System Balancing – Flexibility and Systems Integration Session

Dr. Debra Lew, ESIG
System Balancing – Medium-term reliability
May 20, 2021

NARUC
National Association of Regulatory Utility Commissioners

NASEO
National Association of State Energy Officials

NASUCA
National Association of State Utility Consumer Advocates

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

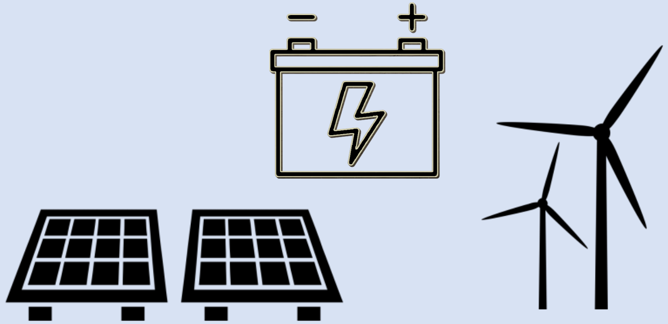
What is ESIG?

- ESIG addresses the technical challenges for transforming energy systems through collaboration, education and knowledge sharing. Workshops, webinars, reports available freely at www.esig.energy
- 175 members worldwide broadly focused on decarbonization and integration of energy systems
- ESIG is part of the Global Power System Transformation Consortium and leads their System Operator Research and Peer Learning pillar.

The grid must be reliable

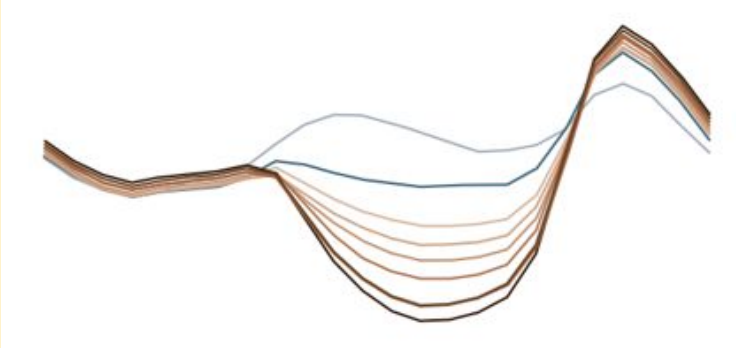
System Stability

- High penetrations of inverter-based resources (IBR)
  - Frequency response
  - Transient stability
  - Small-signal stability



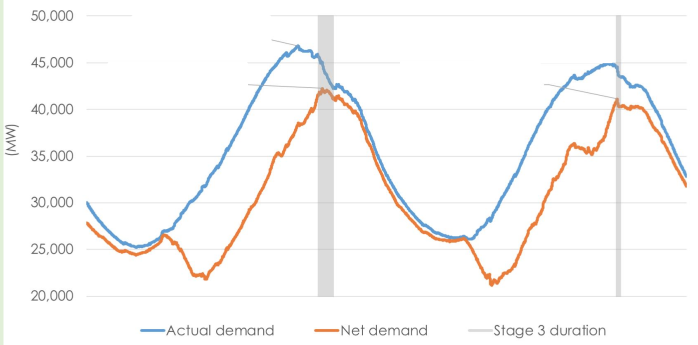
System Balancing

- Wind and solar variability and uncertainty
- Diurnal mismatch of supply and demand
- Reducing curtailment
- Flexibility needs



Resource Adequacy

- Seasonal mismatch of supply and demand
- Periods of low wind/solar/hydro
- 1 day in 10 years Loss of Load Expectation



Seconds → **Hours/Days** → **Years**

Graphics: CAISO, https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf; http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf

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  - Frequency resp
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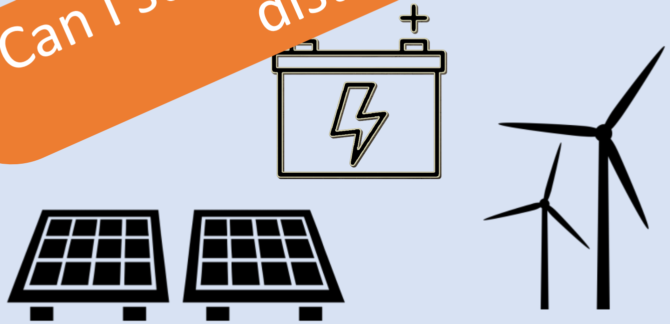
  - Sm

Can I survive and recover from a disturbance?



System Balancing

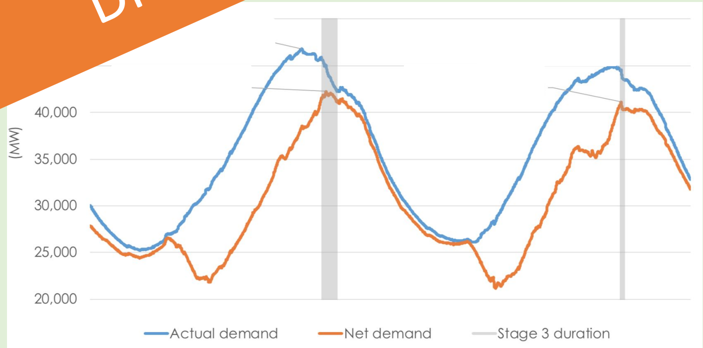
- Wind and solar variability and uncertainty
- Diurnal mismatch of su demand
- Reducing
- Flex

Can I balance supply and demand?

Resource Adequacy

- Seasonal mismatch of supply and demand
- Periods of low wind/
- 1 day in 10 ye Expect

Did I build enough?



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Educational sessions on grid reliability

- May 6: Resource Adequacy – long-term reliability
- May 20: System Balancing – flexibility and systems integration
- June 10: System Stability – managing disturbances
- June 22: Impacts of Distributed Energy Resources on the Bulk Power System

Dr. Debra Lew, ESIG

Debbie is the Associate Director of ESIG. Her background is in wind, solar and distributed energy resource integration with a focus on 100% clean energy. She was previously a senior technical director at GE Energy Consulting and held a variety of roles during her 16-year tenure at the National Renewable Energy Laboratory, including secondment to the Hawaiian Electric Company. She is the Immediate Past Chair of the IEEE Power & Energy Society's Wind and Solar Power Coordinating Committee. She has a PhD in Applied Physics from Stanford University and a BS degrees in Electrical Engineering and Physics from MIT.

