Operational Challenges and Potential Opportunities Transitioning to a Low Carbon Grid

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California is aggressively pursuing a low carbon future

- Aggressive renewable energy goals

33% by 2020 → 60% by 2030 → 100% zero-carbon by 2045

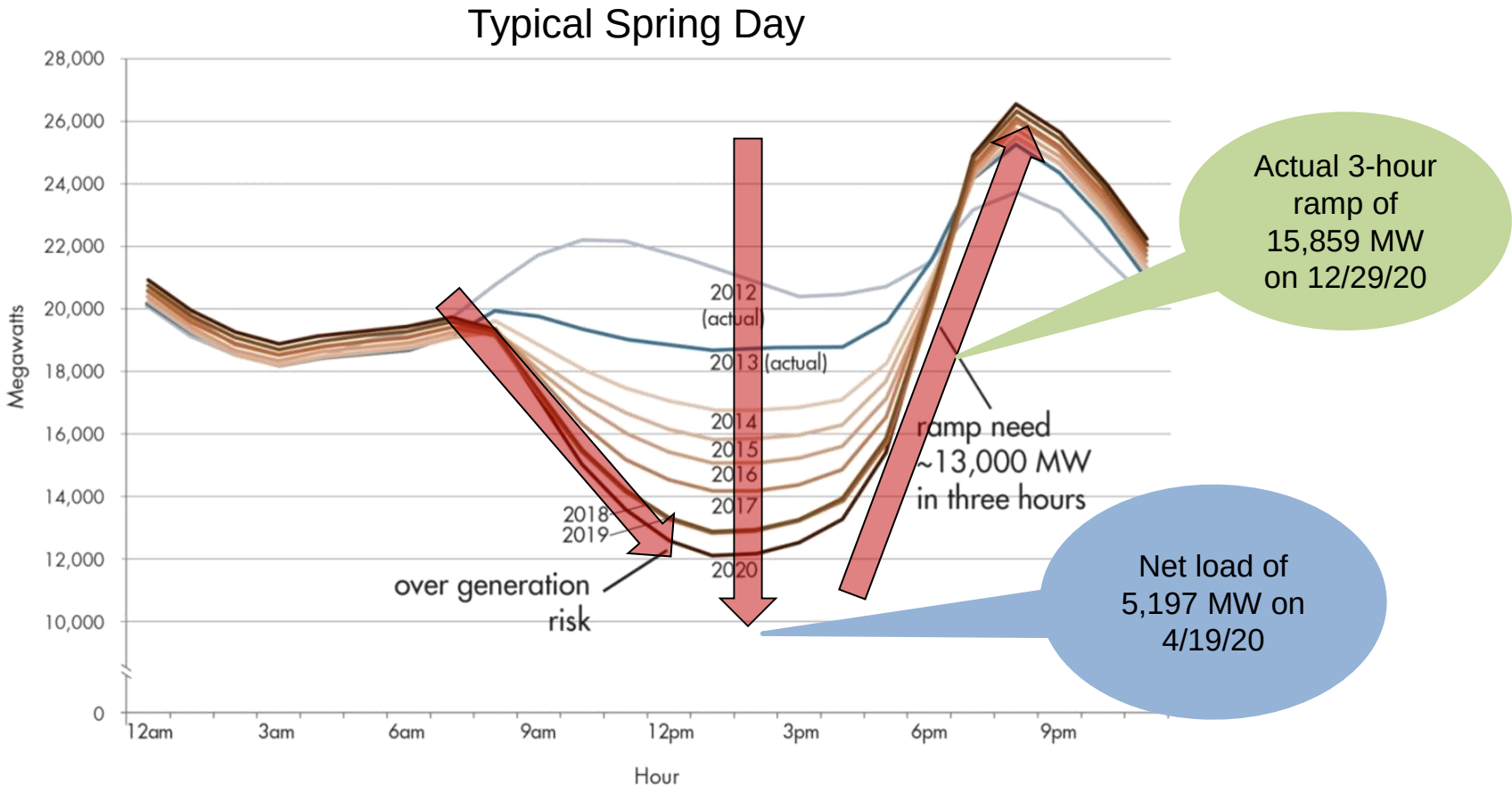
- Deep greenhouse gas (GHG) reduction goals

2020 Target	2030 Target	2050 Target
Reduce GHG emissions to 1990 levels	40% below 1990 levels	80% below 1990 levels

- Robust electric vehicles goal: 1.5 million by 2025
- 12,500 MW of distributed generation by 2022;
- 2 GW of battery storage by 2021

Decarbonization is creating opportunities to develop a high renewables and high DER energy service industry

Actual net load and 3-hour ramps are ahead of original estimates primarily due to underestimating BTM solar



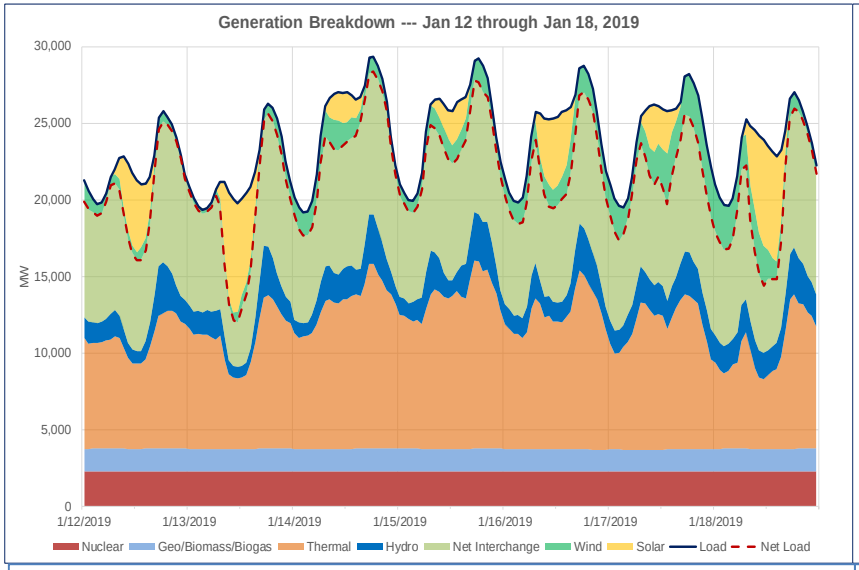
What is the “Duck” telling us?

