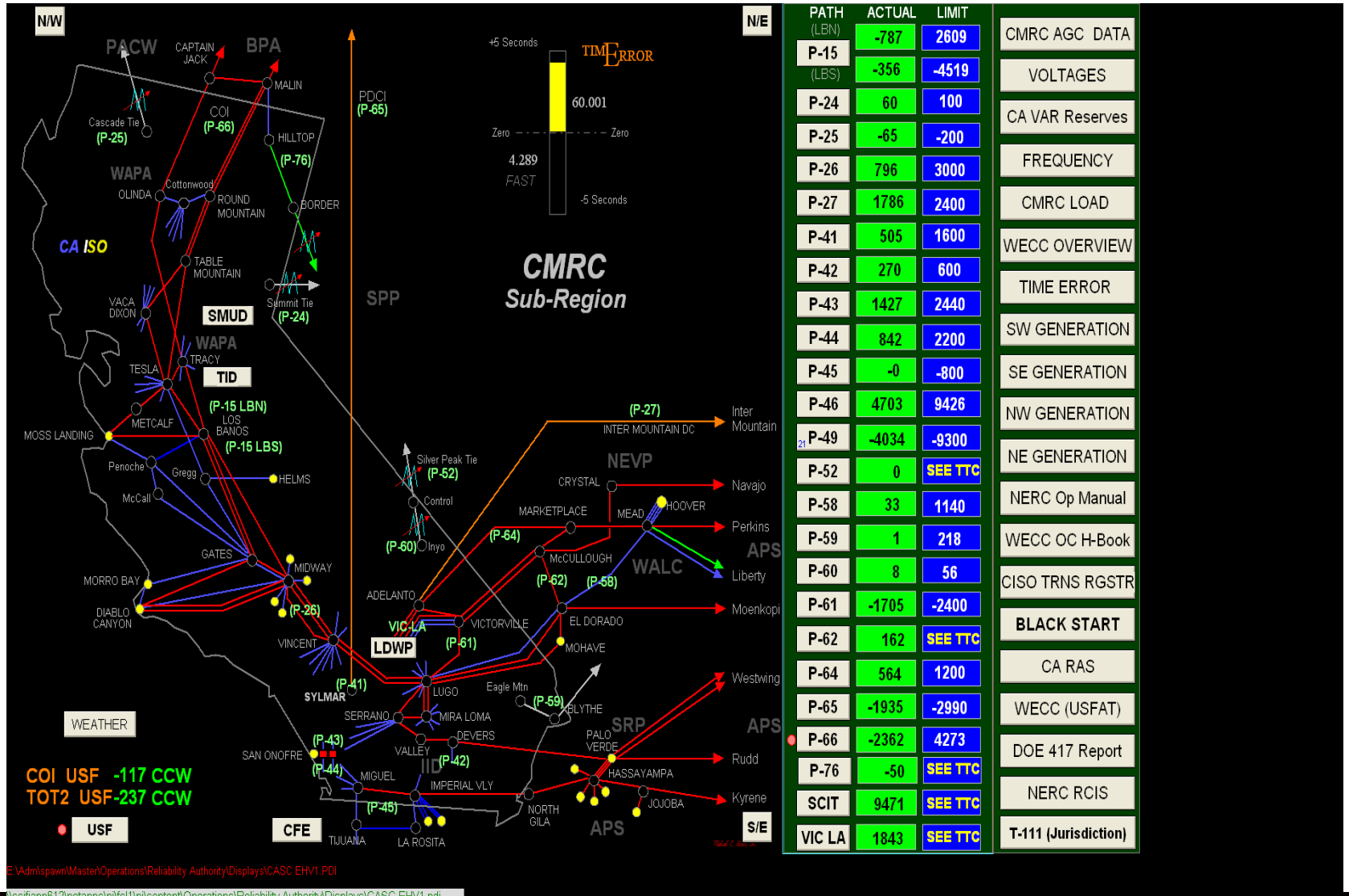
Equipment	Normal Rating (MVA)	Emergency Rating (MVA)
Sylmar Bank E	600	800 (2-hour)
Sylmar Bank F	672	800 (2-hour)
Sylmar Bank G	900	1134 (2-hour)
		1305 (30-minute)

Select Current System Condition

- (•) All Lines in Service
- ( ) Hass-N.Gila / N.Gila-IV 500 kV Line O/S
- ( ) Palo Verde-Devers 500 kV Line O/S
- ( ) Eldorado-Lugo 500 kV Line O/S
- ( ) Lugo-Mohave / Eldorado-Mohave 500 kV line O/S