Dr. Aidan Tuohy, EPRI

Aidan Tuohy is a Program Manager at the Electric Power Research Institute (EPRI). He joined EPRI in 2010 and works in the Grid Operations and Planning group. He is the program manager for the EPRI research program on bulk system integration of variable generation, with research focusing on the impact of variable generation on power system operations and planning. Prior to joining EPRI, Dr. Tuohy completed his PhD at the University College, Ireland, and consulted at the IEA. He has published several journal papers and frequently presents at industry conferences. He is the secretary of the IEEE Wind and Solar Power Coordinating Committee and chairs the Energy Systems Integration Group working group on Operating Impacts and Market Design, while he is also involved in IEA, IEC and CIGRE activities.

Marc Keyser, MISO

Marc Keyser is a Regional Director for the Central Region of MISO, managing relationships with members and customers in Michigan, Kentucky, and Wisconsin. During his 14 years with MISO, he has held roles in operational support, market design and implementation, corporate strategy, invented Dispatchable Intermittent Resources, led customer service and member relation teams. Prior to joining MISO, Marc spent five years in merchant operations at Consumers Energy. Marc has a Masters in Nuclear Engineering from the University of Michigan, and undergraduate degrees in Engineering Physics and Nuclear Engineering from the University of Michigan.

Jon Olson, SMUD

Jon is the Director of Energy Trading and Contracts at the Sacramento Municipal Utility District.

Agenda

- 2 pm ET Introduction - Danielle Sass Byrnett, NARUC and Debra Lew, ESIG
- 2:10 pm System Operations and the Need for Flexibility – Dr. Debra Lew, ESIG
- 2:50 pm Future System Operations with an Evolving Grid – Dr. Aidan Tuohy, EPRI
- 3:35 pm Break
- 3:40 pm Daily Portfolio Management at SMUD – Jon Olson, SMUD
- 4:05 pm Changing Needs of System Operations: MISO's Perspective – Marc Keyser, MISO
- 4:30 pm Breakout rooms for detailed Q&A and discussion
- 5 pm Adjourn

System Operations and the Need for Flexibility

Dr. Debra Lew, ESIG

System Balancing – Medium-term reliability

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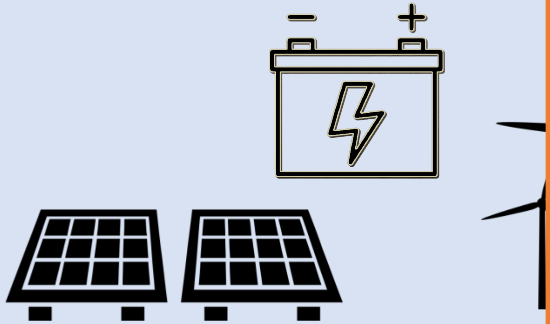

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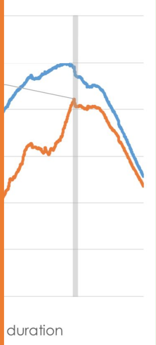
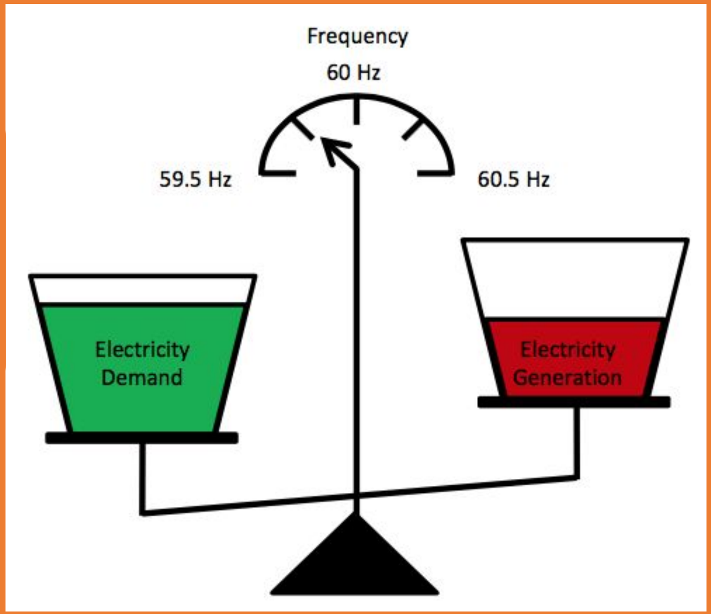


Seconds

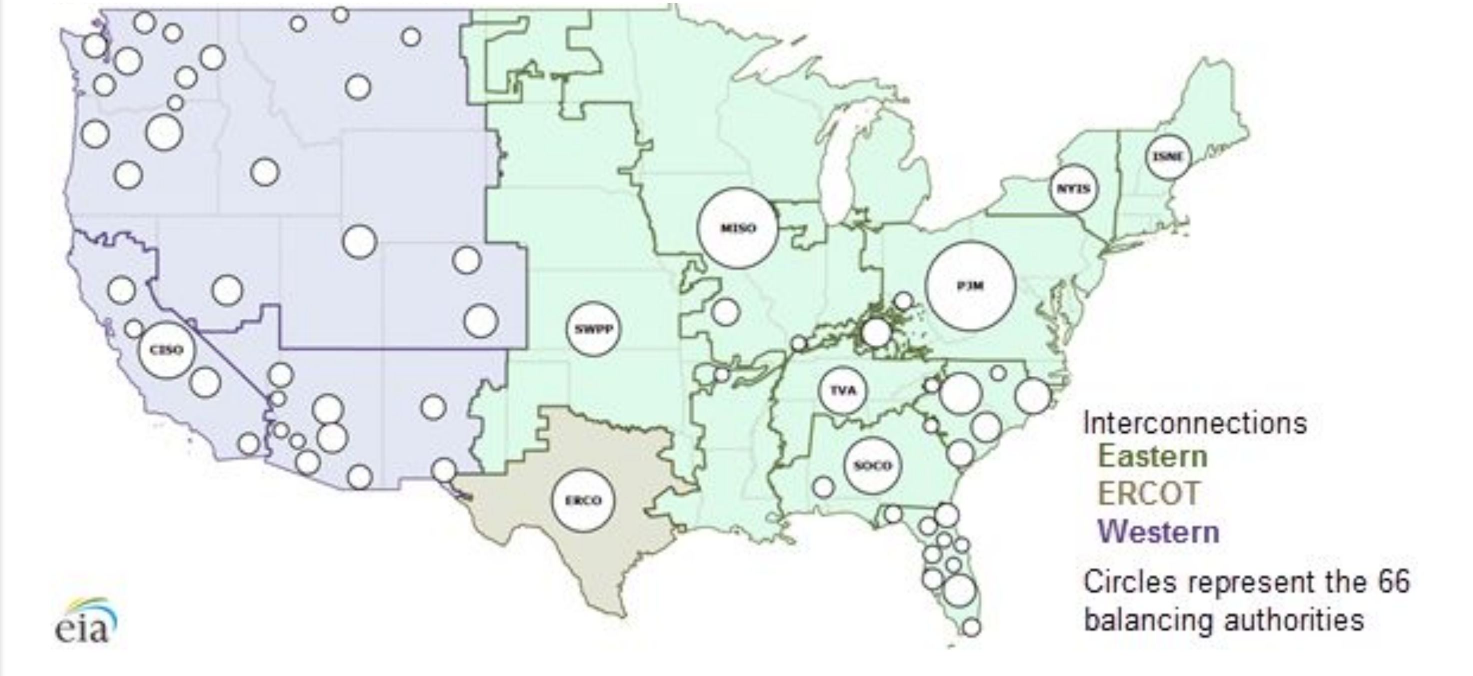
These are all fundamentally about the generation and demand balance



