California ISO
Shaping a Renewed Future

Forecasting and Scheduling Renewable Generation for Operating a Reliable Grid

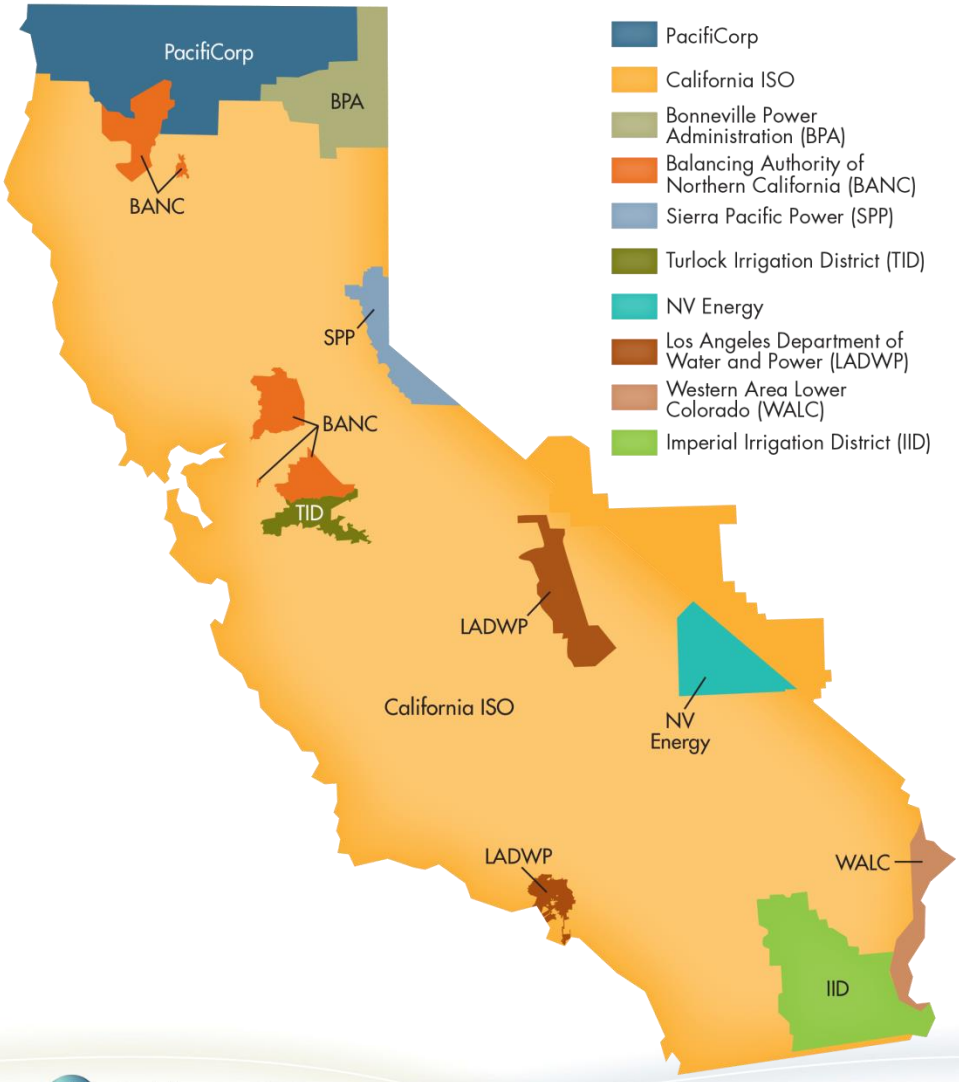
FESC Workshop
Florida
February 3, 2015

Hani Alarian
Director, Power System Technology - Operations

Agenda

- Getting to know the California ISO
- Knowing the plan for renewable
- Operations challenges with renewables
- Understanding the new paradigm
- Considerations
- Summary

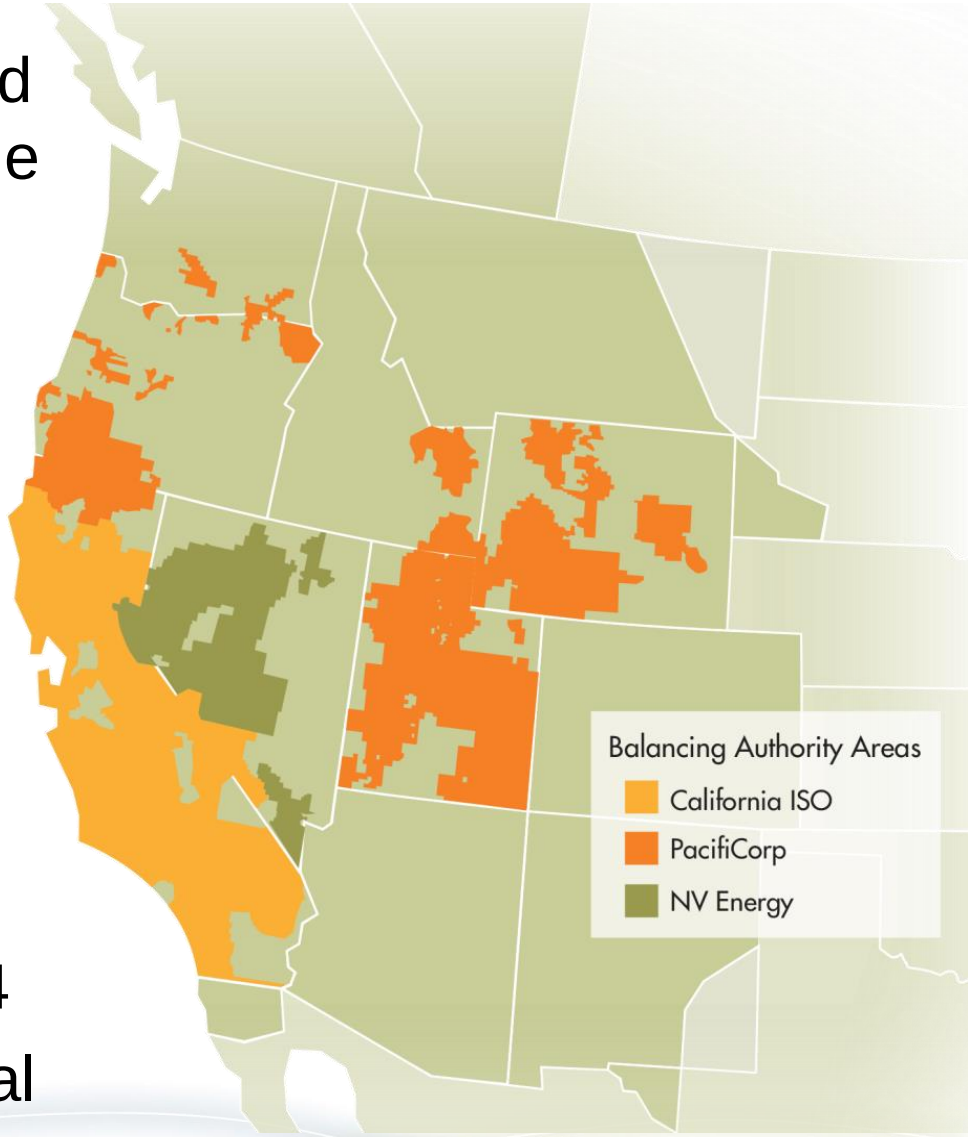
California ISO by the numbers



- **65,225** MW of power plant capacity (net dependable capacity)
- **50,270** MW record peak demand (July 24, 2006)
- **27,076** market transactions per day
- **26,024** circuit-miles of transmission lines
- **30 million** people served
- **244 million** megawatt-hours of electricity delivered annually

Energy Imbalance Market

- extends real-time market and 5-minute dispatch outside the ISO
- builds on existing market platform
- easily scalable, offering low-cost, low risk option to new entities
- provides integration, economic, and reliability benefits.
- PacifiCorp go-live Nov. 2014
- NVE seeking PUCN approval