Static | Nomogram | DATA | Tracer Data | Revision History

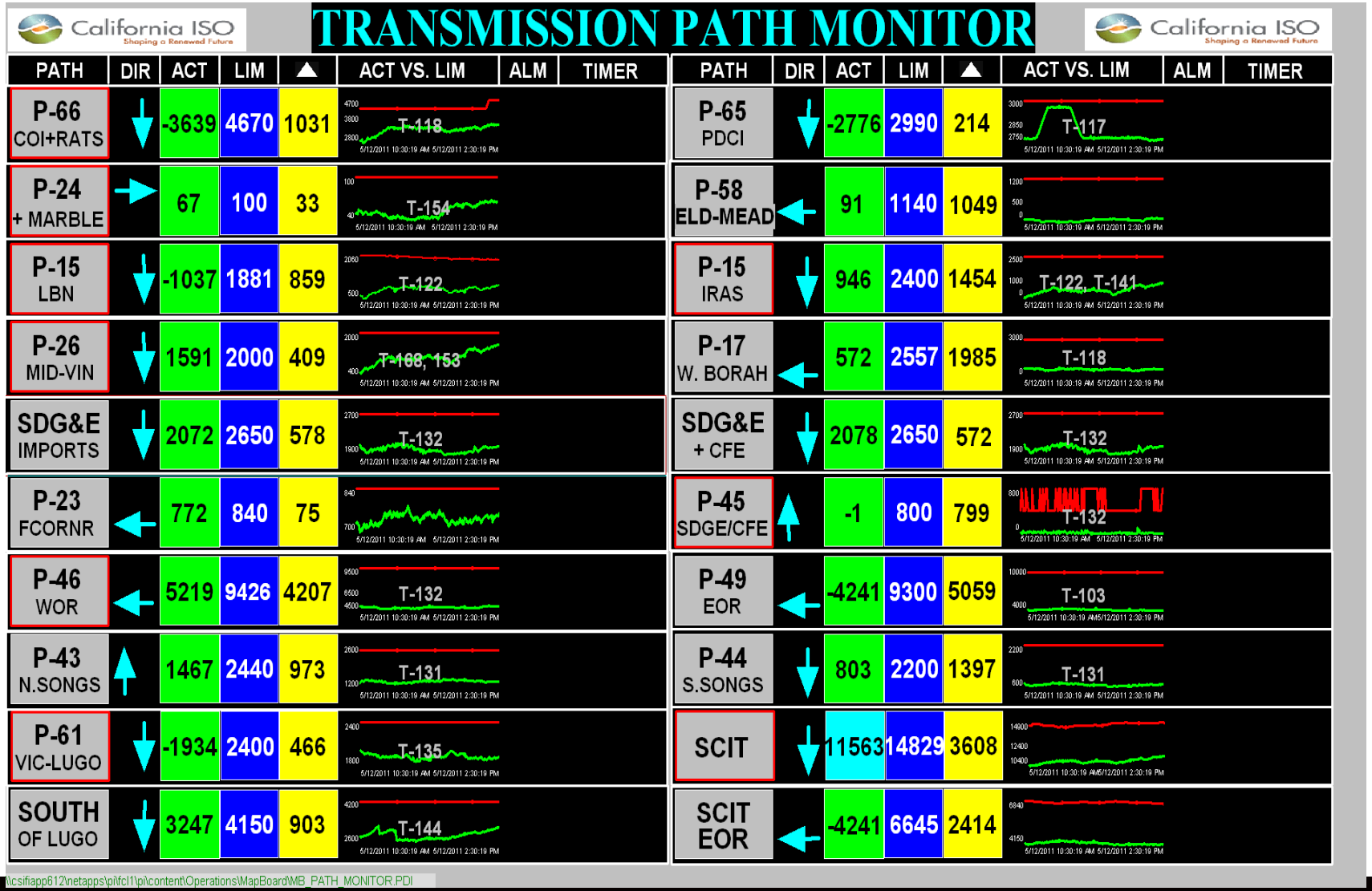
CAISO PI Display – reliability WECC transmission path overview



PATH	ACTUAL	LIMIT
(LBN) P-15 (LBS)	-787 / -356	2609 / -4519
P-24	60	100
P-25	-65	-200
P-26	796	3000
P-27	1786	2400
P-41	505	1600
P-42	270	600
P-43	1427	2440
P-44	842	2200
P-45	-0	-800
P-46	4703	9426
P-49	-4034	-9300
P-52	0	SEE TTC
P-58	33	1140
P-59	1	218
P-60	8	56
P-61	-1705	-2400
P-62	162	SEE TTC
P-64	564	1200
P-65	-1935	-2990
P-66	-2362	4273
P-76	-50	SEE TTC
SCIT	9471	SEE TTC
VIC LA	1843	SEE TTC

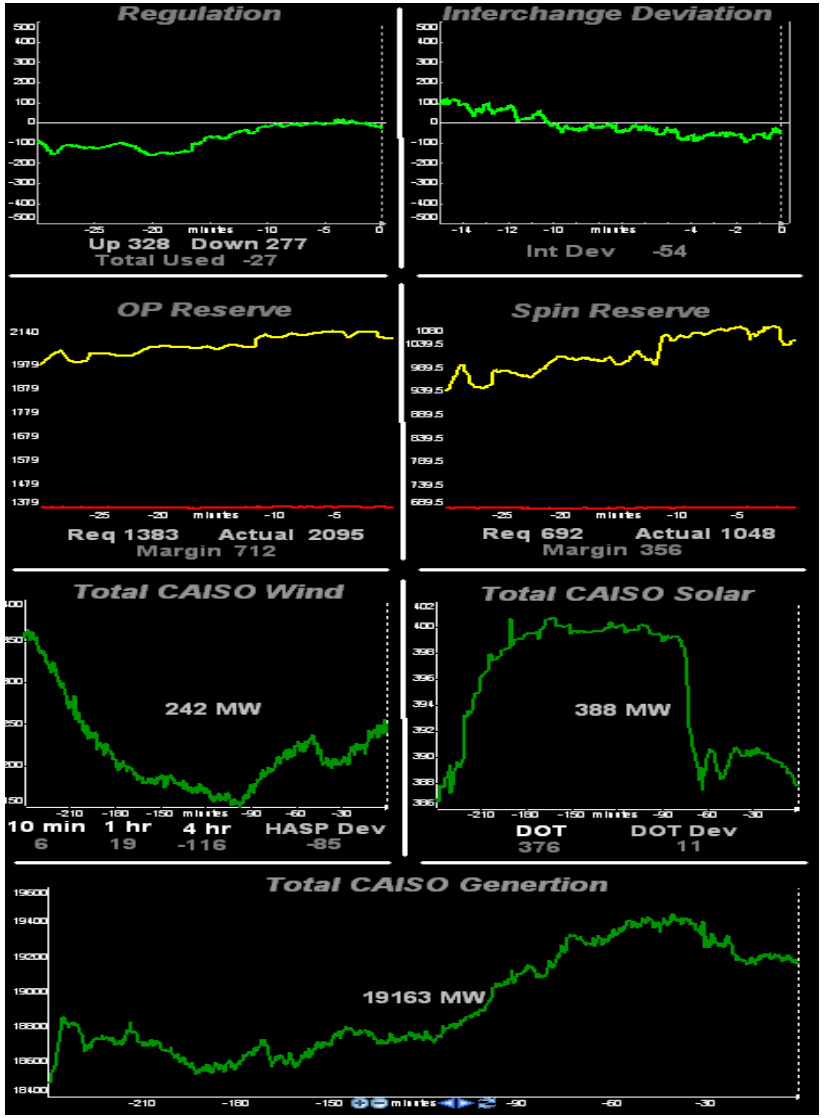
CMRC AGC DATA
VOLTAGES
CA VAR Reserves
FREQUENCY
CMRC LOAD
WECC OVERVIEW
TIME ERROR
SW GENERATION
SE GENERATION
NW GENERATION
NE GENERATION
NERC Op Manual
WECC OC H-Book
CISO TRNS RGSTR
BLACK START
CA RAS
WECC (USFAT)
DOE 417 Report
NERC RCIS
T-111 (Jurisdiction)