Slide from Lew, Western Interstate Energy Board, Tutorials May 2020

System operators at each Balancing Authority (BA) are responsible for balancing the system

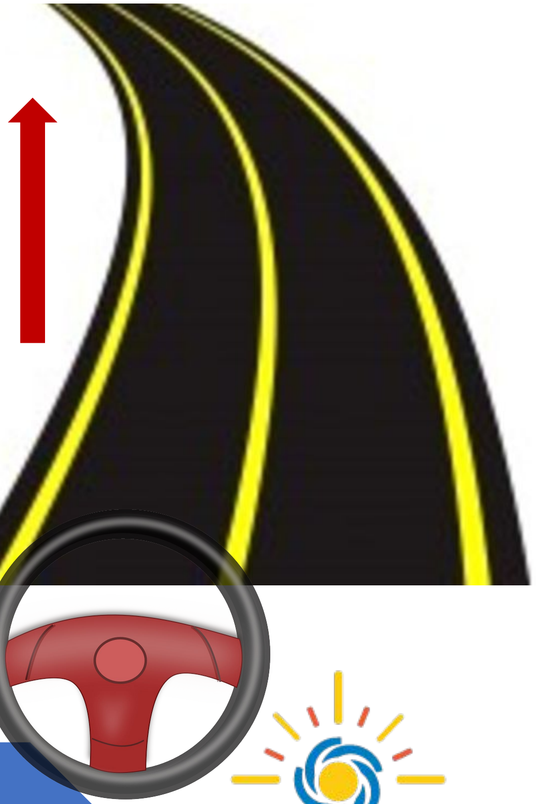
66 Balancing Authorities Balance Load and Generation in Real-Time



EIA, https://www.eia.gov/todayinenergy/detail.php?id=27152

Like driving down the highway and staying between the yellow lines

Looking ahead



Providing control

System operators at each Balancing Authority (BA) are responsible for balancing the system

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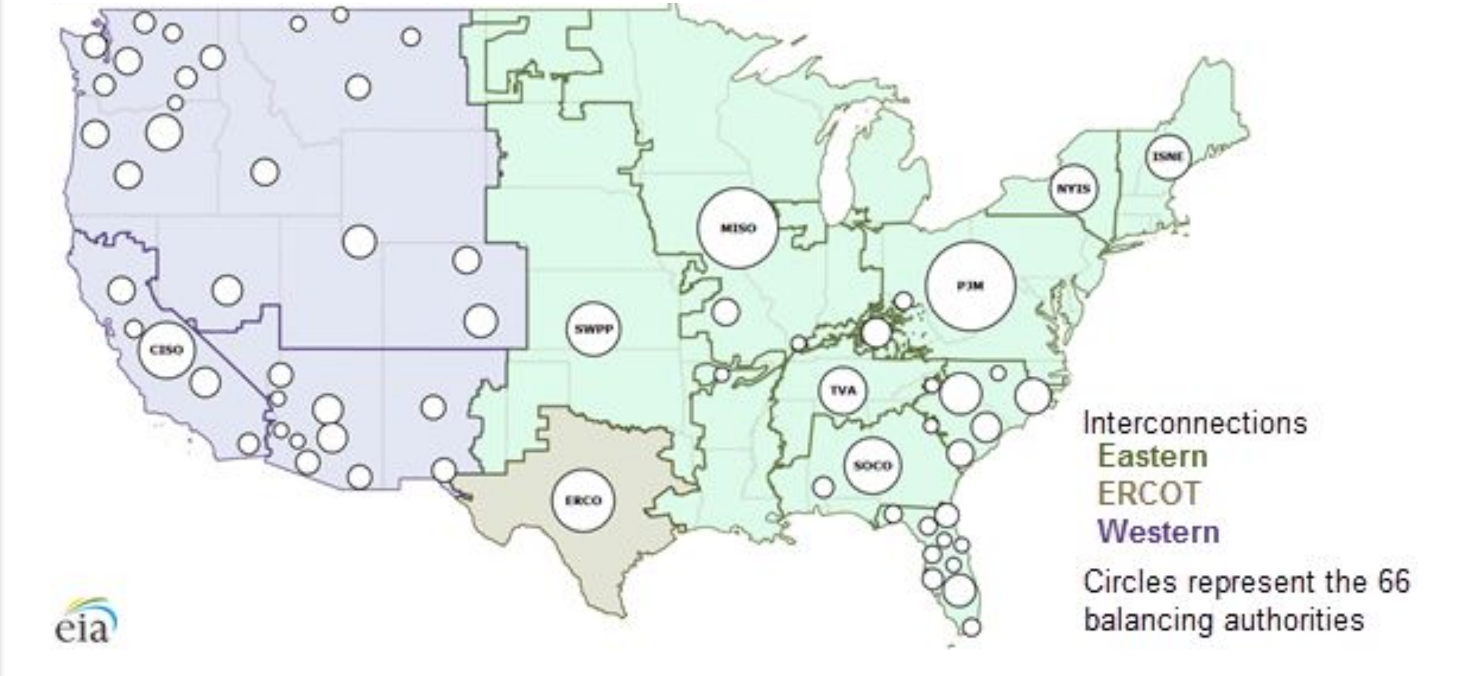
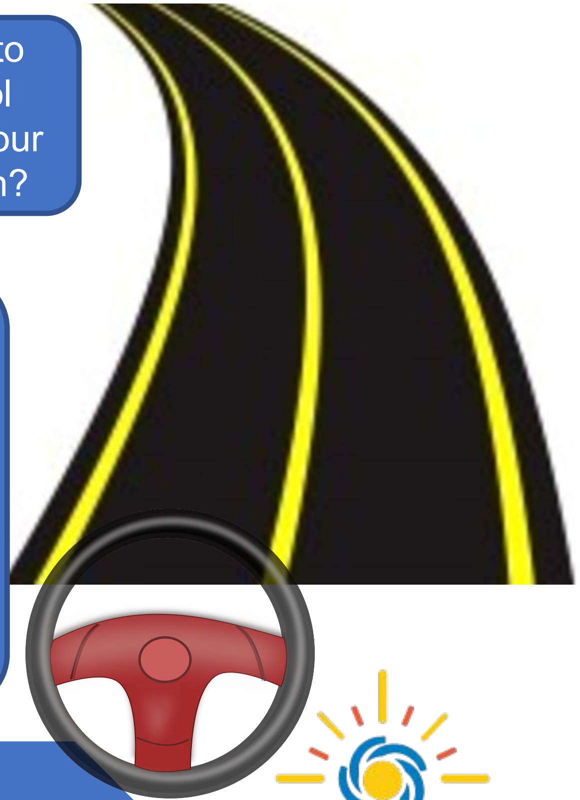