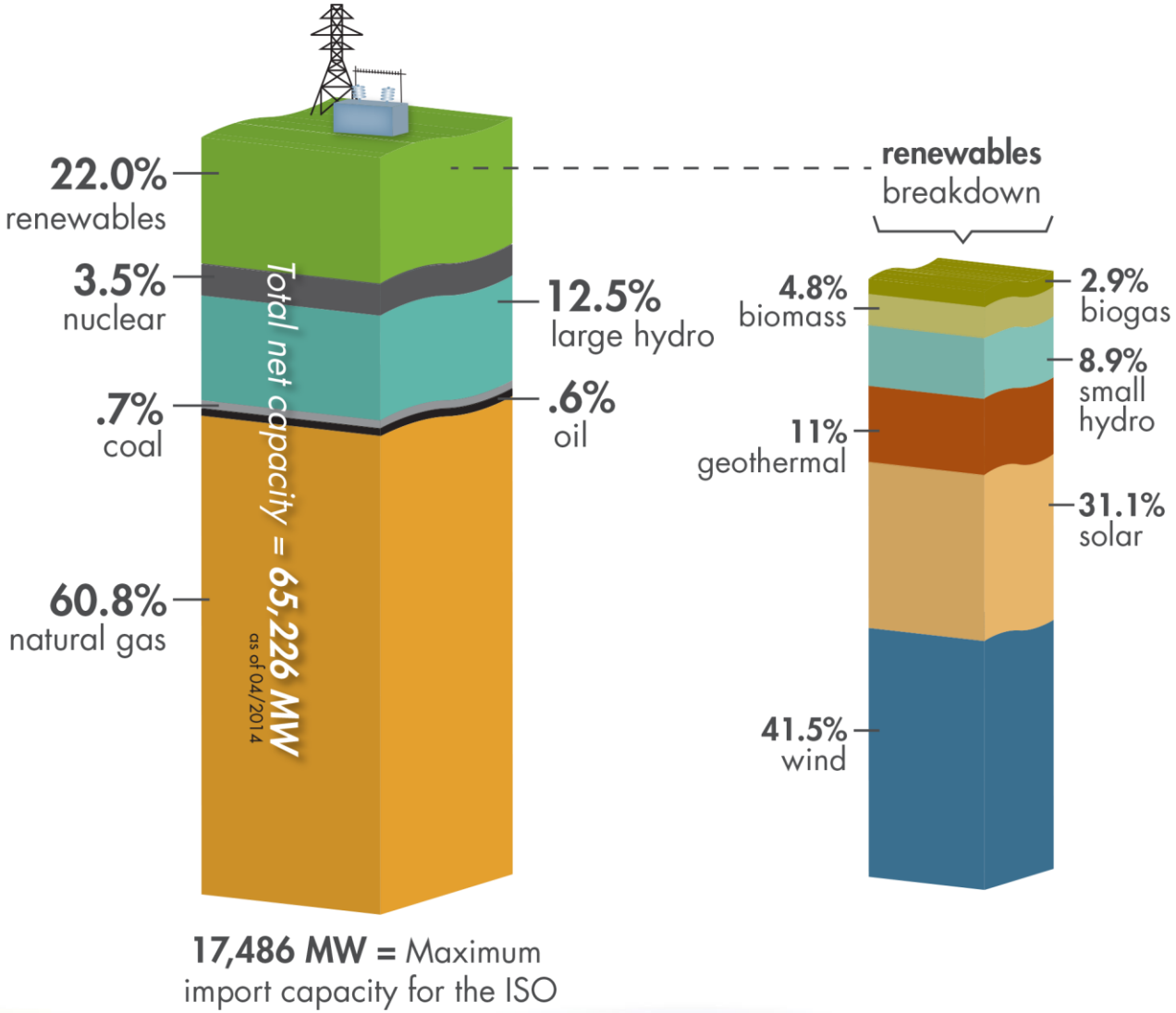


California ISO Building

California ISO Building

Folsom, CA – Control Room

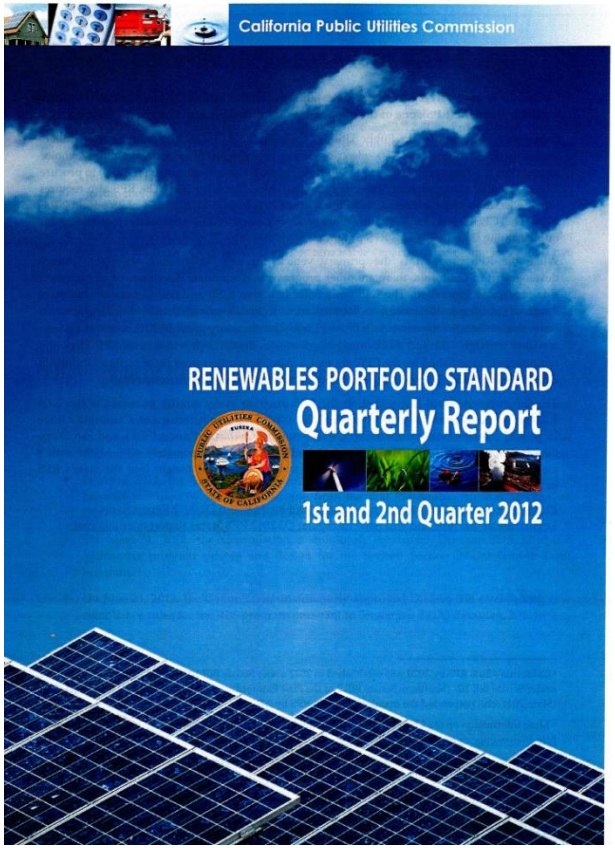
Generating resource mix



California's growing wind/solar resources

Net Dependable Capacity
Solar (all): 5,560 MW
Wind: 5,900 MW

California has the highest renewables portfolio standard in the continental United States



+5% +8%

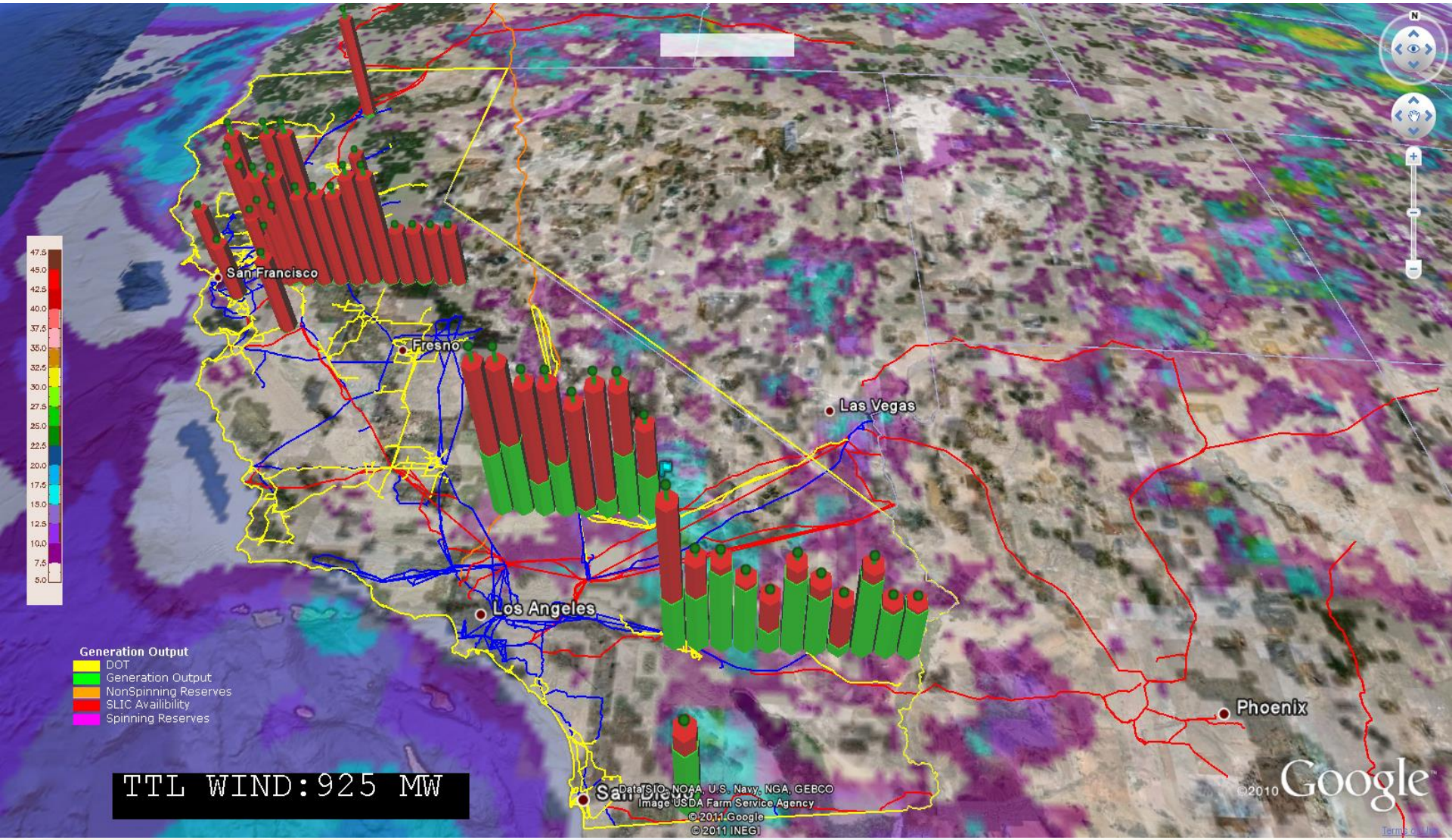
20%	25%	33%	50%
2011-2013	2014-2016	2017-2020	2020-2030

"In 2015, Over 6,500 MW of Solar peak and over 7,000 MW of Wind Peak.

Variable renewable generation

- what was “load following” is now “energy imbalance following”
- regulation is leaned on to meet energy imbalance
- forecast uncertainty for both load and generation
- system flexibility with wider operating range and higher ramp rate is needed
- increase in the occurrence and magnitude of overgeneration and undergeneration
- more unit cycling
- overgeneration during the day