CAISO PI Display – transmission path monitor

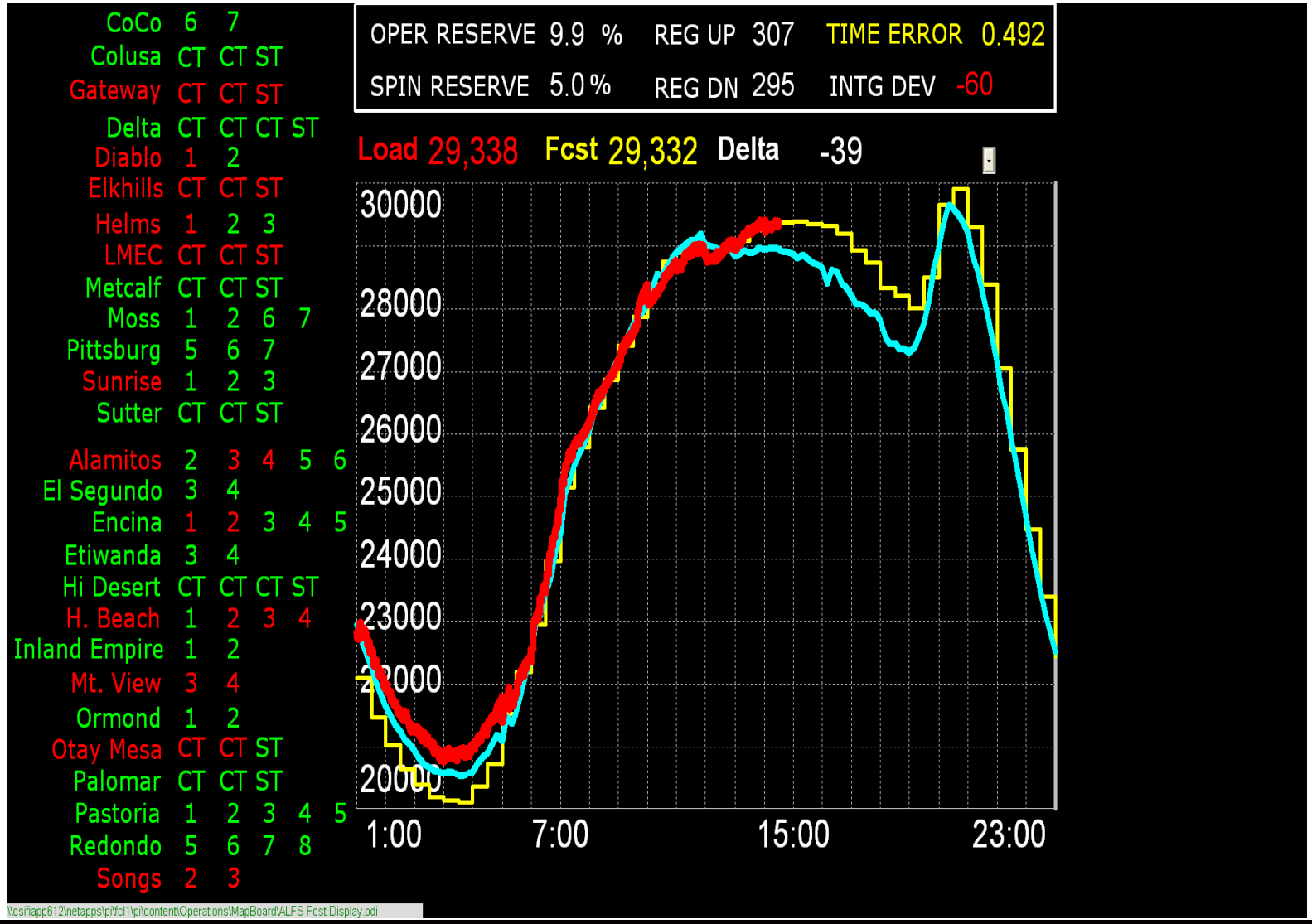


PI for Generation

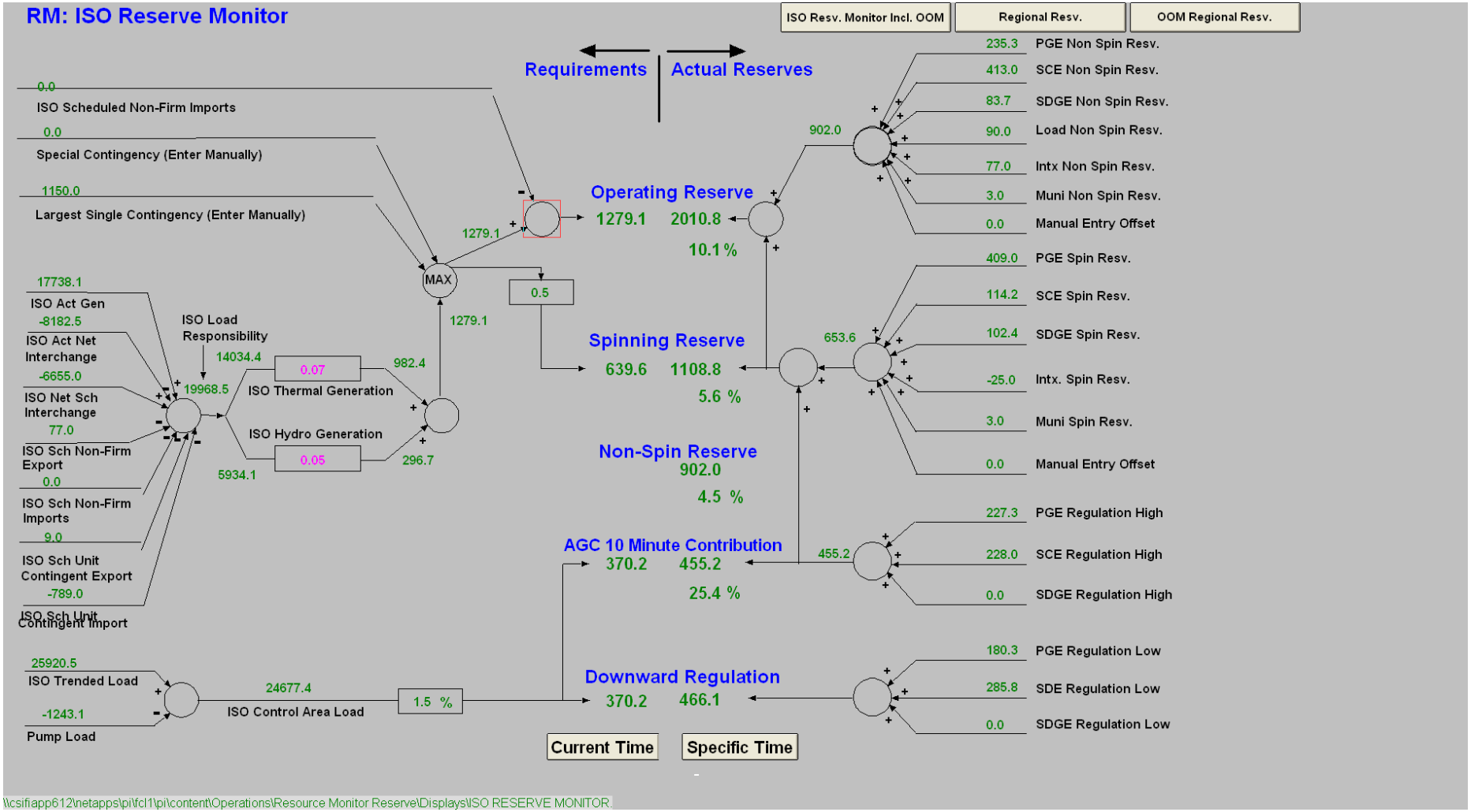