EIA, https://www.eia.gov/todayinenergy/detail.php?id=27152

There are large control actions that you take with your steering wheel

Do you want to take a control action every hour or every 5 min?

And there are small tweaks that the car safety features might ***autonomously*** use to keep the car within the lines



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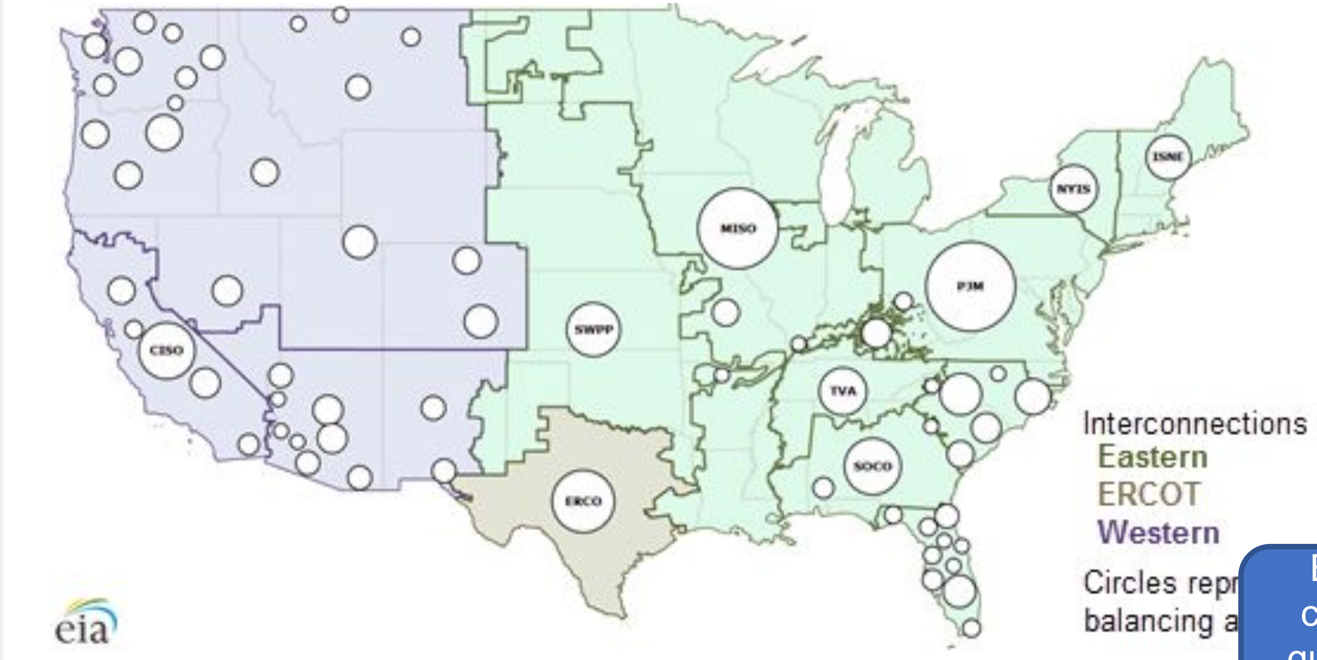


EIA, https://www.eia.gov/todayinenergy/detail.php?id=27152

How much you cross over the line is your "area control error" (ACE)

NERC judges your driving performance with 2 metrics

CPS1: Touching the line isn't a problem but going far over the line is a problem

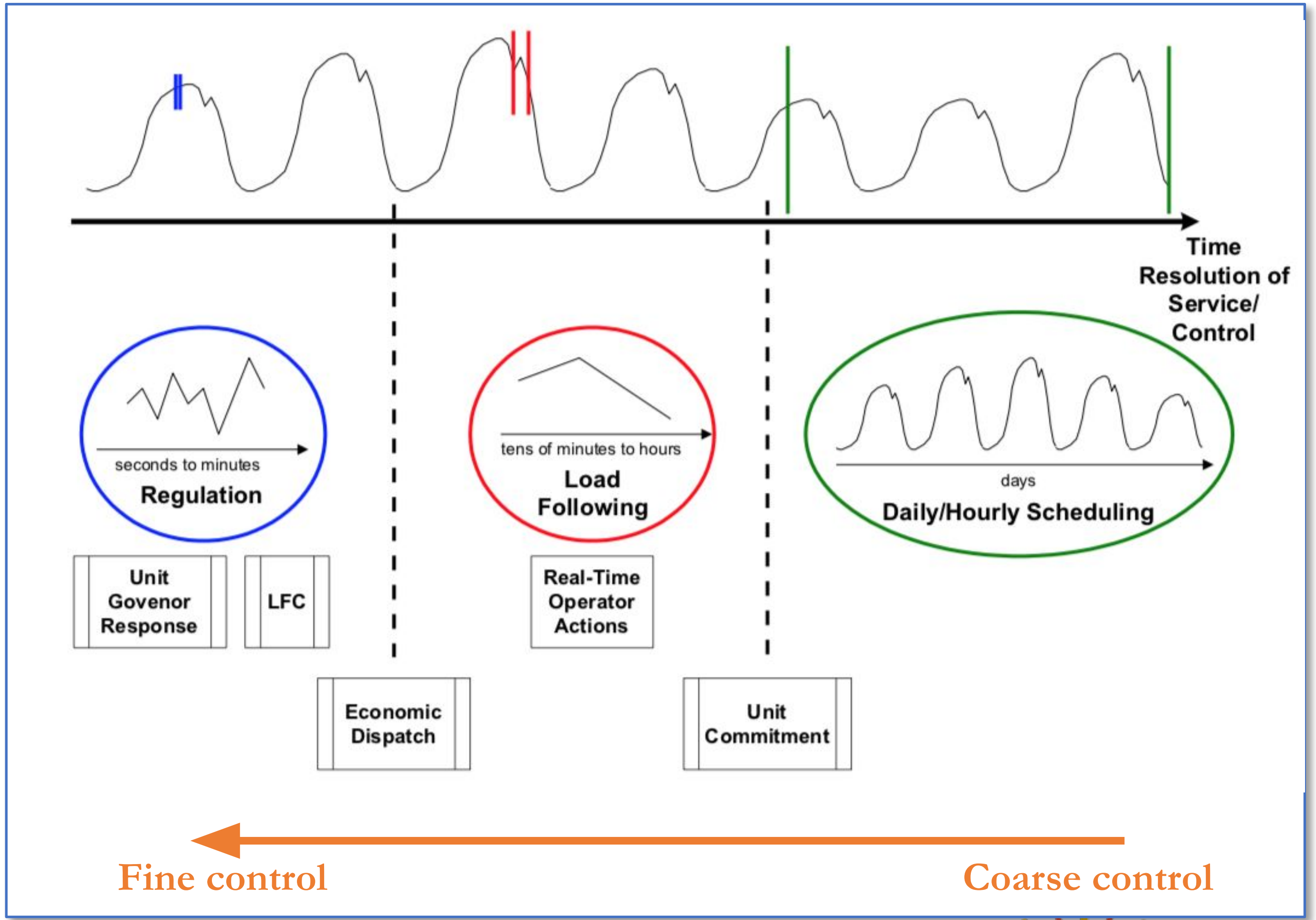
BAAL: Going over the line could be a good thing if the guy next to you is going over the line into your lane