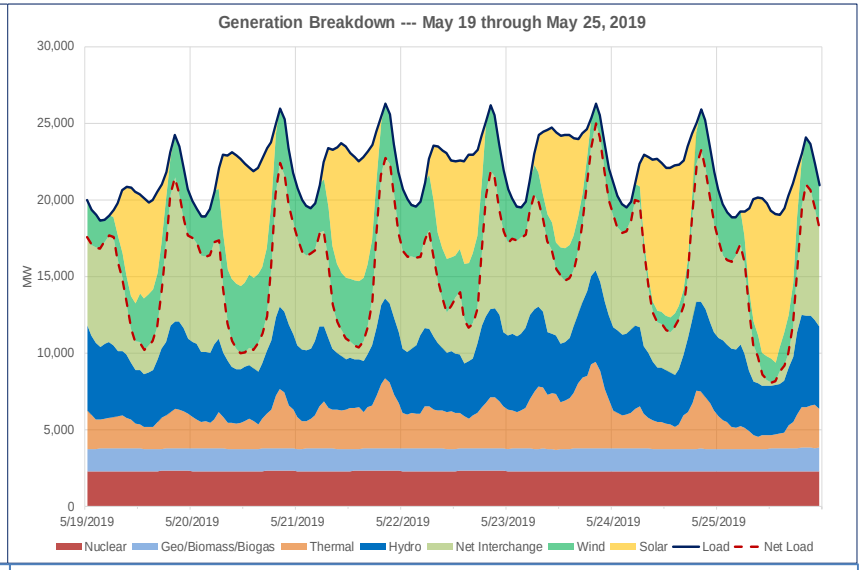
- Integrating renewables is making significant impact on how we meet mid-day demand
- Management of increased oversupply requires economic bids from all resources, including renewables
- Increasing evening ramp requires flexible capacity to balance supply and demand
- Need additional solutions such as storage, TOU rates, regional collaboration, and flexibility of all resources
- Need to maintain sufficient production capacity during periods of low renewable production due to multiple days of cloud cover and low winds
- The volume and speed at which solar resources ramp up is faster than demand is increasing and needs to be managed
- Renewable resources need to follow dispatch instructions similar to other resources

Operational challenges on the grid associated with large scale DERs and loads

- Lack of visibility of distribution system
- Uncontrollable nature of DER output
- PV inverters in large amounts can affect the frequency response and voltage profile of the system
- Forecast assumptions of “net load” seen by operators
- Variability of “combined heat and power” production due to load, natural gas prices, real-time energy prices etc.
- Predicting price responsive loads behavior to real-time prices
- Demand response variability and forecast uncertainty
- Uncertainty/assumptions associated with commercial, Industrial and residential storage; and plug in electric vehicles

Challenges under different operating conditions show the need for VERS including storage to provide grid services