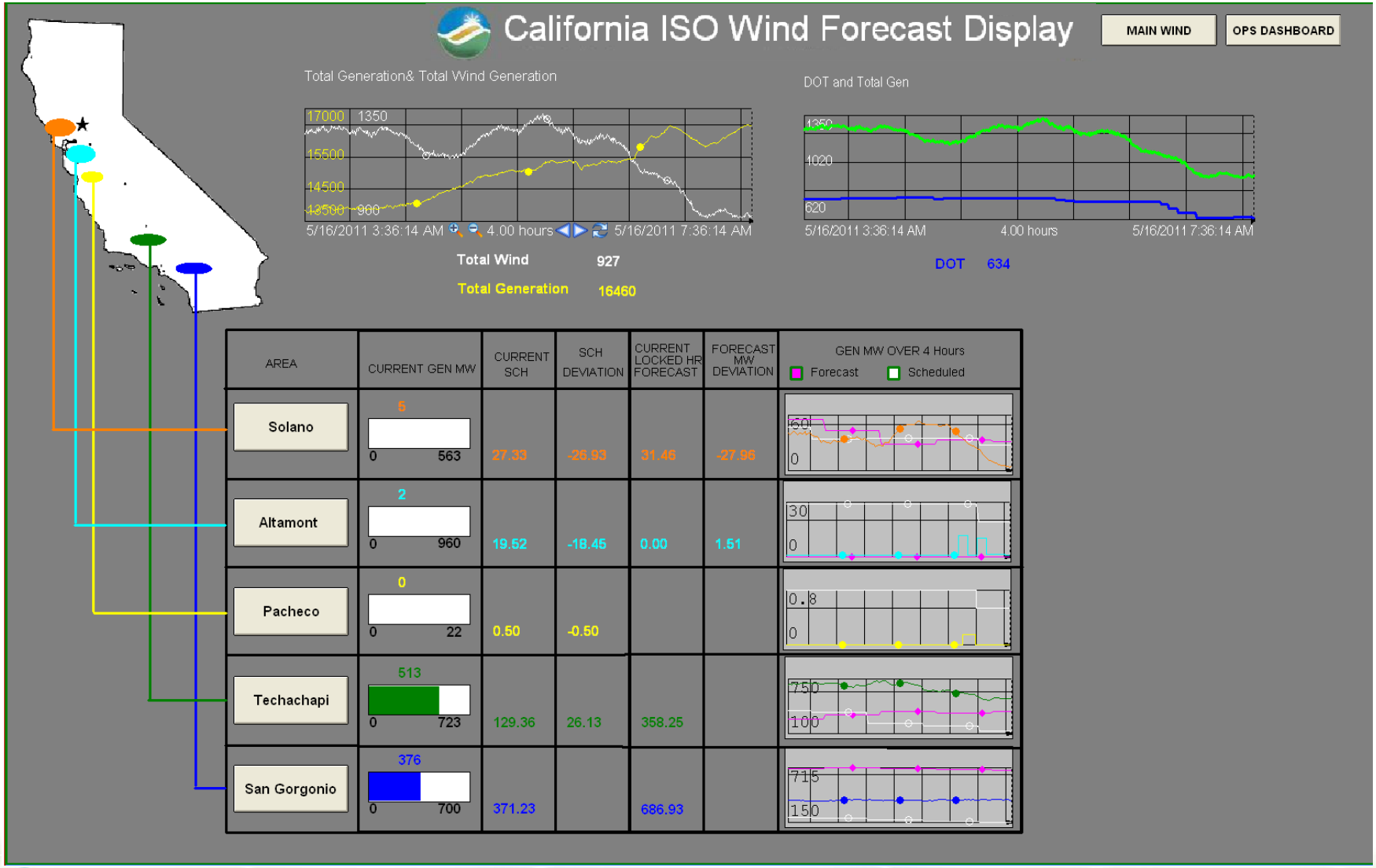
Wind Summary Visualization



Key Elements of Future Integration of Renewables

- interconnection and transmission upgrades inside the balancing authority
- well-functioning market providing the right granularity range of scheduling periods
- improve system operational tools through improved forecasting
- increase system flexibility through demand response and storage options
- define policies and capabilities dealing with system issues such as transient stability, voltage collapse, and reactive power support

Wind forecast and generation summary

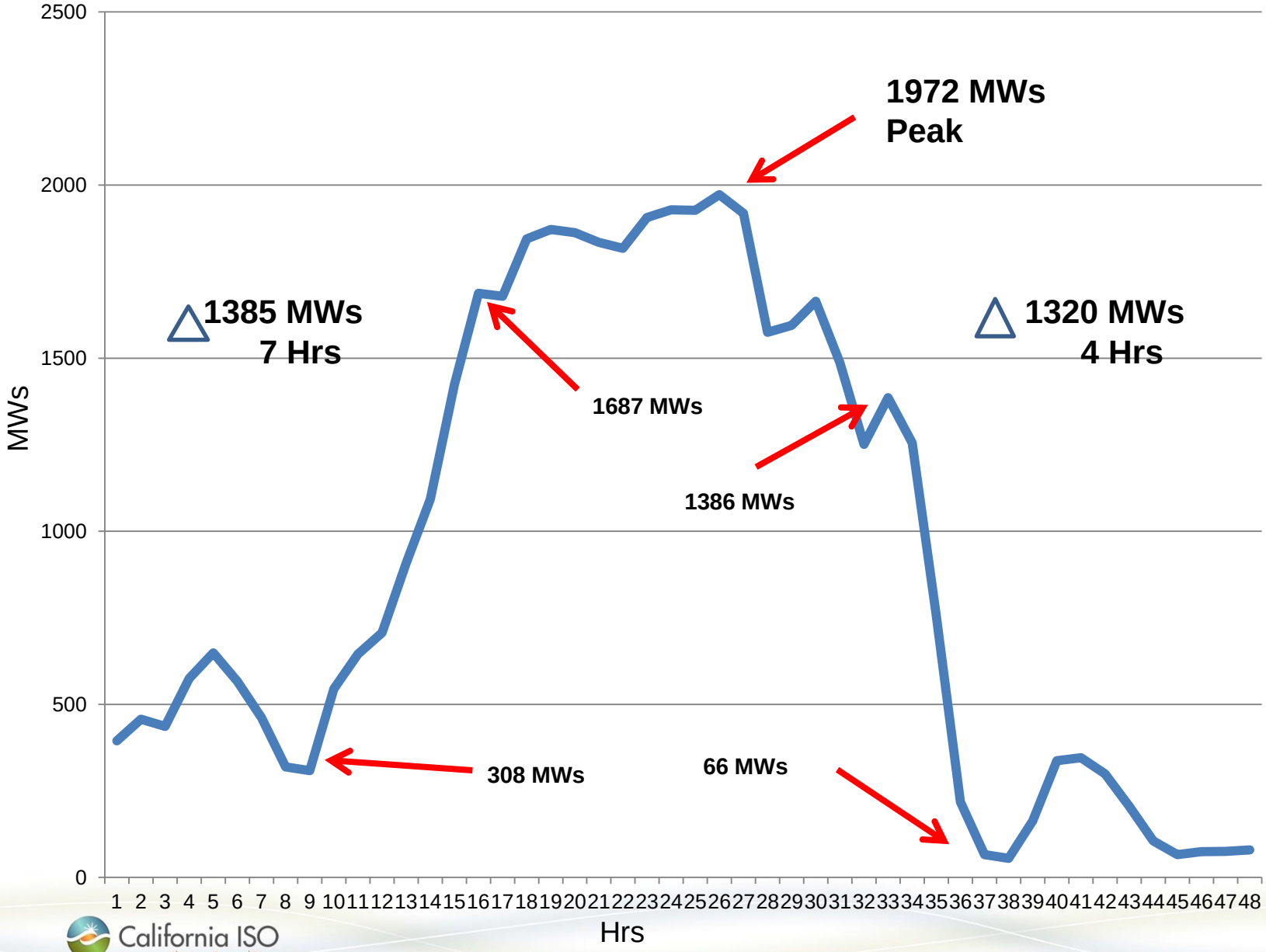


Wind Generation and System Reliability

Modern wind turbines can now contribute to the grid reliability and efficiency

- Voltage/Var control and regulation of power factor
- Fault ride-through low and high voltages or low and high frequency ranges
- Real power control, ramping, and curtailment using unit set-point control on wind turbines with blade pitch-control
- Primary frequency regulation using unit set-point control (active-stall, pitch-control)
- Inertia response through special control mechanism
- Short-circuit duty control to limit magnitude of fault current

Nov 24-25 2011 Wind Event



Variable Energy Generation Forecast at ISO

- in one year the wind peak went from under 1600 MW to above 3300 MW — and now is 4769 MW
- in one year solar peak went from around 500 MW to almost 1000 MW — and now is 4903 MW
- photo voltaic (PV) rooftops have grown at similar pace but no telemetry or solid numbers that are affecting the load (estimate 2,300 MW)
- the growth is not linear
- more than 1200 MW drop caused by wind

Variables/Drivers for Renewables

- wind speed
- wind direction
- humidity
- sun irradiance minutes
- cloud coverage
- turbine type and characteristics/ efficiency
- MW capacity
- cut-off speed
- pressure gradient

Other Variables/Drivers for Renewables affecting the system

- LMP prices
- adjacent LMP prices
- dynamic scheduling
- pseudo ties
- location
- outages
- new turbines

Detailed information needed for renewables

- geographic center of the wind power plant such as latitude, longitude, and height
- metered power output of the wind power plant at 5-min intervals
- number of wind turbines available to generate now and type
- number of wind turbines expected to be available tomorrow and type
- curtailment instructions historical data
- wind speed and direction actual and forecasted at each full turbine-level data
- off-site meteorological data such as temperature, wind speed, wind direction, humidity, and air pressure. This constitutes the ultimate level of granularity that could be considered.