CAISO PI Display – generation regulation summary



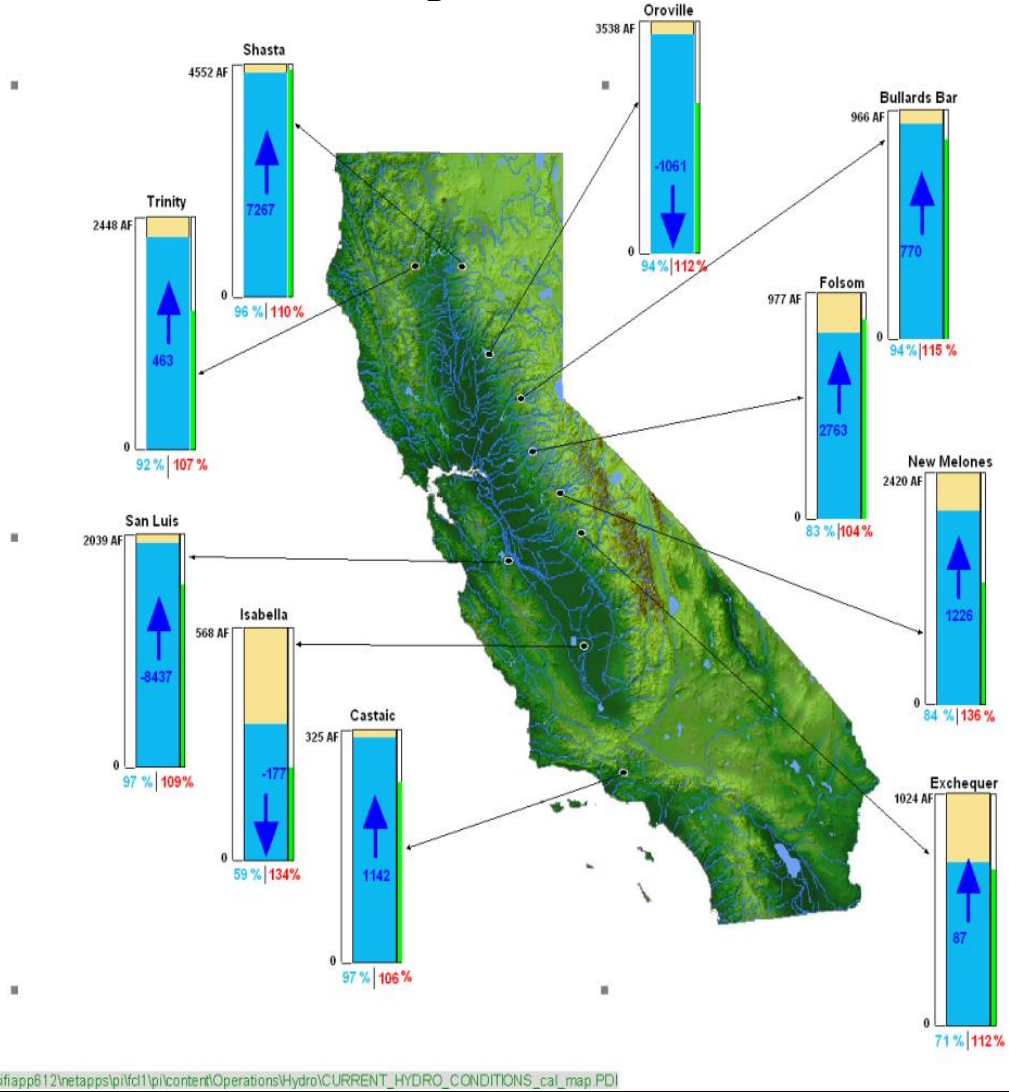
CAISO PI Display – generation load forecast and DCS generator status summary