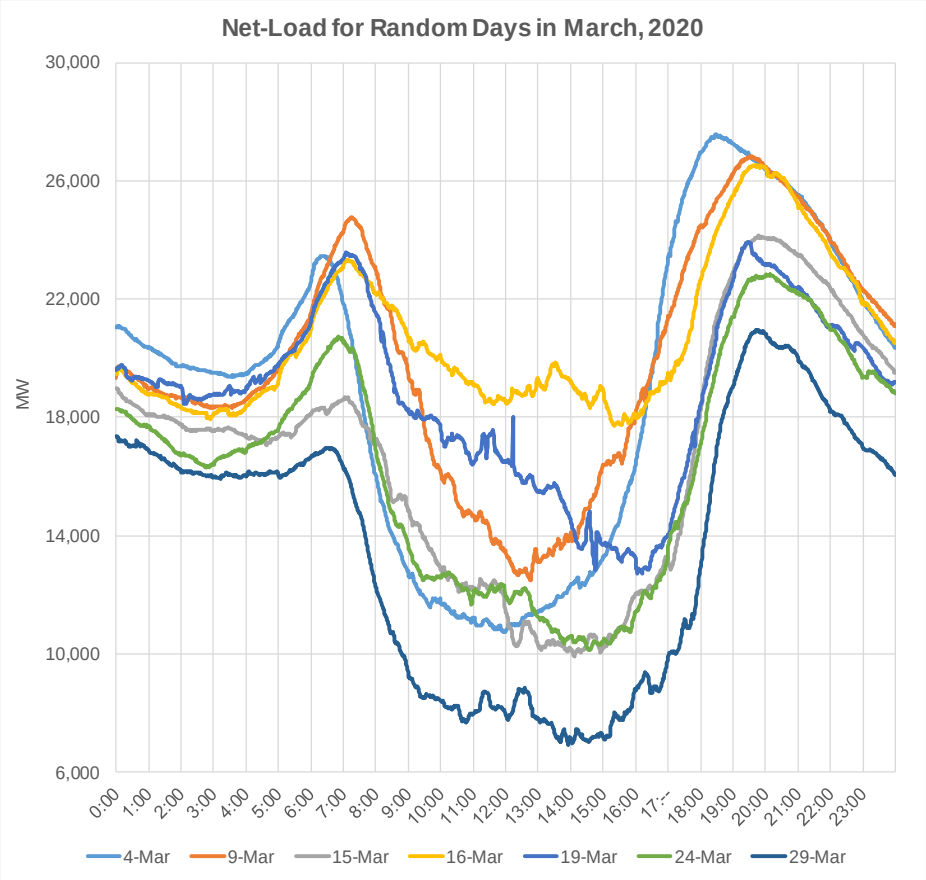
Cloudy/Rainy Days

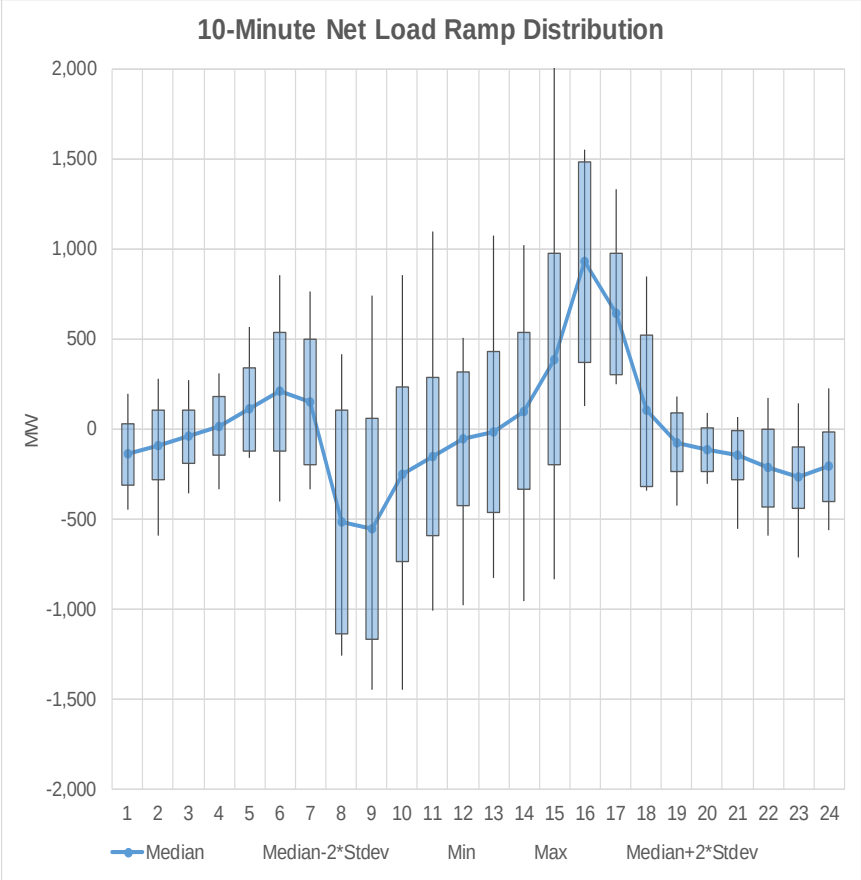
- Maximum net import was 9,820 MW
- Max hourly solar production was 1,970 MW
- Maximum simultaneous wind/solar was about 3,800 MW and occurred during HE11
- Maximum thermal generation was about 12,000 MW
- Need long-tern storage to address extended periods with minimal wind/solar production

During Hydro Spill Conditions

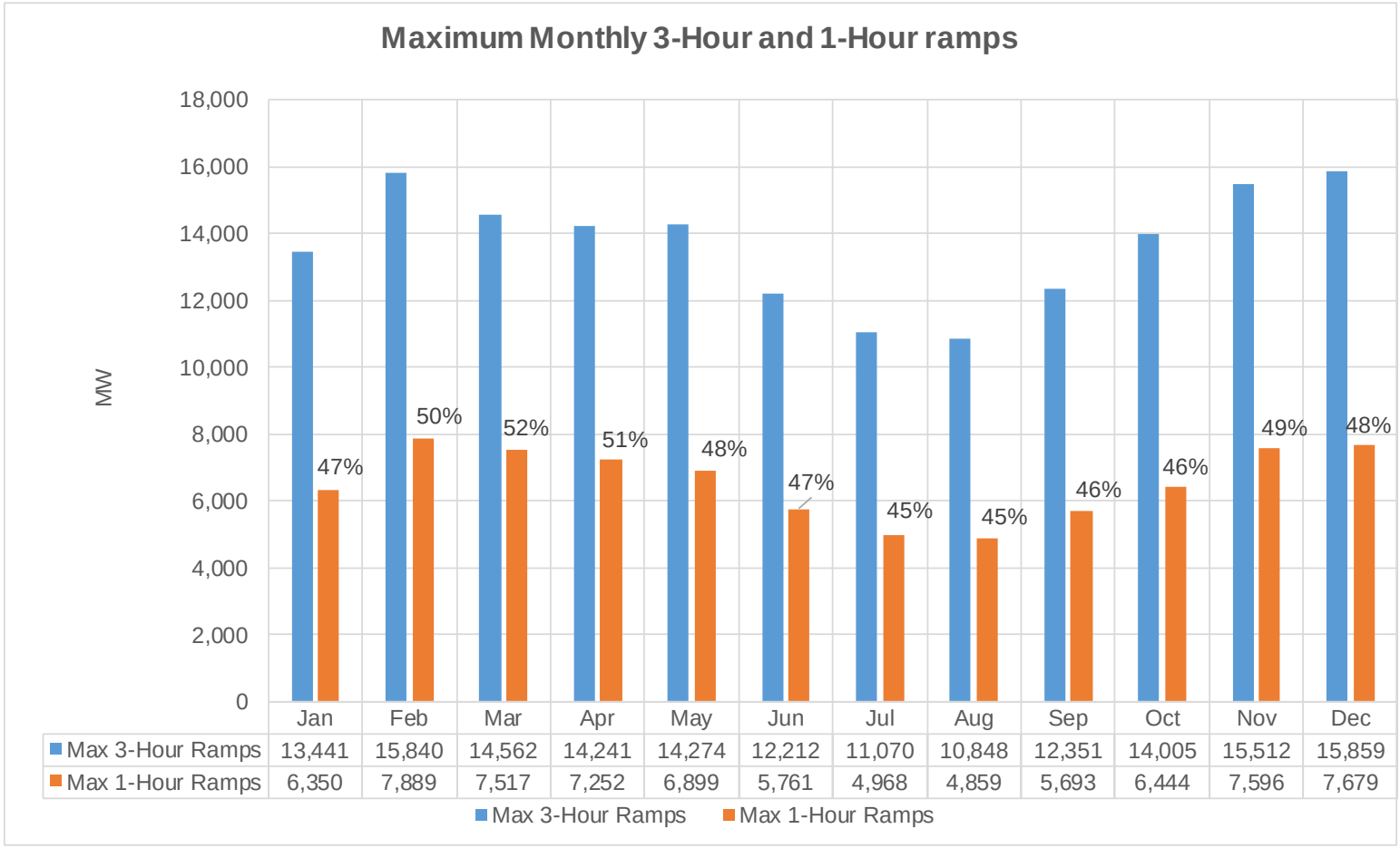
- Rely on gas fleet for most ancillary services
- Typically operate gas fleet at low operating levels to minimize over supply
- Committed gas fleet cannot provide adequate primary frequency response obligation
- Need renewable resources to provide essential grid services
- Need storage devices to provide ancillary services, intra-hour and multiple hour ramping needs