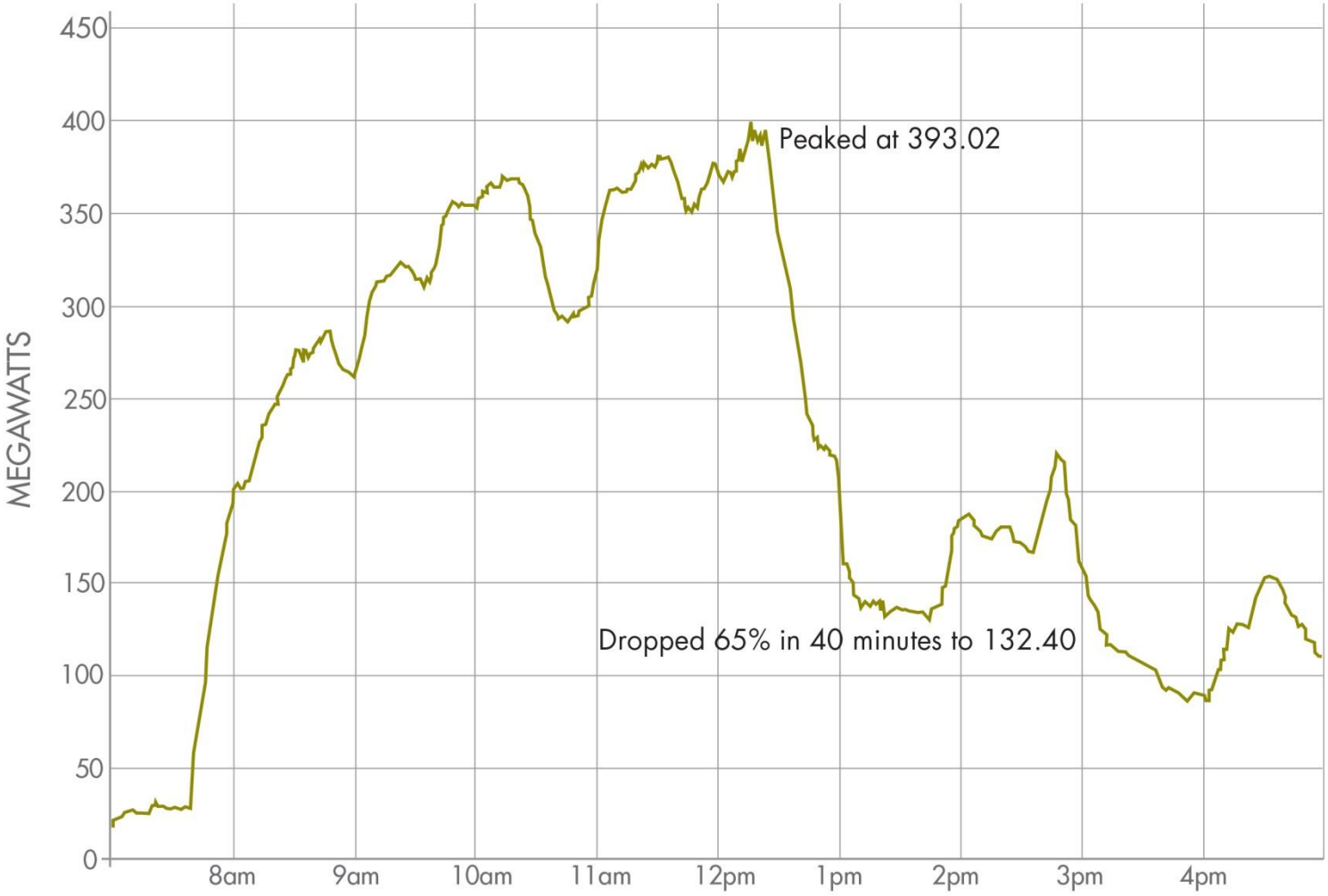
Forecast methods for renewables and their limitations

- Persistency – does not predict the turns
- Autoregressive – not as accurate
- Weather sensitive – weather forecast accuracy
- Blend/Ramp – good to blend between methods
- Forecast the confidence band

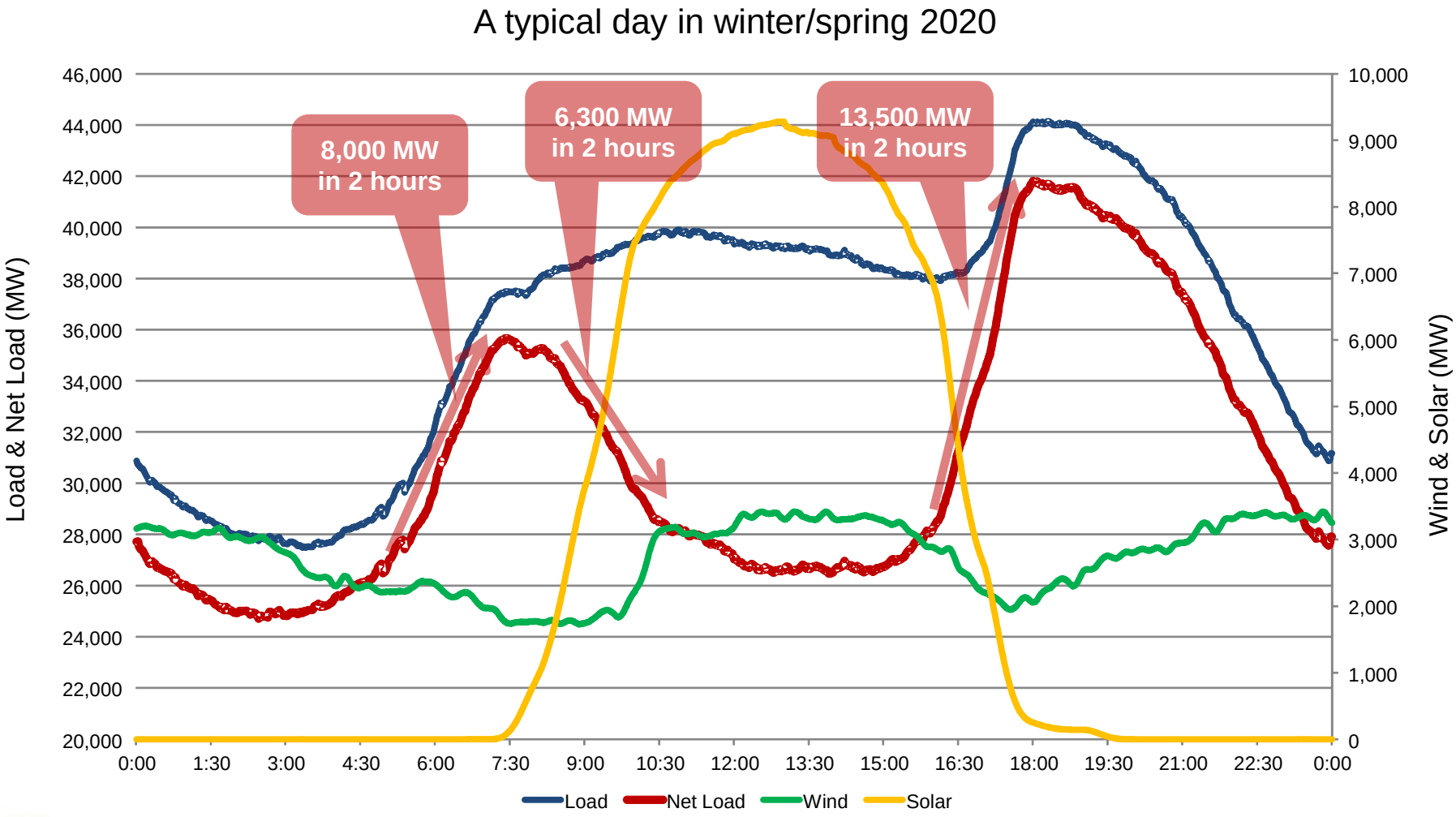
Future Challenges

- Reliability Requirements Forecast
  - load
  - generation
  - flexramp
  - operating reserve (spin and non-spin)
  - regulation
- Predictive Market – using the prediction of the future imbalance instead of the adaptive rear view mirror
- Advance Application
- Intelligent Agents
- Visualizations — tools, tools and more tools

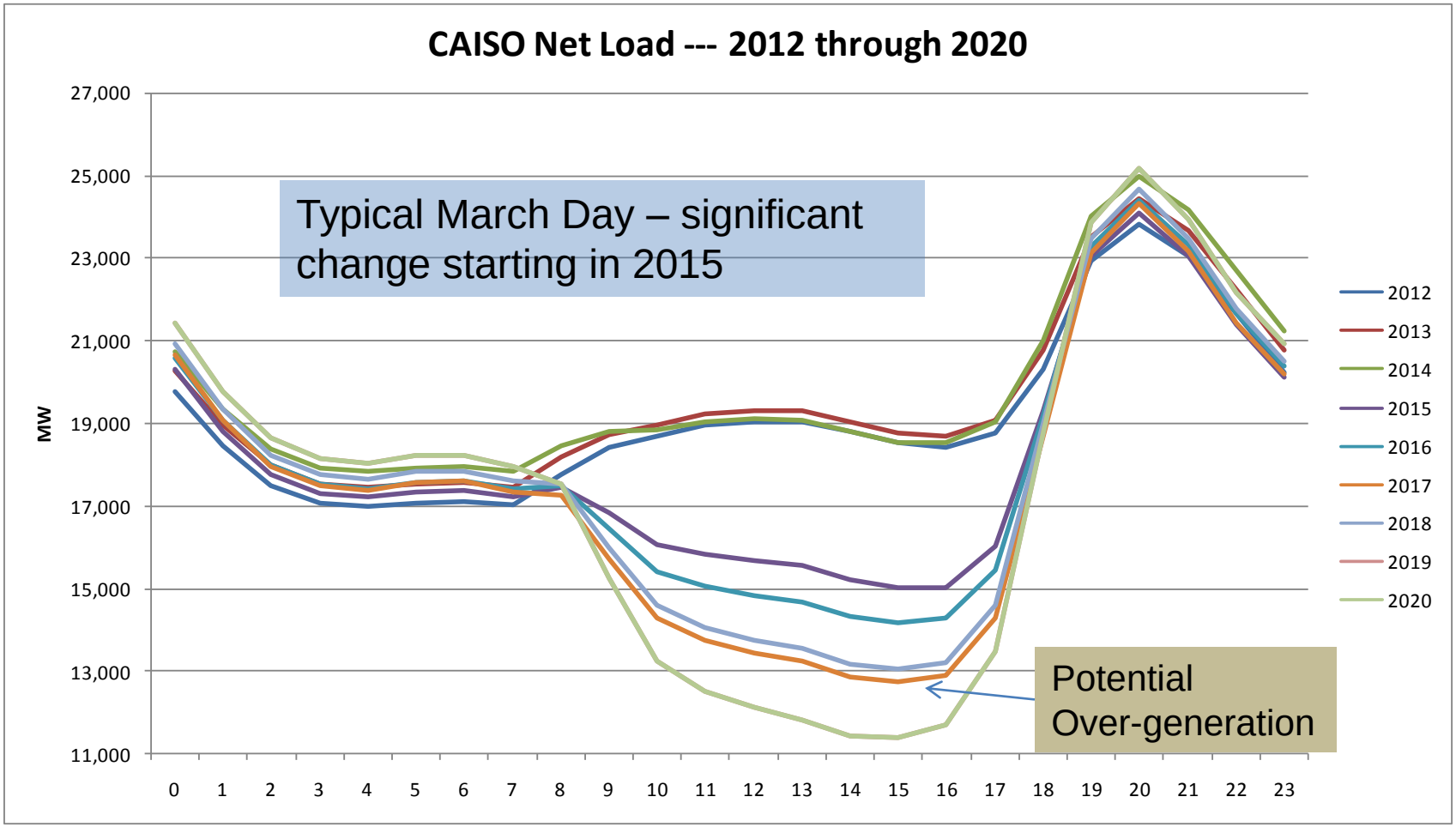
July 3, 2011 Solar Event – 65% production drop