Chronological operations

This varies by utility

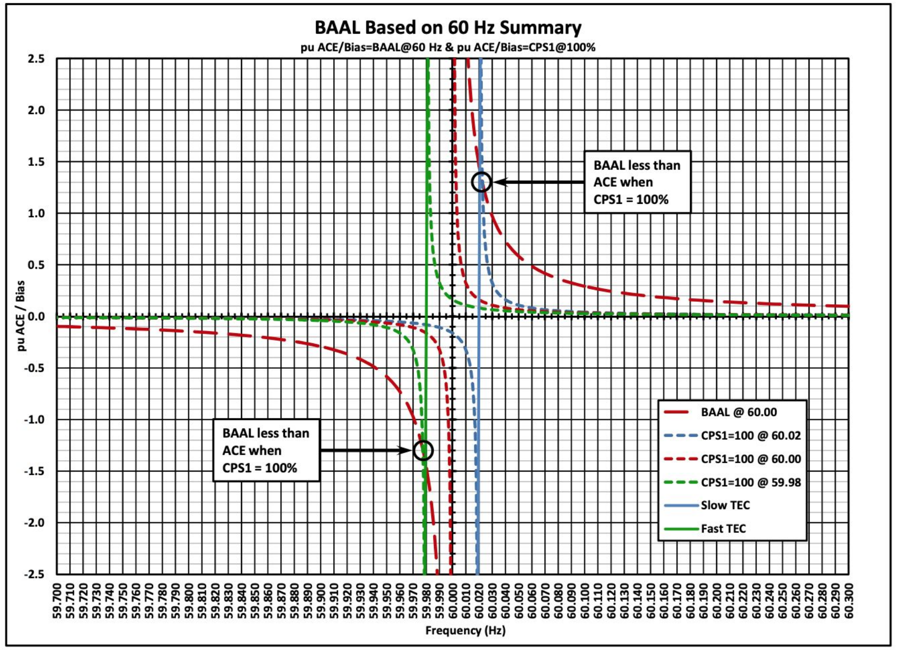
- Forecast load
- Day-ahead – run security-constrained unit commitment and economic dispatch
- Determine hourly schedules for all generators
- Dispatch generators to set points at each interval (5-60 min)
- Regulation reserve adjusts generator output (4-6 seconds) for variability within the interval
- Autonomous frequency response manages fine balance (no signal from operator)

It can be much more complicated than this!



Slide from Lew, Western Interstate Energy Board, Tutorials May 2020; Graphic Ela, ESIG Forecasting Workshop 2018

NERC standards dictate how much control the BA needs

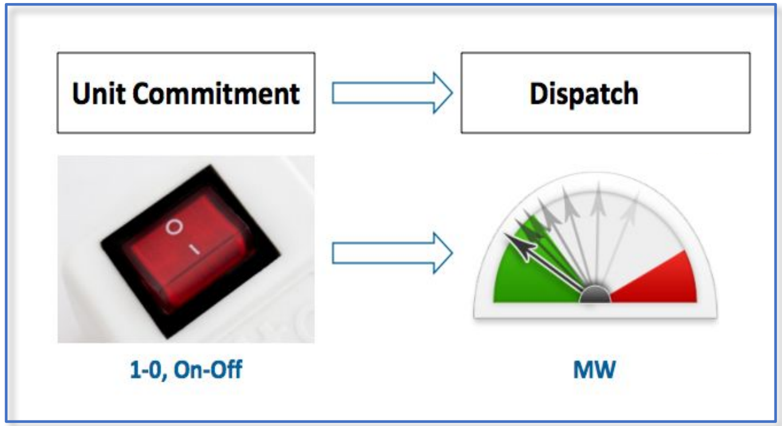


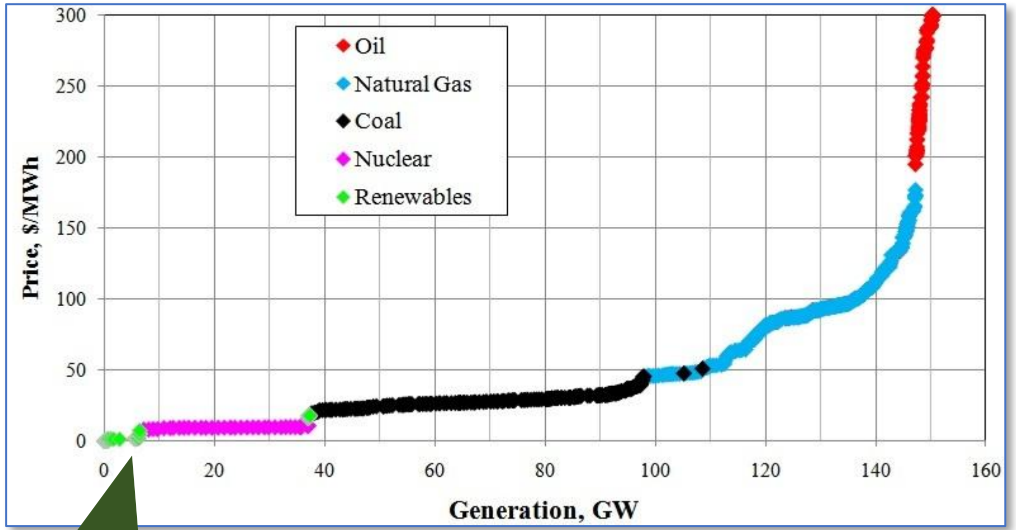
Graphic: NERC 2013, https://www.nerc.com/pa/StandProject2010141Phase1ofBalancingAuthorityRe/BAL-001-2_Background_Document_Clean-20130301.pdf