Example of net-load variability for seven random days in March 2020



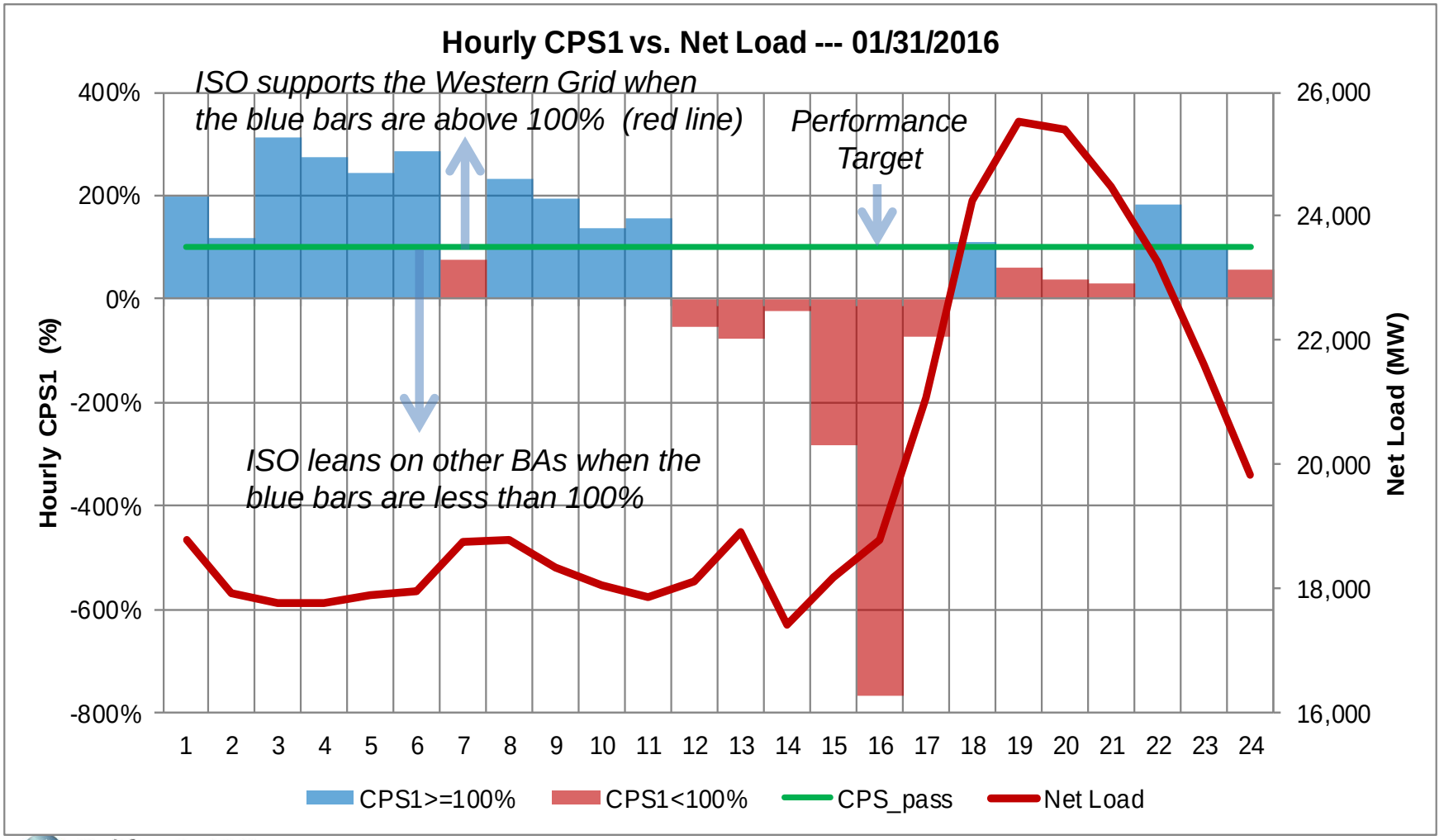


Maximum 3-Hour upward ramps are not evenly distributed each hour which demonstrates the need for faster ramping capability