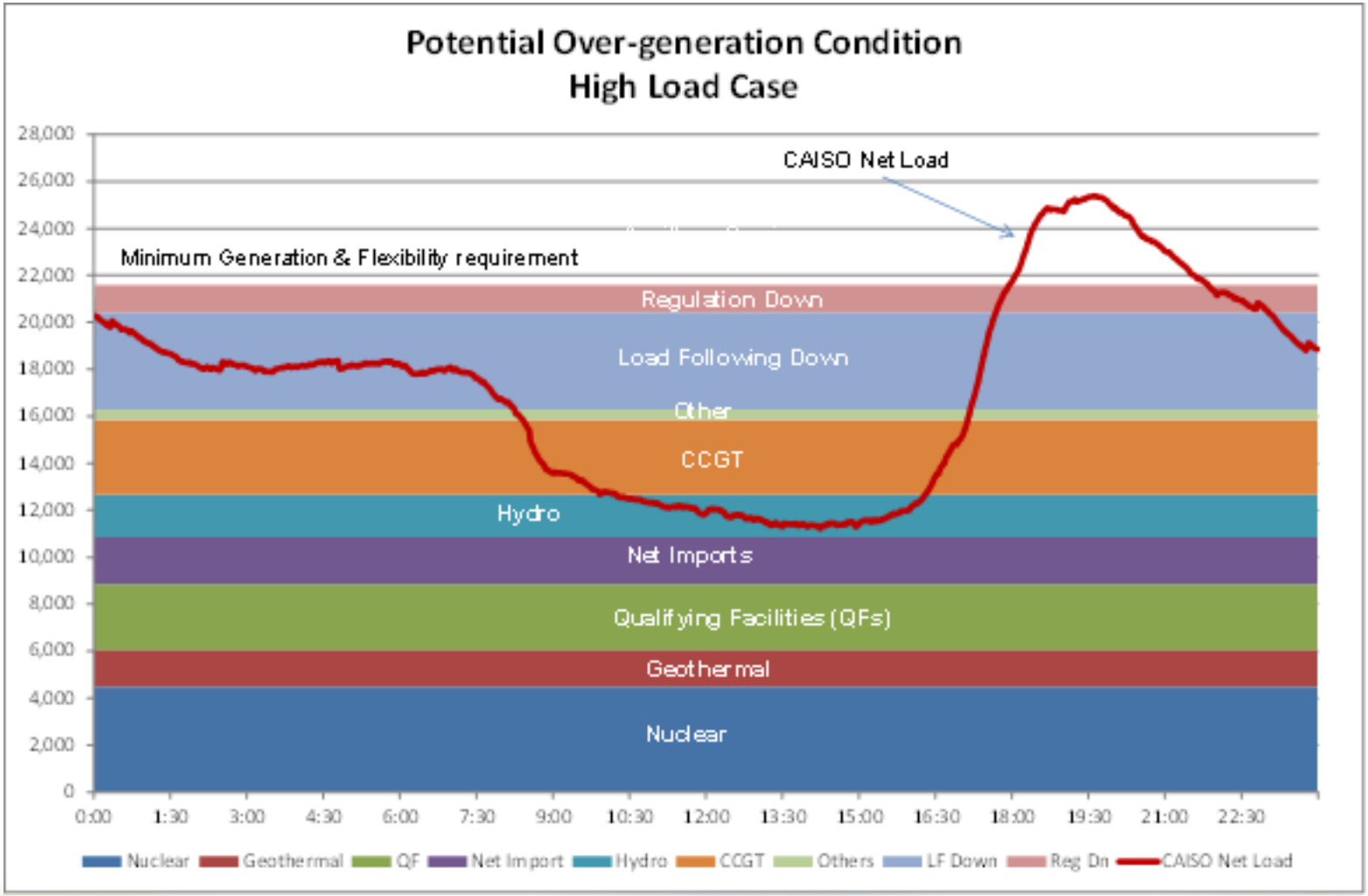
What the future holds for ISO to follow net load



Net load pattern changes significantly starting in 2015



Non-flexible supply creates dispatch issues and potential overgeneration conditions



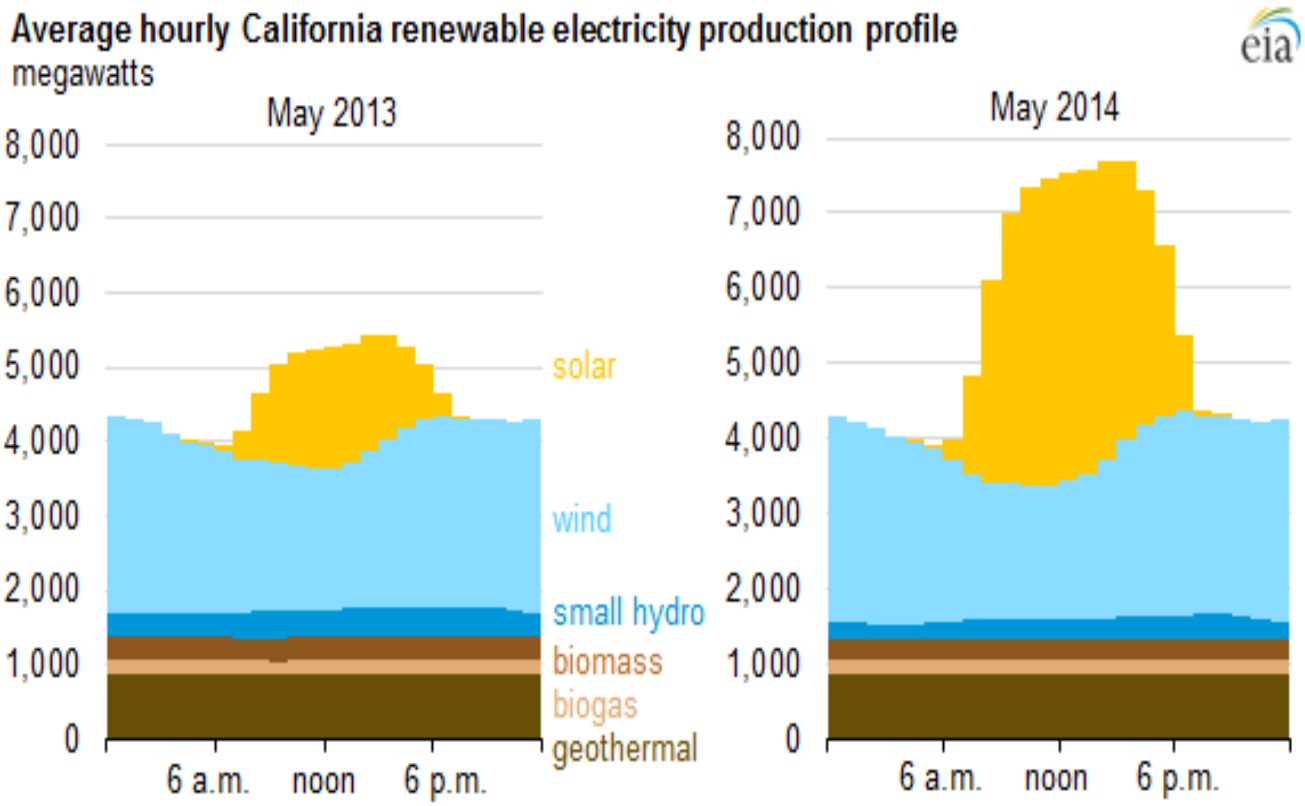
Solar Production Rate of Increase in California

(eia.gov Energy Watch June 2014)

CA 5/2014: Solar production: 4,100 MW (12% of demand)

variability risk managed for grid reliability

TX 03/2014: 10,000+ MW from wind on several days



Changes in the industry on the horizon affecting the grid

- renewable generation – consistently setting new peaks wind unpredictable output (>4,768 MW peak)
  - solar unpredictable output for telemetry generation (4,903 MW peak)
  - photo voltaic (PV) on rooftops without telemetry (2,300 MW estimate)
- NERC CIP/ security requirements
- Accurate power flow at the seems and intra-zones in real-time
- inter-ties limited to hourly changes
- many small generations than few big ones
- demand response and storage devices
- visualization and situational awareness