CAISO PI Display – generation CAISO reserve monitor



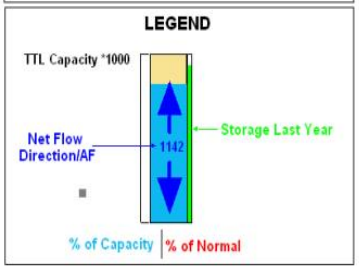
CAISO PI Display – generation hydro conditions summary



California ISO
Your Link to Power

- TRINITY RIVER SHED
- RUSSIAN RIVER SHED
- SACRAMENTO RIVER SHED
- FEATHER RIVER SHED
- YUBA RIVER SHED
- AMERICAN RIVER SHED
- STONY CREEK SHED
- CALAVERAS RIVER SHED
- MOKELUMNE RIVER SHED
- STANISLUAS RIVER SHED
- TUOLUMNE RIVER SHED
- MERCED RIVER SHED
- FRESNO RIVER SHED
- SAN JOAQUIN RIVER SHED
- SAN LUIS CREEK SHED
- KINGS RIVER SHED
- KAWEAH RIVER SHED
- TULE RIVER SHED
- KERN RIVER SHED
- SOUTH COAST

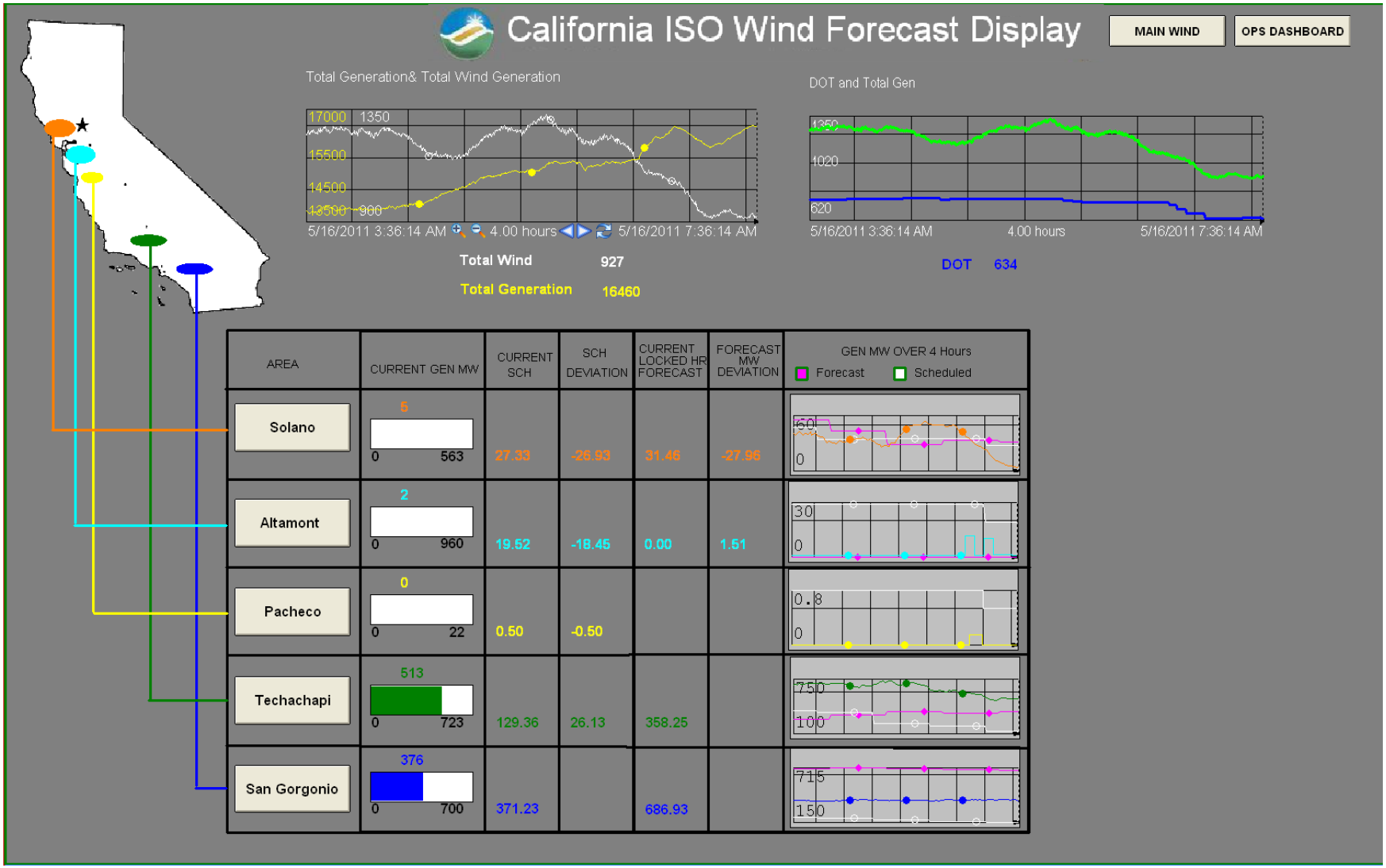
DAILY RESERVOIR SUMMARY



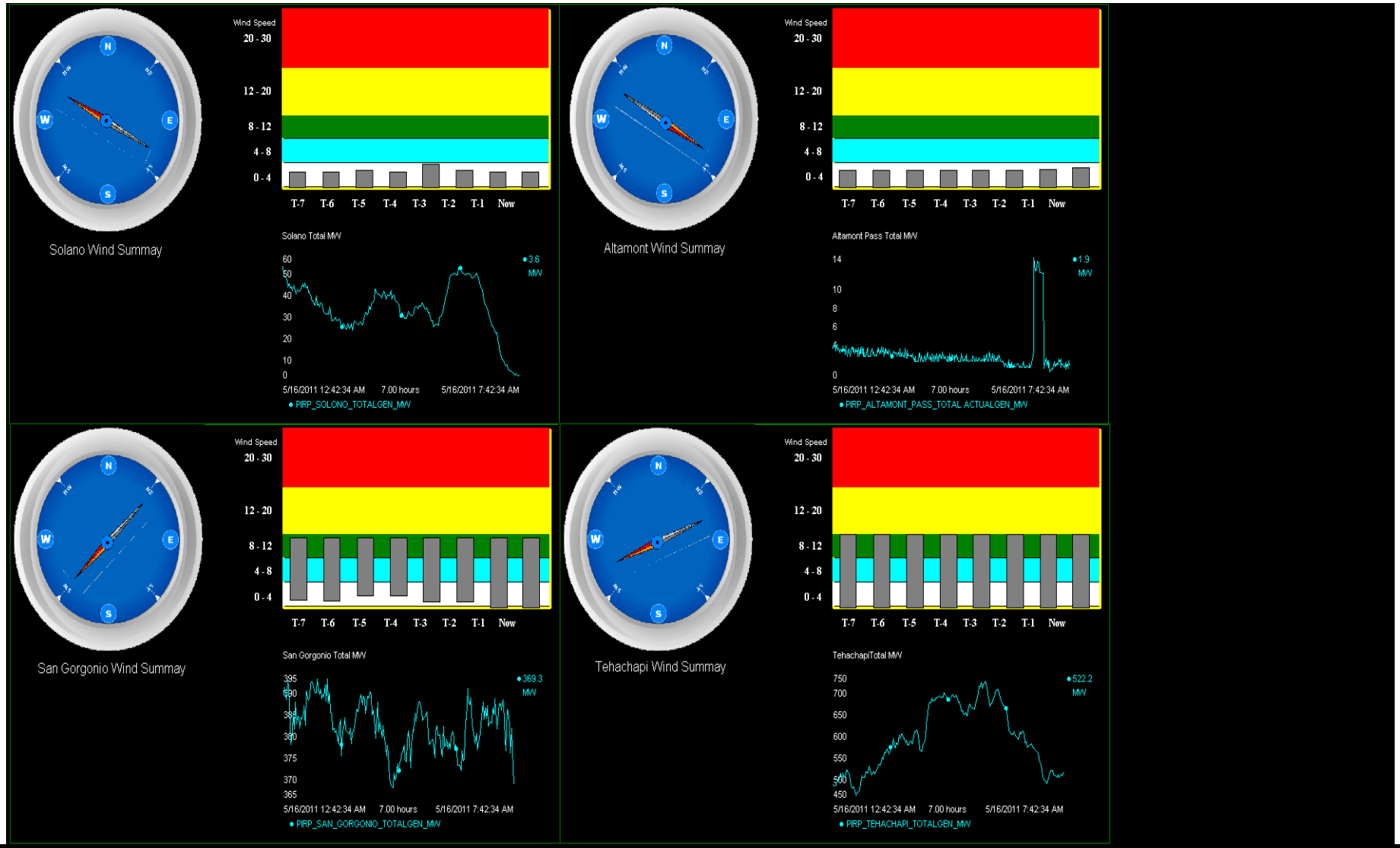
\\csifiapp612\netapps\pi\fcl1\pi\content\Operations\Hydro\CURRENT_HYDRO_CONDITIONS_cal_map.PDI