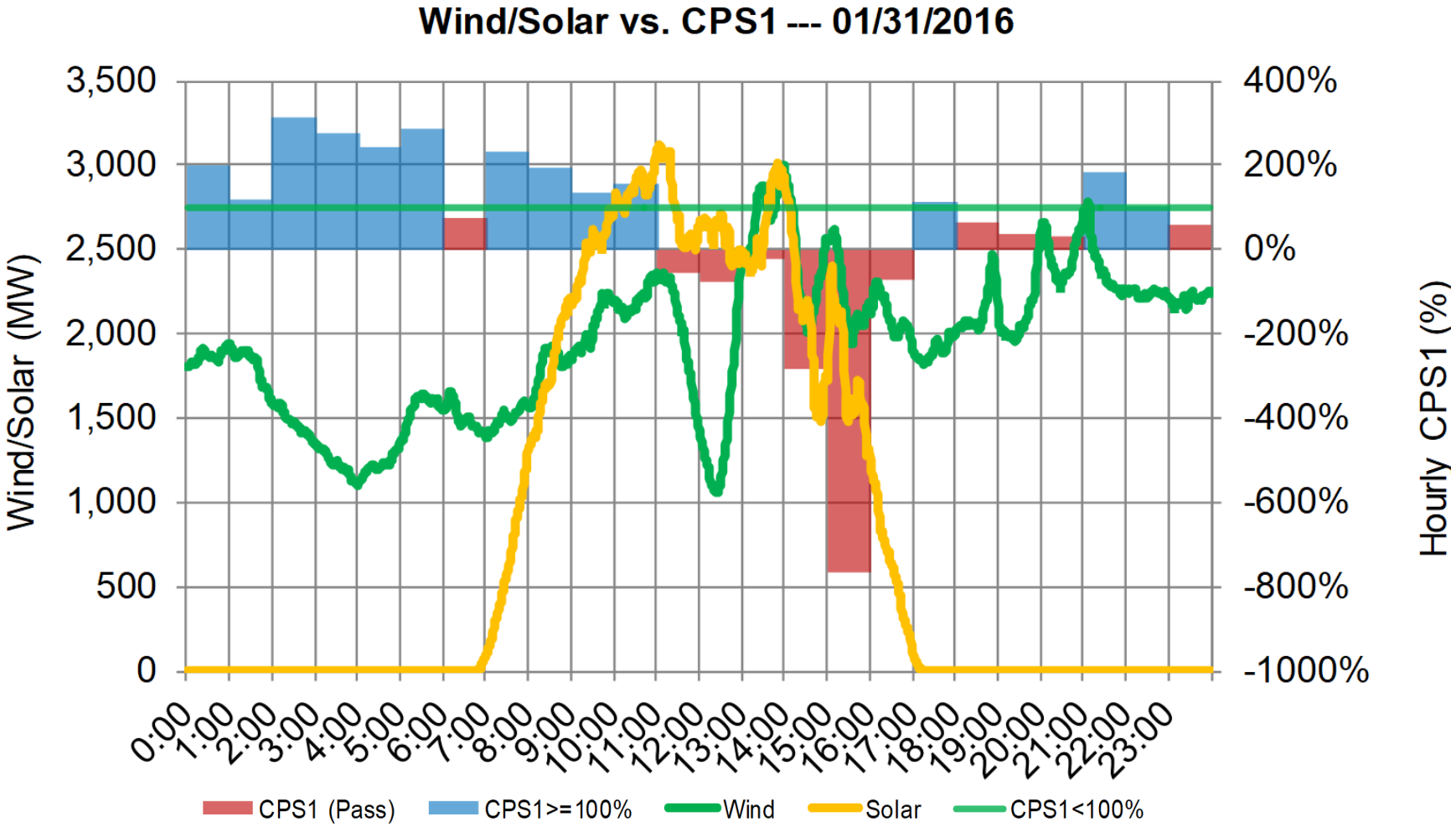


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max 3-Hour Ramps	13,441	15,840	14,562	14,241	14,274	12,212	11,070	10,848	12,351	14,005	15,512	15,859
Max 1-Hour Ramps	6,350	7,889	7,517	7,252	6,899	5,761	4,968	4,859	5,693	6,444	7,596	7,679

ISO tracks real-time supply and demand balance as a measure of operational effectiveness