- Area Control Error (ACE) is essentially the Balancing Authority's (BA's) power balance error
- Real Power Balancing Control Performance BAL-001-2
  - Control interconnection frequency within defined limits
  - Control Performance Standard 1 (**CPS1**) is a measure of ACE variability. Want CPS1≥100%
  - BA ACE Limit (**BAAL**) limits ACE as a function of frequency
  - Regulation reserves provide this control. BA's decide how much regulation reserves to hold

The Balancing Act: Cost and Reliability

- Run the lowest production cost resources (fuel and variable O&M; capital costs do NOT matter here)
- What units need to be ON (committed)? At what output (dispatch)? Accounting for:
  - Resource minimum generation levels, startup times, min up and down times, ramp rates
  - Transmission constraints
  - “Security-constrained” in case of contingency
  - Headroom for operating reserves

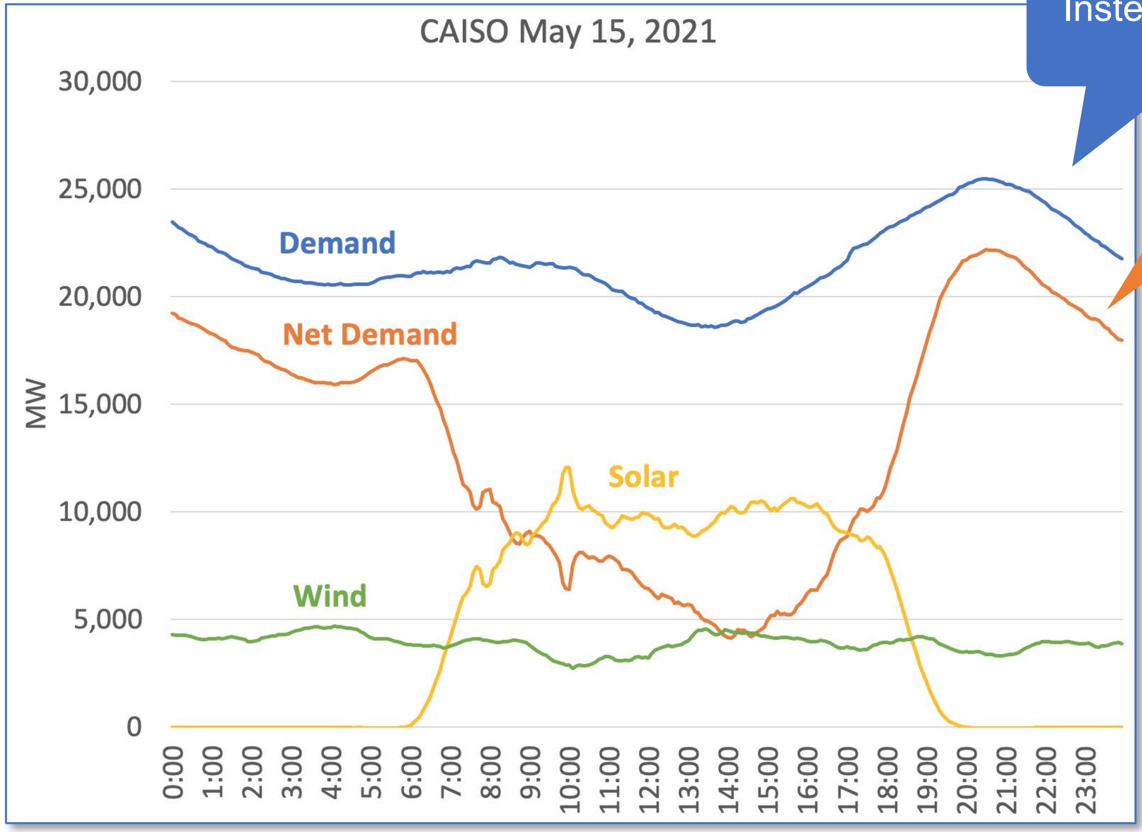




Wind and solar have zero marginal cost so they get run first

Source: B. Posner, PJM 2008

Wind and solar are variable and uncertain



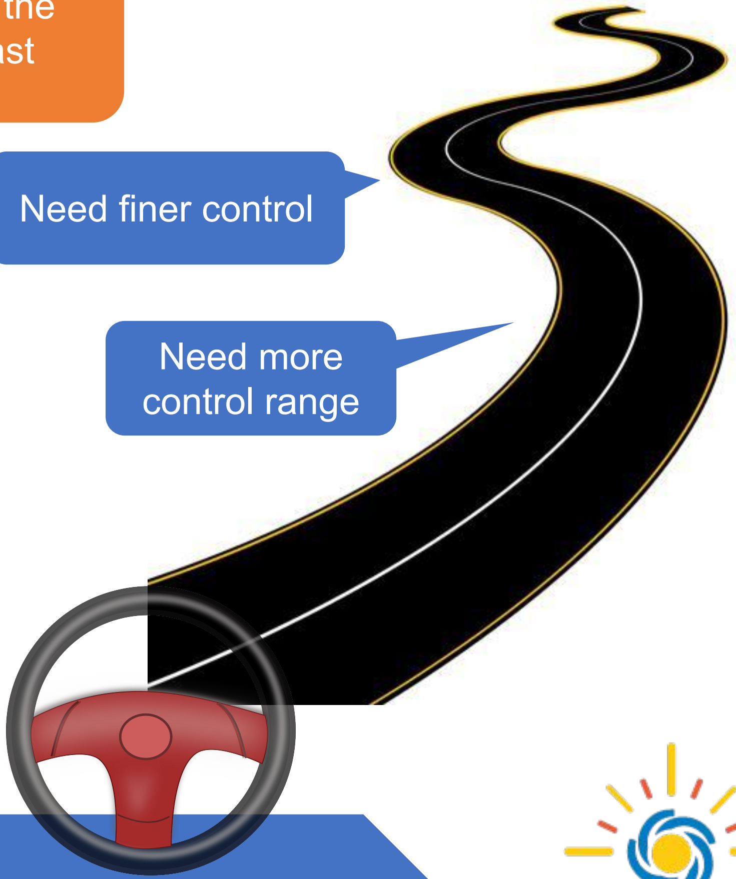
Instead of driving I-95…

…operators are now driving the Pacific coast highway

Need to look-ahead farther out and often!