PI for Renewable

CAISO PI Display – wind forecast and generation summary



CAISO PI Display –
wind speed, directions and output summary



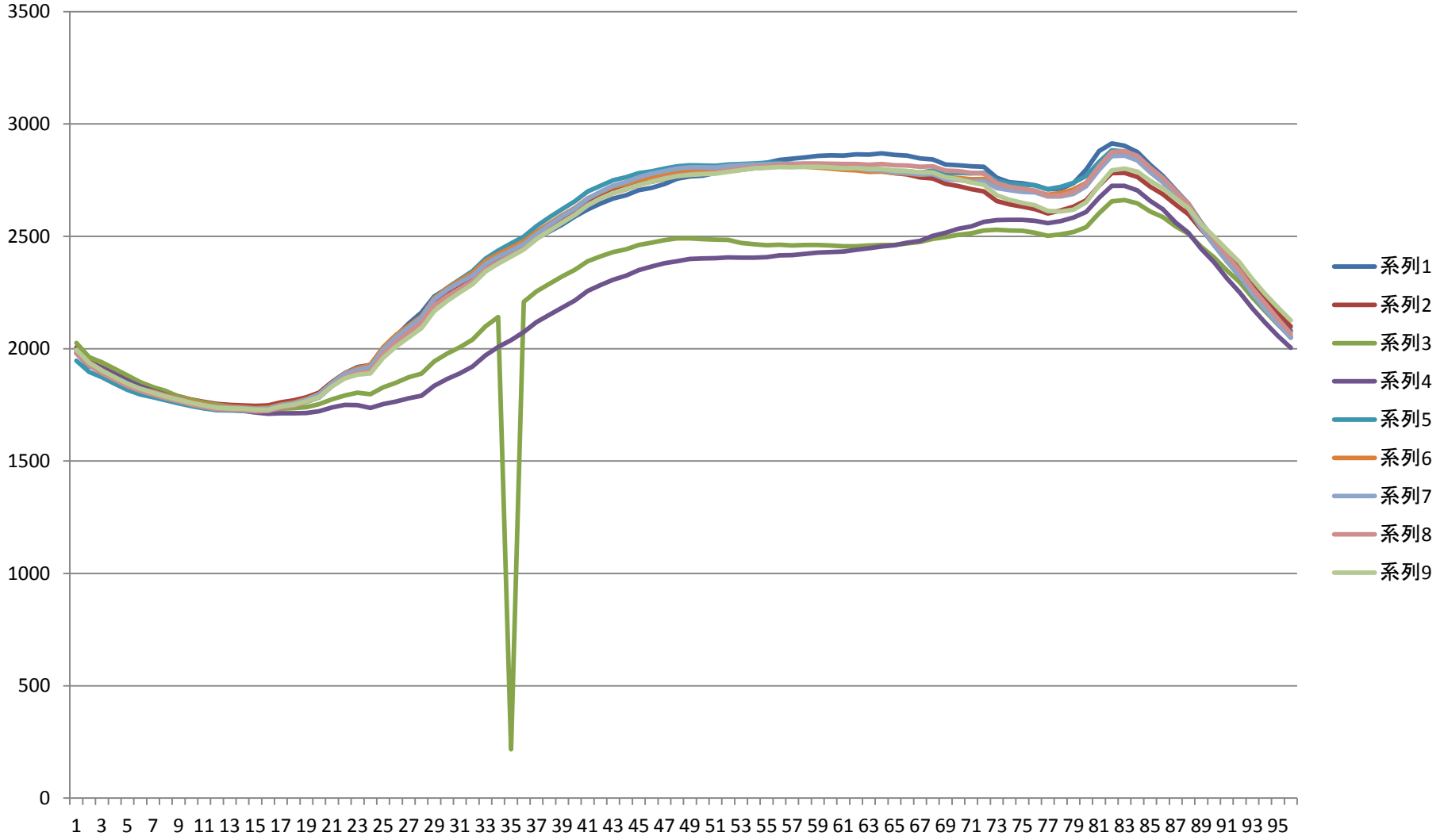
CAISO Current PI Projects

- Synchro-Phasor Integration
- Western Interconnection Synchrophasor Project
- 56 PMUs already sending data
- 100 PMUs estimated by December 2011
- 180 PMUs estimated by December 2012
- 250 – 300 PMUs estimated by December 2013

Example in Numbers only 6 hours of 24 – Can you find the mistake?

4:30	1766.807	1770.041	1735.584	1712.094	1748.954	1760.249	1756.513	1746.813	1751.224
4:45	1782.593	1783.582	1740.005	1713.625	1763.2	1776.202	1772.523	1762.432	1765.907
5:00	1804.619	1804.311	1753.202	1722.105	1782.787	1798.3	1796.214	1783.199	1785.155
5:15	1851.697	1851.983	1775.265	1738.878	1833.121	1848.069	1846.02	1832.959	1832.181
5:30	1891.173	1889.403	1791.779	1749.428	1874.77	1890.169	1887.194	1871.383	1867.261
5:45	1918.68	1914.849	1803.538	1749.229	1901.105	1913.318	1905.974	1891.461	1883.946
6:00	1927.751	1928.128	1797.334	1736.343	1917.293	1927.759	1919.787	1900.453	1889.87
6:15	2001.637	2003.804	1827.463	1753.16	1994.741	2006.415	1996.289	1975.221	1958.406
6:30	2054.95	2058.036	1848.321	1764.349	2050.196	2060.041	2051.025	2028.24	2008.001
6:45	2112.258	2103.88	1872.549	1778.843	2095.131	2102.328	2094.292	2072.529	2050.109
7:00	2160.629	2137.386	1888.932	1790.602	2135.888	2143.732	2138.594	2116.436	2091.379
7:15	2232.516	2211.839	1943.359	1834.518	2220.943	2225.654	2219.614	2192.266	2166.789
7:30	2267.812	2254.537	1978.218	1865.147	2270.142	2268.746	2261.528	2233.358	2211.937
7:45	2294.774	2288.251	2006.233	1889.359	2308.142	2303.487	2294.172	2266.28	2249.907
8:00	2325.94	2322.89	2040.28	1920.23	2345.282	2336.993	2324.838	2299.474	2286.259
8:15	2370.621	2371.534	2099.076	1970.189	2400.857	2389.888	2377.086	2352.518	2342.512
8:30	2398.012	2401.169	2140.396	2007.306	2437.142	2420.344	2408.794	2385.162	2377.984
8:45	2427.269	2429.596	217.261	2038.443	2468.24	2449.527	2436.273	2415.056	2409.495
9:00	2452.356	2457.249	2208.352	2074.063	2499.239	2478.301	2465.481	2444.879	2441.46
9:15	2490.627	2502.216	2255.25	2117.835	2544.785	2520.463	2509.126	2488.076	2487.573
9:30	2521.597	2540.463	2288.521	2151.365	2584.2	2557.204	2550.518	2526.244	2525.164
9:45	2551.844	2575.42	2321.138	2182.995	2621.057	2593.661	2588.434	2561.901	2560.209
10:00	2588.298	2611.475	2350.499	2213.857	2655.357	2626.772	2622.822	2596.66	2594.748
10:15	2619.03	2650.911	2388.768	2256.956	2699.702	2668.777	2666.828	2638.944	2637.933
10:30	2645.652	2678.506	2411.097	2283.247	2724.45	2695.779	2698.503	2667.695	2667.878
10:45	2668.184	2703.642	2430.173	2307.043	2749.066	2720.254	2725.196	2691.454	2693.37
11:00	2682.564	2718.079	2442.608	2324.405	2763.242	2733.837	2741.958	2709.303	2710.661
11:15	2705.387	2736.648	2461.428	2349.543	2780.964	2750.594	2762.598	2728.487	2728.311
11:30	2715.591	2742.262	2472.007	2365.656	2788.949	2764.653	2778.697	2743.69	2742.778