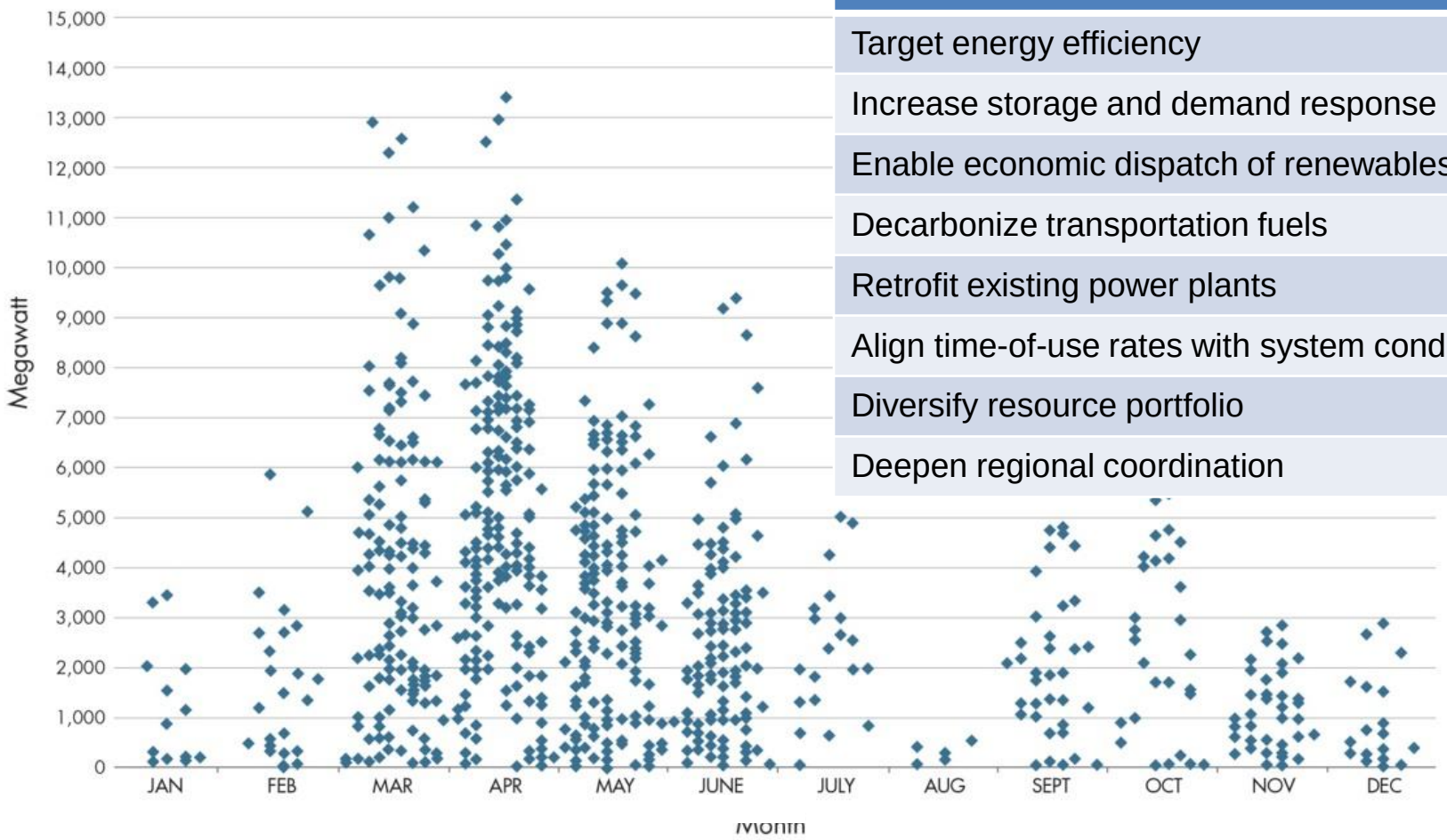


Enhance operational performance during periods of increased supply variability



CPS1 is NERC Control Performance Standard which is evaluated on a rolling 12-month average. Over the past few years, the rolling average has been declining as a result of some poor daily performances.
Thus, the CAISO need to take measures to enhance daily performance on days with higher variability.

Renewable curtailment in 2024 at 40% RPS is significant



Solutions
Target energy efficiency
Increase storage and demand response
Enable economic dispatch of renewables
Decarbonize transportation fuels
Retrofit existing power plants
Align time-of-use rates with system conditions
Diversify resource portfolio
Deepen regional coordination

What levers must we pull to create a more favorable load shape and operationally sustainable grid?

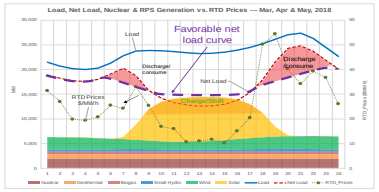
Shifting

Shaping

Storage – increase the effective participation by energy storage resources.	**Western EIM expansion** – expand the western Energy Imbalance Market.
Demand response – enable adjustments in consumer demand, both up and down, when warranted by grid conditions.	**Regional coordination** – offers more diversified set of clean energy resources through a cost effective and reliable regional market.
Time-of-use rates – implement time-of-use rates that match consumption with efficient use of clean energy supplies.	**Electric vehicles** – incorporate electric vehicle charging systems that are responsive to changing grid conditions.
Renewable portfolio diversity – explore procurement strategies to achieve a more diverse renewable portfolio.	**Flexible resources** – invest in fast-responding resources that can follow sudden increases and decreases in demand.

What are some potential opportunities and what is the ISO doing?

Targeting energy efficiency

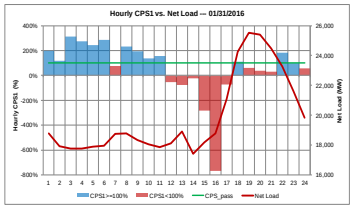


Minimizing curtailment, diversifying VERs portfolio, increasing storage and demand response participation

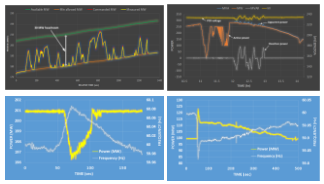
Decarbonizing transportation fleet

Expanding Western EIM enabling economic dispatch of renewables

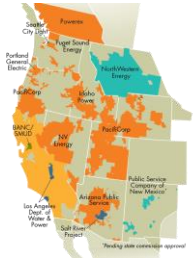
Aligning time-of-use rates with system conditions



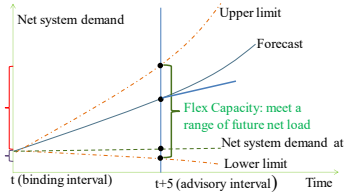
Ensuring compliance with NERC's operational performance standards



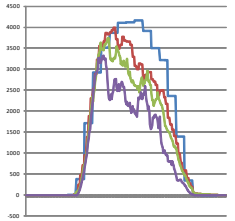
Utilizing Grid/DER resources to provide essential reliability services



Exploring Regional Coordination



Enhancing market products and timelines



Enhancing forecast to better manage supply/demand uncertainty

FERC Order 2222 is a landmark, foundational rule that paves the way for the grid of tomorrow

- The order enables distributed energy resources, or DERs, to participate in regional wholesale energy markets, opening a new way for them to make money and potentially grow
- DERs can include electric storage, distributed generation like solar, demand response programs, energy efficiency, thermal battery storage, electric vehicles and even smart appliances like dryers
- Regional grid operators must now revise their tariffs to allow DERs to aggregate and participate in markets
- The new rule removes market barriers for storage technologies like batteries