Challenges for the grid in the horizon

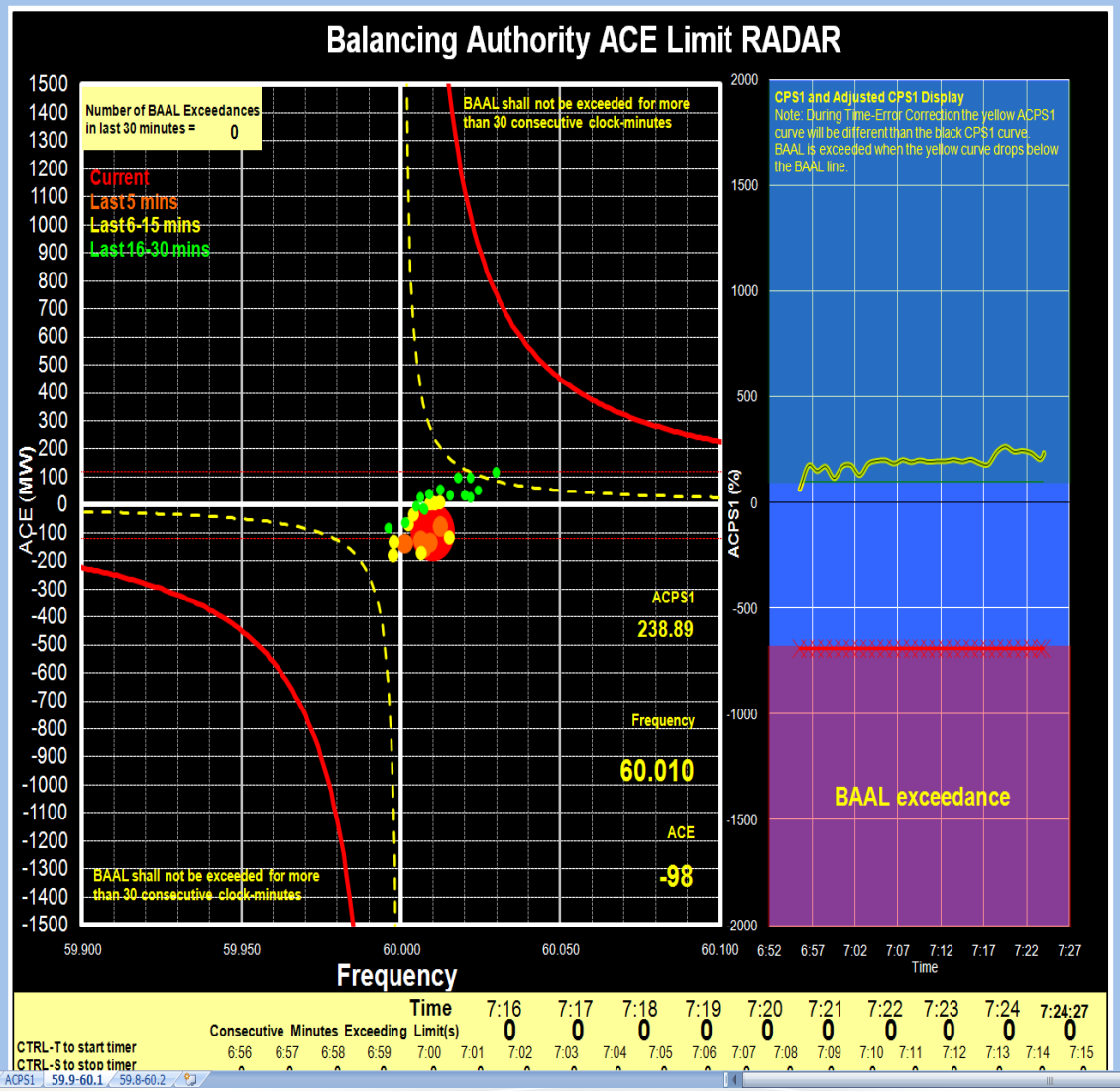
- unpredictable generation in the horizon depending on weather forecast
- more ramp rate is required to meet sudden changes in weather
- true actual load is deformed by PV roof tops
- need to know accurate and immediate power flow as it is becoming more dynamic
- implemented inter-ties schedule 15 minutes market instead of only hourly
- need to know the sequence of event immediately during important events (Sep 8, 2011 outage)
- handle negative generations, storage devices, and demand response

New paradigm to view grid operations

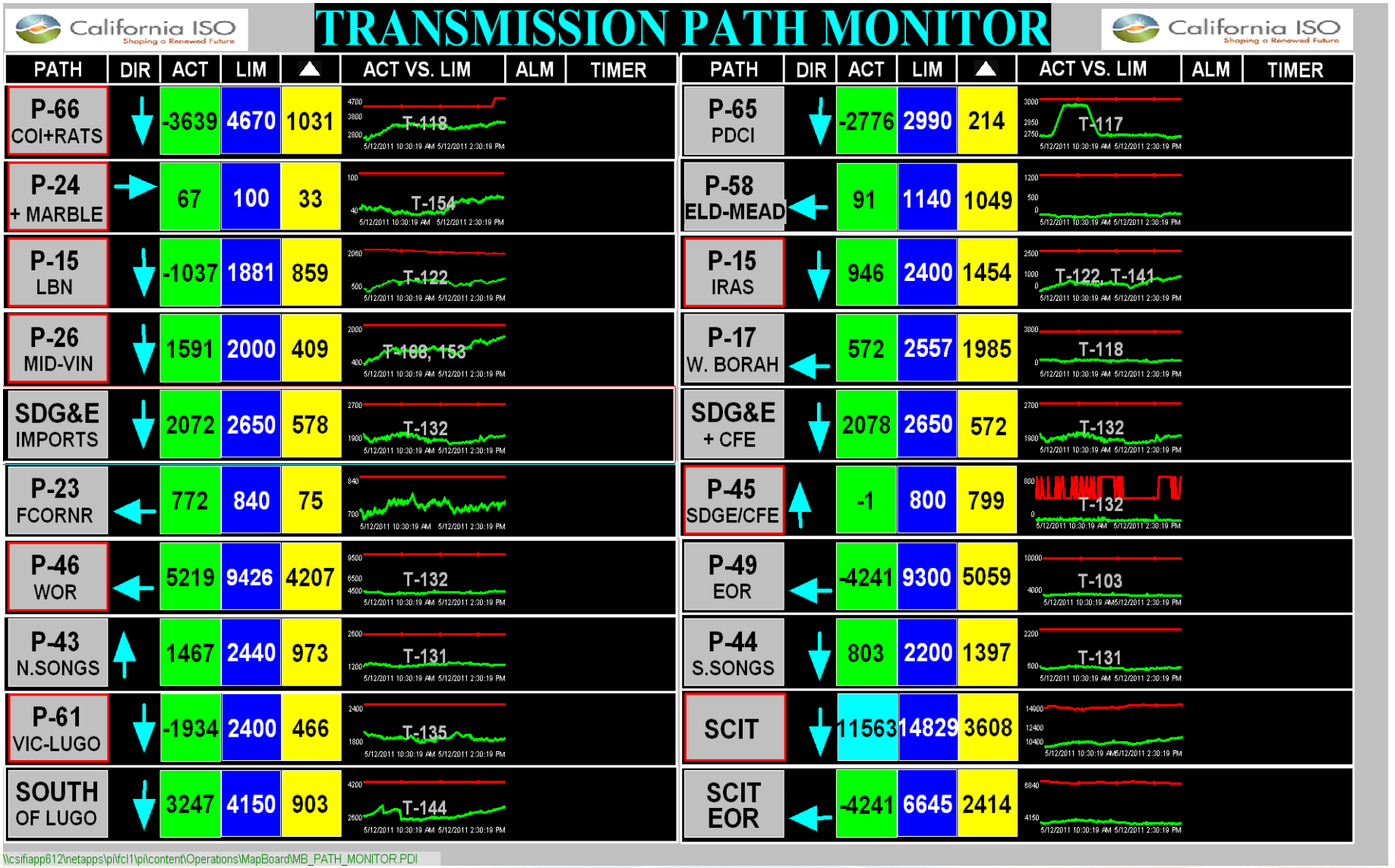
- To view the **Past**: Use a historian with displays – EMS with History
- To view the **Present**: Use the EMS current telemetry and State Estimator
- To view the **Future**: Use the market — the market is the best forecast of the reality to come from current time up to several days in the future
- We are working to provide operators visualization to tie the past, present and the future
- Operators' confidence is increased as we provide the visualizations and accuracy of the forecast

Visualization is the method for operators to see and analyze the past, operate the present, and proactively make decisions by preventing a negative future

Focus on true reliability and not just rules of reliability – reliability balancing authority ACE (area control error) limit radar



Transmission Path Monitoring



Solutions are helped if you think this way

- EMS provides reality and history of the reality
- EMS is the system used to operate reality
- the market is the forecast of the reality to come
- improve the forecast of reality
- provide operators visualization of the future, current, and the past
- operators' confidence is increased as you provide the visualizations and accuracy of the forecast

Solutions the future must provide

- Better forecast beyond load forecast
  - forecast wind generation
  - forecast solar generation
  - forecast PV and use it a variable into the load forecast
  - forecast ancillary services required and not the minimum that NERC requires
  - forecast the amount of ramp rate required
  - forecast system stability
    - voltage stability
    - dynamic stability
    - system inertia
    - handling a DCS

Solutions the future must provide (continue 1)

- improve NERC CIP security to always be way ahead of the requirements
- document it – if it is not documented you don't get credit for doing it
- bigger footprint of the network model with more accurate details
- control area scheduling should be fully designed to handle 15 minutes schedule changes including hourly details for integrated and instantaneous
- simplified interfaces, protocols, and telecommunications to EMS to accommodate tiny generators, electric storage devices, and demand response