Same Example in visual – Can you find the mistake?



Example in Numbers only 6 hours of 24 – Can you find the mistake?

4:30	1766.807	1770.041	1735.584	1712.094	1748.954	1760.249	1756.513	1746.813	1751.224
4:45	1782.593	1783.582	1740.005	1713.625	1763.2	1776.202	1772.523	1762.432	1765.907
5:00	1804.619	1804.311	1753.202	1722.105	1782.787	1798.3	1796.214	1783.199	1785.155
5:15	1851.697	1851.983	1775.265	1738.878	1833.121	1848.069	1846.02	1832.959	1832.181
5:30	1891.173	1889.403	1791.779	1749.428	1874.77	1890.169	1887.194	1871.383	1867.261
5:45	1918.68	1914.849	1803.538	1749.229	1901.105	1913.318	1905.974	1891.461	1883.946
6:00	1927.751	1928.128	1797.334	1736.343	1917.293	1927.759	1919.787	1900.453	1889.87
6:15	2001.637	2003.804	1827.463	1753.16	1994.741	2006.415	1996.289	1975.221	1958.406
6:30	2054.95	2058.036	1848.321	1764.349	2050.196	2060.041	2051.025	2028.24	2008.001
6:45	2112.258	2103.88	1872.549	1778.843	2095.131	2102.328	2094.292	2072.529	2050.109
7:00	2160.629	2137.386	1888.932	1790.602	2135.888	2143.732	2138.594	2116.436	2091.379
7:15	2232.516	2211.839	1943.359	1834.518	2220.943	2225.654	2219.614	2192.266	2166.789
7:30	2267.812	2254.537	1978.218	1865.147	2270.142	2268.746	2261.528	2233.358	2211.937
7:45	2294.774	2288.251	2006.233	1889.359	2308.142	2303.487	2294.172	2266.28	2249.907
8:00	2325.94	2322.89	2040.28	1920.23	2345.282	2336.993	2324.838	2299.474	2286.259
8:15	2370.621	2371.534	2099.076	1970.189	2400.857	2389.888	2377.086	2352.518	2342.512
8:30	2398.012	2401.169	2140.396	2007.306	2437.142	2420.344	2408.794	2385.162	2377.984
8:45	2427.269	2429.596	217.261	2038.443	2468.24	2449.527	2436.273	2415.056	2409.495
9:00	2452.356	2457.249	2208.352	2074.063	2499.239	2478.301	2465.481	2444.879	2441.46
9:15	2490.627	2502.216	2255.25	2117.835	2544.785	2520.463	2509.126	2488.076	2487.573
9:30	2521.597	2540.463	2288.521	2151.365	2584.2	2557.204	2550.518	2526.244	2525.164
9:45	2551.844	2575.42	2321.138	2182.995	2621.057	2593.661	2588.434	2561.901	2560.209
10:00	2588.298	2611.475	2350.499	2213.857	2655.357	2626.772	2622.822	2596.66	2594.748
10:15	2619.03	2650.911	2388.768	2256.956	2699.702	2668.777	2666.828	2638.944	2637.933
10:30	2645.652	2678.506	2411.097	2283.247	2724.45	2695.779	2698.503	2667.695	2667.878
10:45	2668.184	2703.642	2430.173	2307.043	2749.066	2720.254	2725.196	2691.454	2693.37
11:00	2682.564	2718.079	2442.608	2324.405	2763.242	2733.837	2741.958	2709.303	2710.661
11:15	2705.387	2736.648	2461.428	2349.543	2780.964	2750.594	2762.598	2728.487	2728.311
11:30	2715.591	2742.262	2472.007	2365.656	2788.949	2764.653	2778.697	2743.69	2742.778

Summary

- Data must be timely
- Visual data is superior to number data
- PI is the continuum for the past, current, and the future
- If your forecast is not accurate reliability suffers
- You cannot evaluate or trust forecast if not compared to actual
- Operators must trust the forecast
- Forecast must be based on visualization and not based on numbers
- Situational awareness is reliability

Thank you

777 Davis St., San Leandro, CA 94577