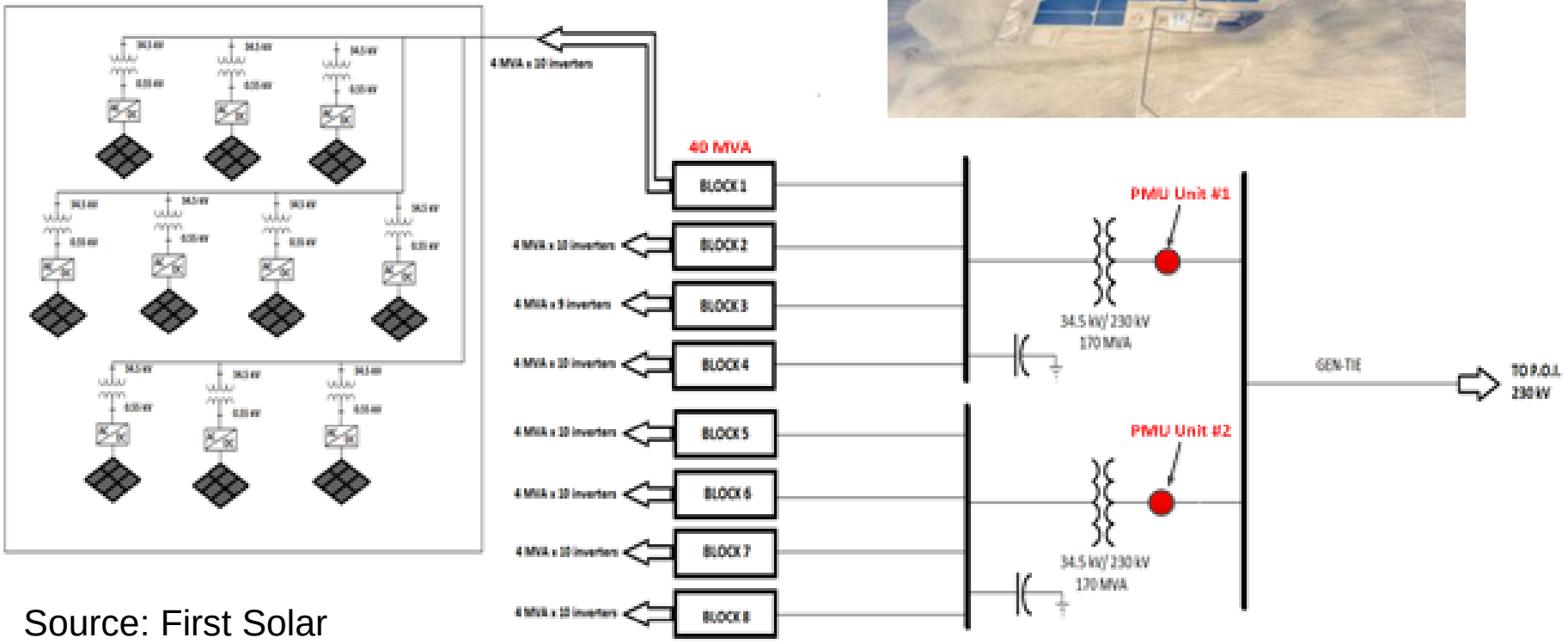
DER can contribute to meeting operational challenges

- Energy Storage can help mitigate over-generation
- Load shifting can help mitigate conventional resource needs
- DERs may also benefit the system by reducing peak demand and thereby avoiding the need for transmission upgrades
- Controlled load dropping can provide spinning reserve and frequency response
- Demand Response can reduce the need for conventional resources
- Distributed Generation can off-set transmission upgrades
- Electric Vehicles can provide regulation service or balancing needs
- Micro grids allows participation in ancillary services markets

Can variable energy resources provide essential reliability services to reliably operate the grid?

- NERC identified three essential reliability services to reliably integrate higher levels of renewable resources
  - Frequency control
  - Voltage control
  - Active power management such as ramping capability or flexible capacity
- Advancement in smart inverter technology allows VERs to provide services similar to conventional resources
- VERs with the right operating characteristics are necessary to integrate higher levels of renewables and decarbonize the grid

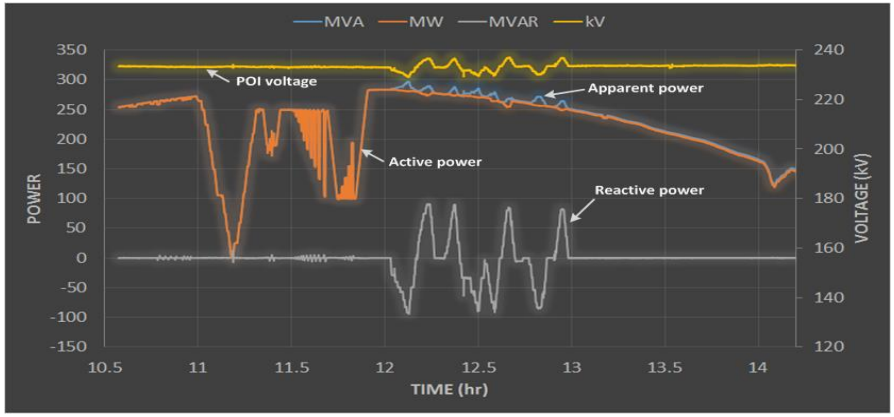
Electrical diagram of 300 MW PV plant without storage