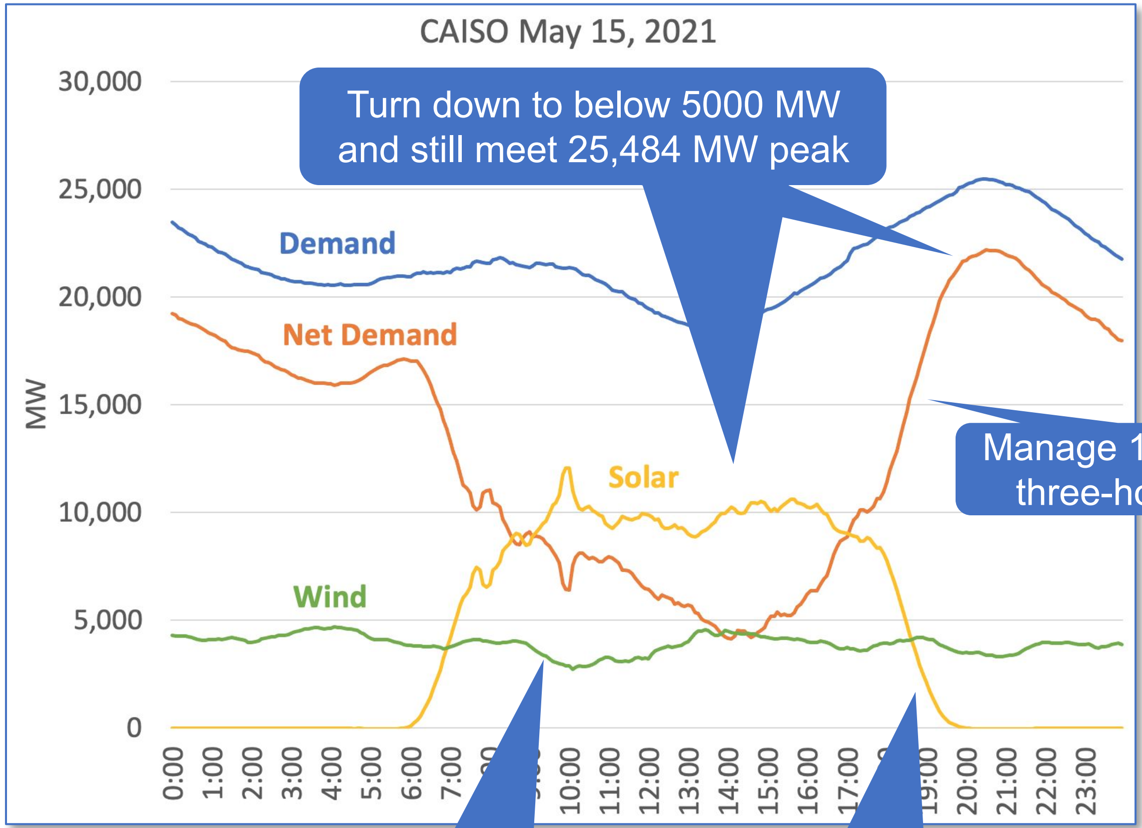
Need finer control

Need more control range



CAISO data 5/15/21

Wind and solar are variable and uncertain



Turn down to below 5000 MW and still meet 25,484 MW peak

Manage 13,433 MW three-hour-ramp

Wind ramps can suffer from forecast errors

Solar ramps are generally known

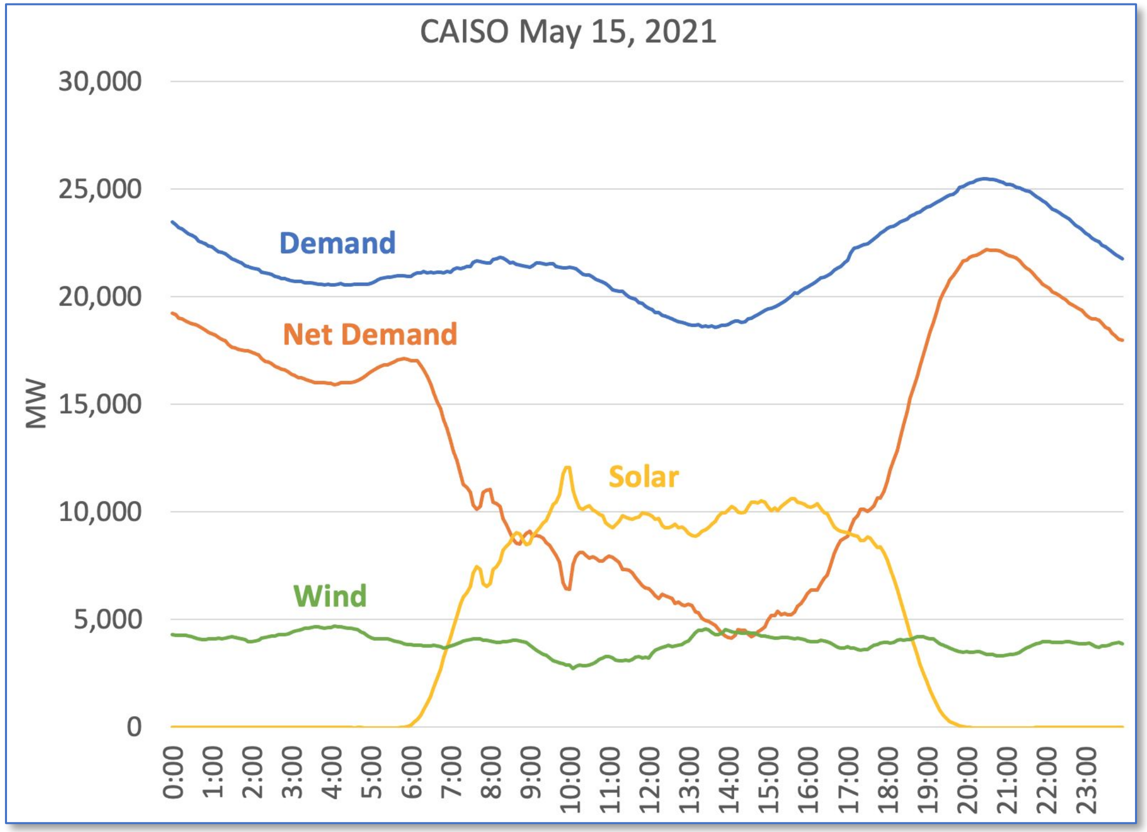
CAISO data 5/15/21