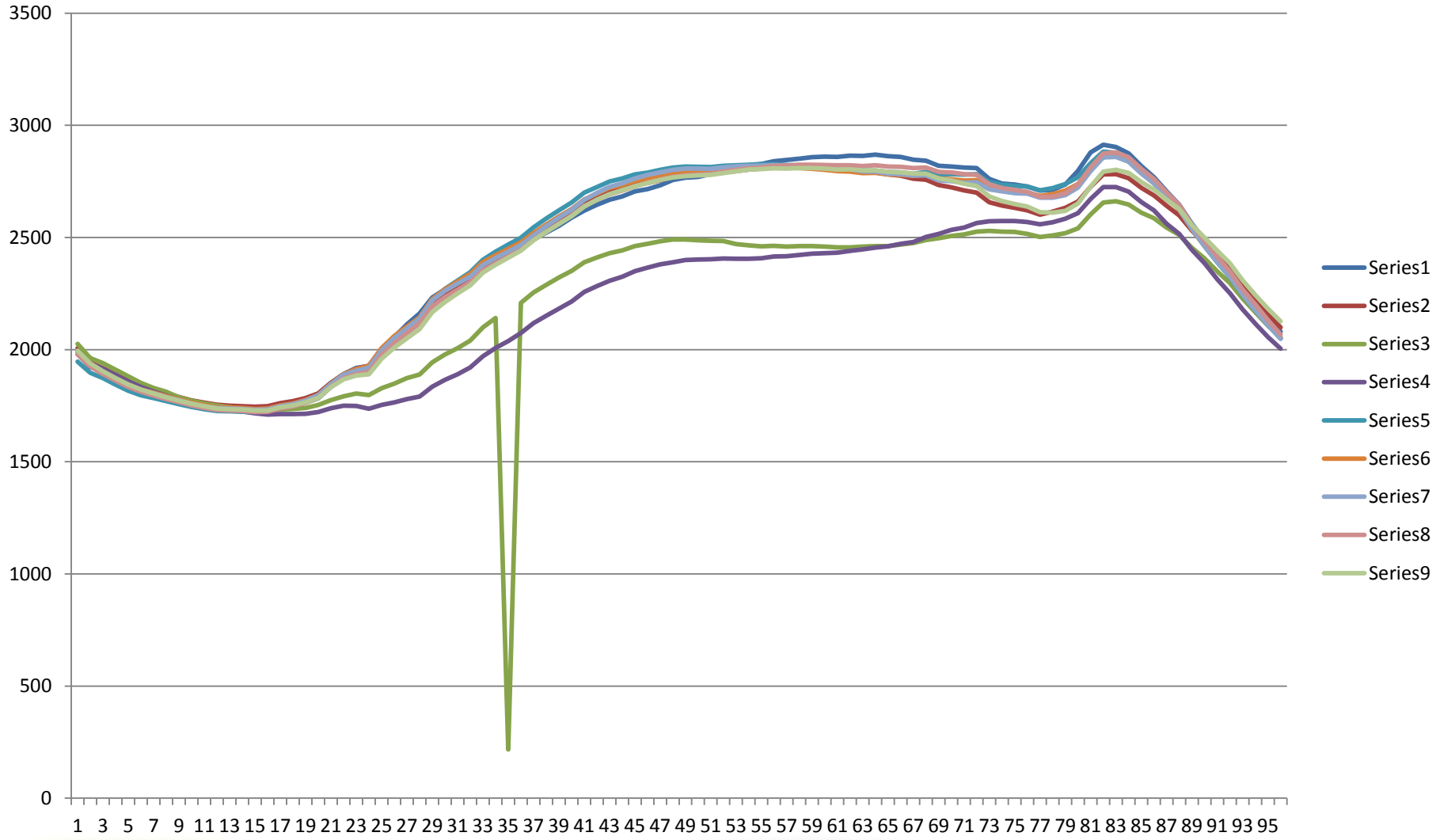
Solutions the future must provide (continue 2)

- allow regulation for demand the same as generations
- separate regulation up and down as demand wants to regulate only up (down for the demand) while renewable resources want to only regulate down
- SE must do topology processor estimation
- telemetry coming to the EMS must accommodate lower cost solutions
- contingency analysis accuracy of the future must be as good as the current situation all the time
- synchrophasor and PMU need to be part of the advanced applications

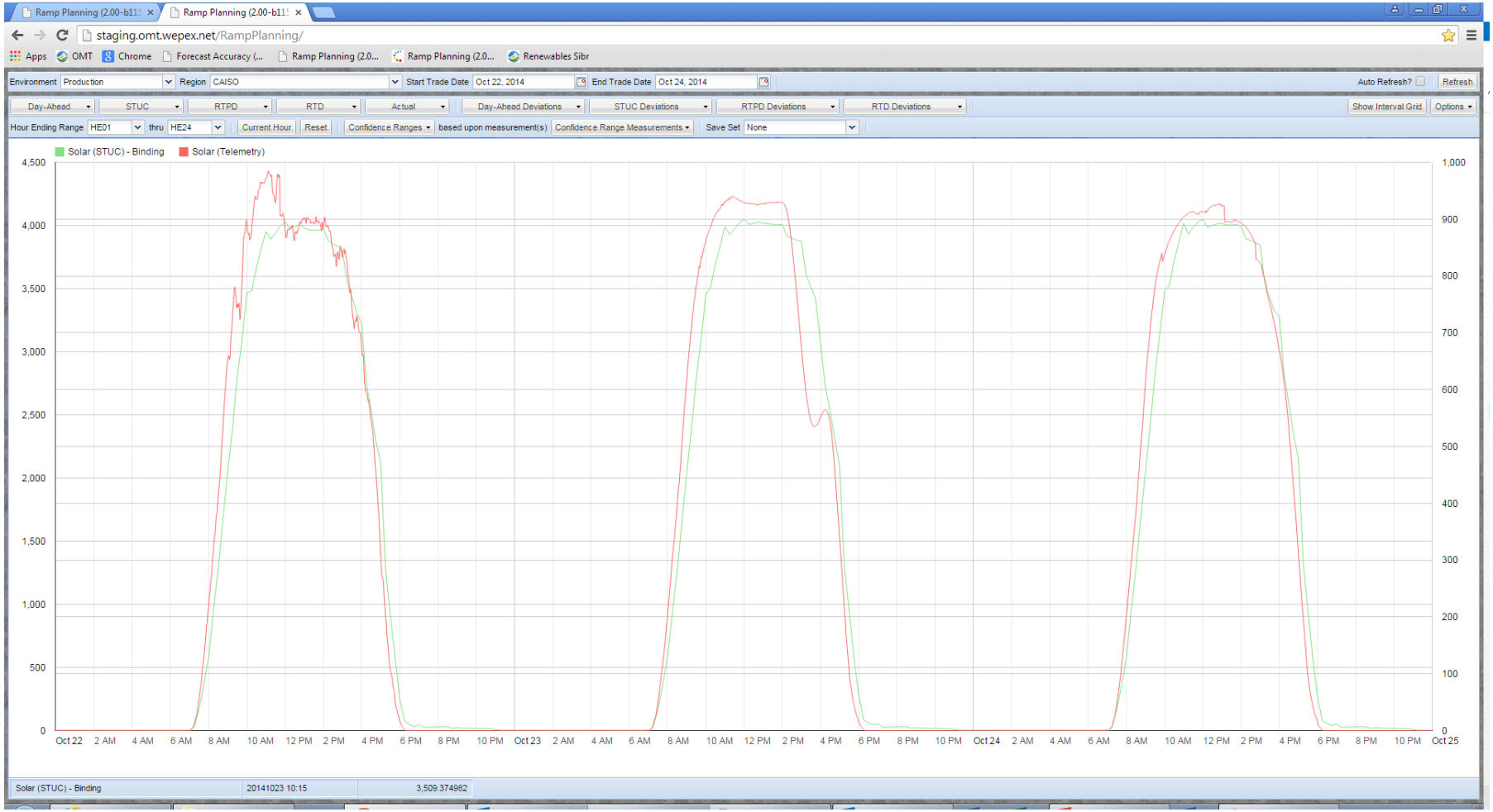
Example in numbers only 6 hours of 24 – can you find the mistake?