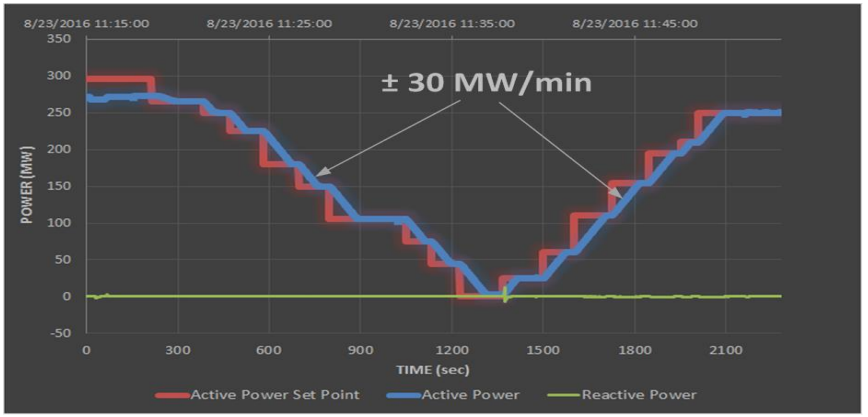
Source: First Solar

Demonstration of various control capabilities

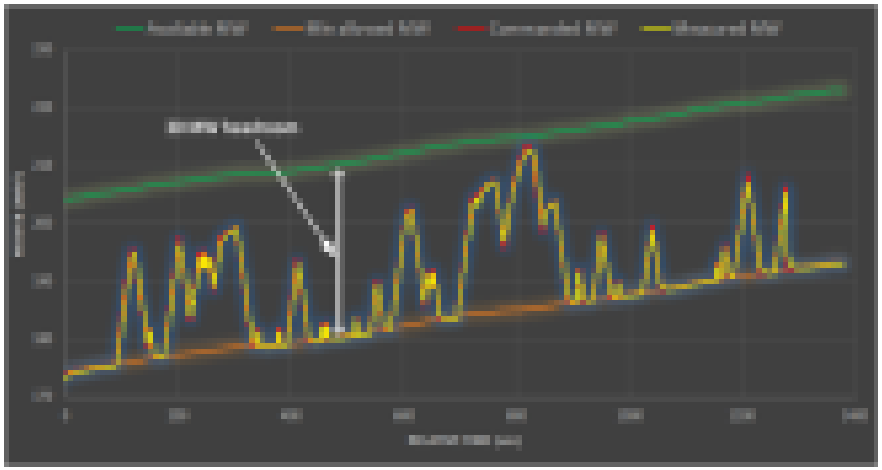
Voltage Control



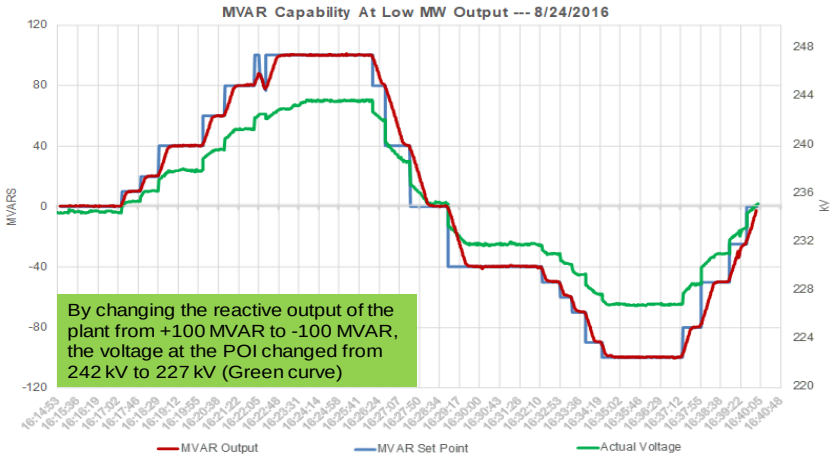
Ramp Rate



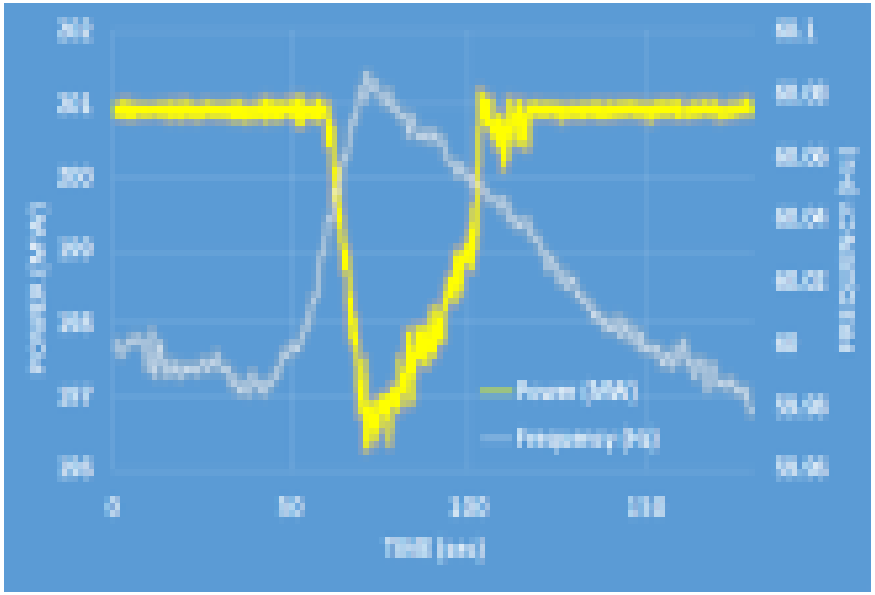
Automatic Generation Control



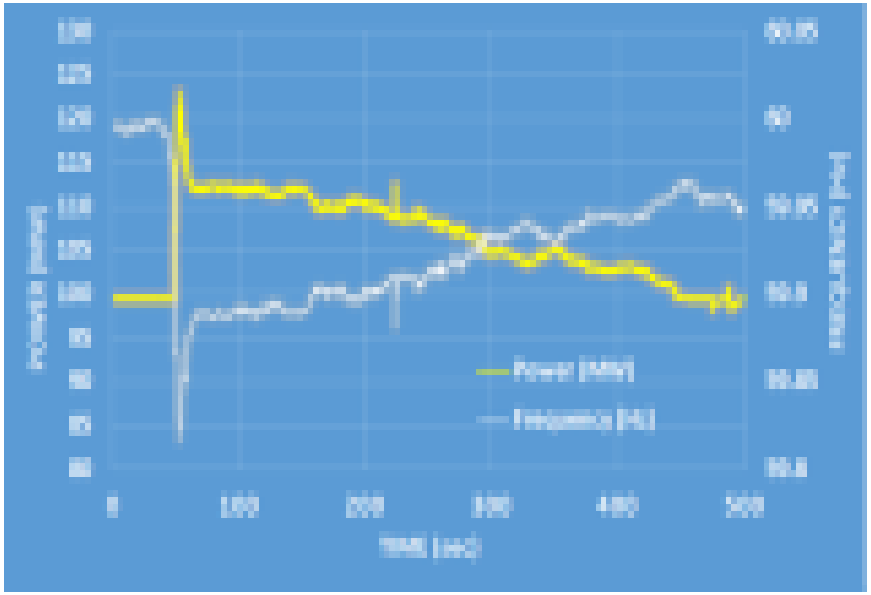
Voltage Control @ Very Low MW



Solar plant frequency response capability to a low and a high frequency events



Response similar to a hydro plant using 5% governor-like droop setting for **high** frequency event



Response similar to a combine cycle plant for a **low** frequency event

Questions

Using Renewables to Operate a Low-Carbon Grid:
Demonstration of Advanced Reliability services from a Utility-Scale Solar PV Plant
http://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf

Avangrid Renewables Tule Wind Farm: Demonstration of Capability to Provide Essential Grid Services
http://www.caiso.com/Documents/WindPowerPlantTestResults.pdf

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