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

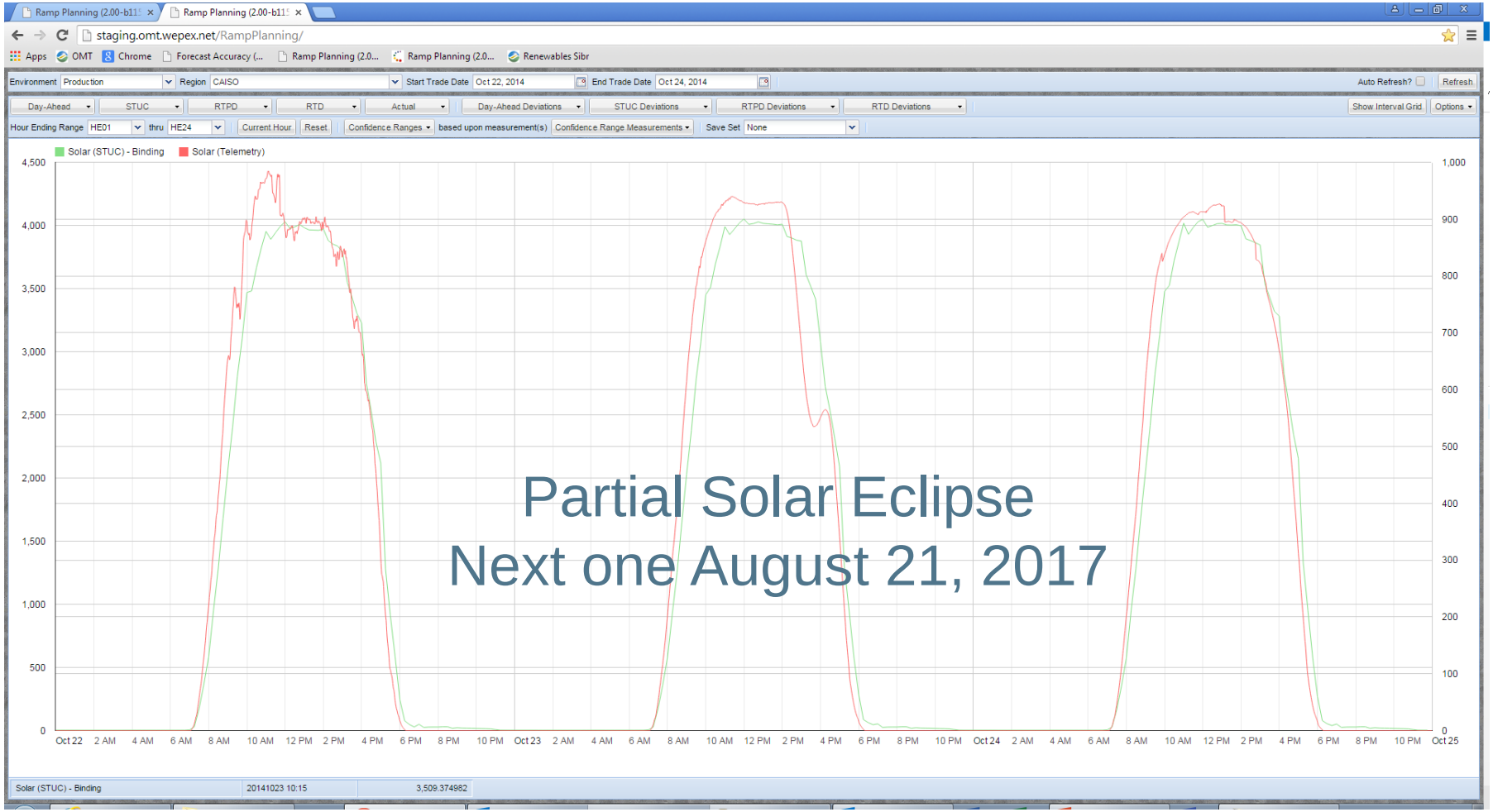
Same example in visual – can you find the mistake?



Happened in April 29, 2014
Here is October 23, 2014 at 14:37 about 2000 MW drop
Next one August 21, 2017



Happened in April 29, 2014
Here is October 23, 2014 at 14:37 about 2000 MW drop



Considerations

- Expect technology to improve
- Accept that the future is not a perfect forecast
- Plan on constantly improving
- Evaluate and adopt new good ideas
- Demand Response will play an important role
- Storage devices should be part of the solution
- Plug-in Electric Vehicles (PEV) is in the future
- Do not assume current solutions or current technologies are the only option

Ramp Planning (2.00-b11 × | Ramp Planning (2.00-b11 ×

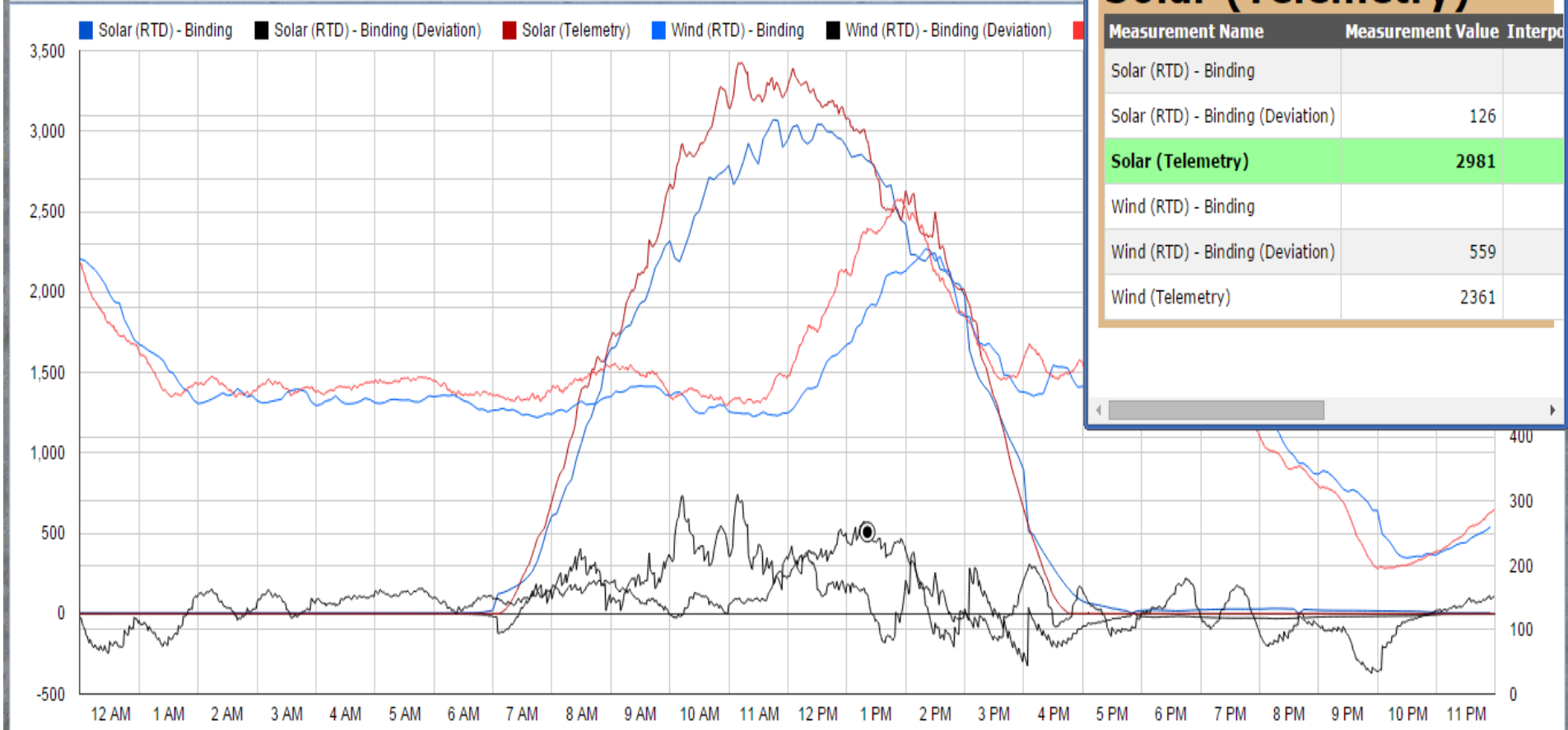
staging.omt.wepex.net/RampPlanning/

Apps | OMT | Chrome | Forecast Accuracy (... | Ramp Planning (2.0... | Ramp Planning (2.0... | Renewables Sibr

Environment: Production | Region: CAISO | Start Trade Date: Dec 31, 2014 | End Trade Date: Dec 31, 2014

Day-Ahead | STUC | RTPD | RTD | Actual | Day-Ahead Deviations | STUC Deviations

Hour Ending Range: HE01 thru HE24 | Current Hour | Reset | Confidence Ranges | based upon measurement(s) | Confidence Range Measurements | Save



Solar (Telemetry) | 20141231 13:19 | 2,981.307129

Untitled - Google Chrome

about:blank

20141231 13:19
Solar (Telemetry)

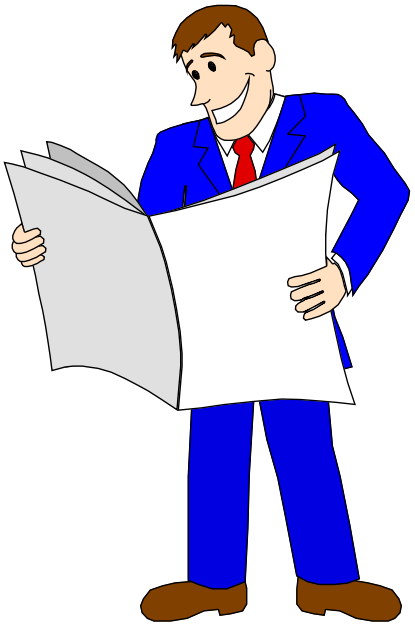
Measurement Name	Measurement Value	Interpo
Solar (RTD) - Binding		
Solar (RTD) - Binding (Deviation)	126	
Solar (Telemetry)	**2981**	
Wind (RTD) - Binding		
Wind (RTD) - Binding (Deviation)	559	
Wind (Telemetry)	2361	

Presenta... | Calenda... | All Mail ... | Inbox - ... | Ramp Pl... | Untitled ... | FESC Fe... | CAISO F... | Microso...

11:02 PM
1/26/2015

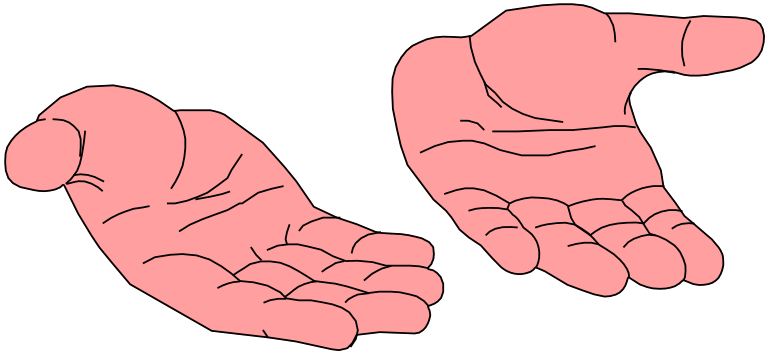
Summary

- data must be timely in real time
- Do not put limitations on yourself based on the past
- systems must be thought of as 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
- system must be nimble and accommodating to many smalls instead of few big ones



Thank you

Your turn



Hani Alarian
Director, PSTO at California ISO
halarian@caiso.com
916-351-2393/work 916-673-7673/cell