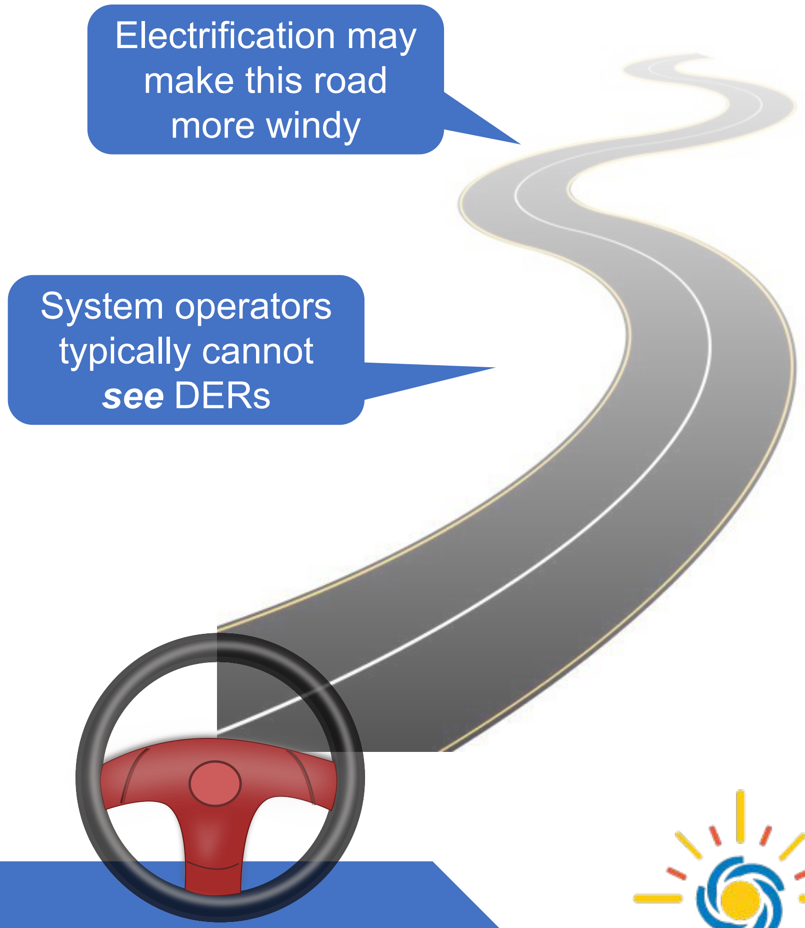
Energy Systems Integration Group

Charting the Future of Energy Systems Integration and Operations

ESIG

Wind and solar are variable and uncertain

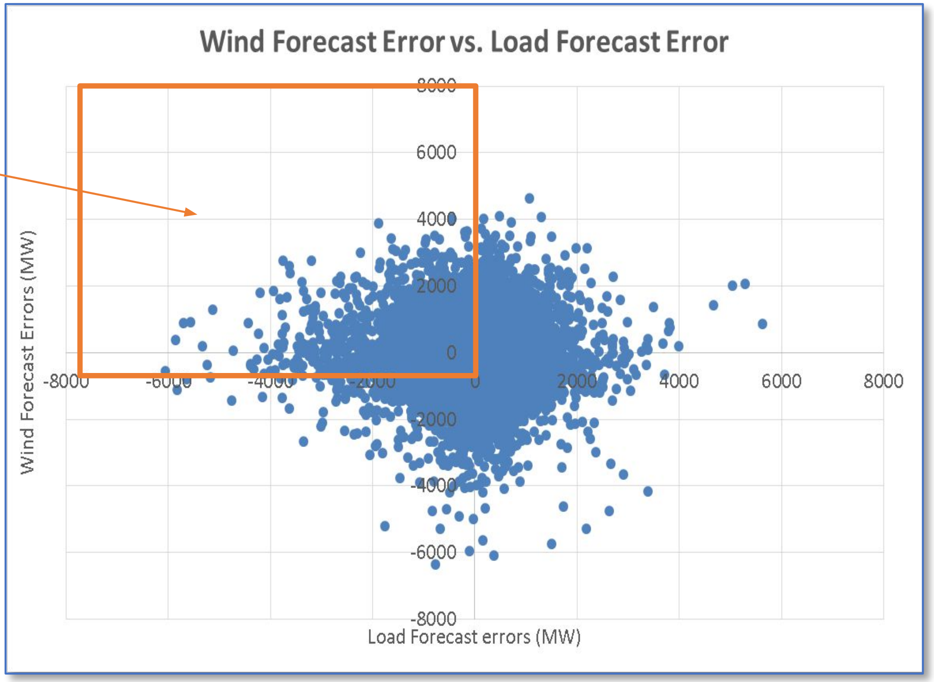




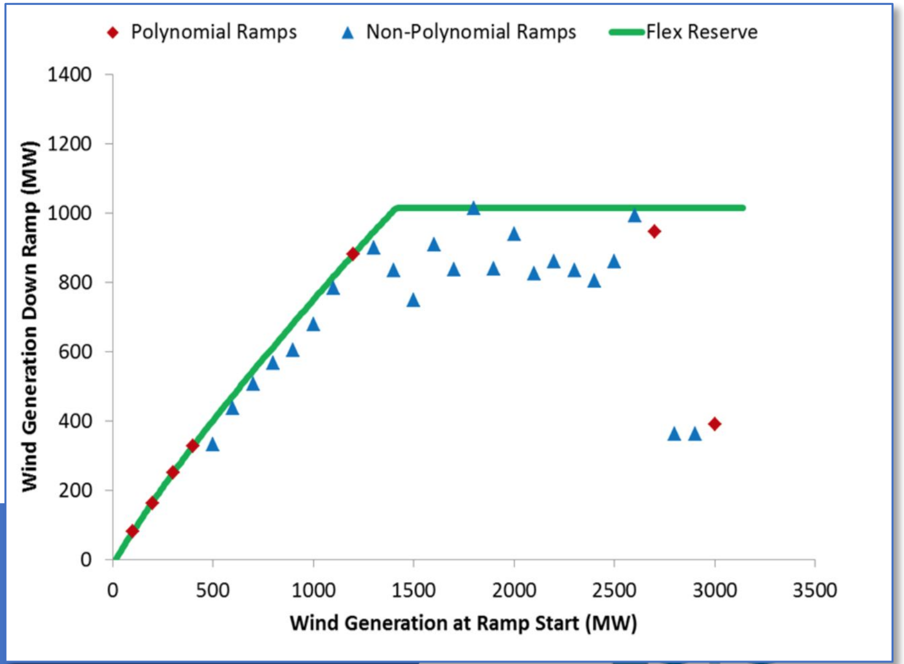
CAISO data 5/15/21

Defining reserve requirements

Must ensure adequate reserves for events where load is underforecast and wind is overforecast



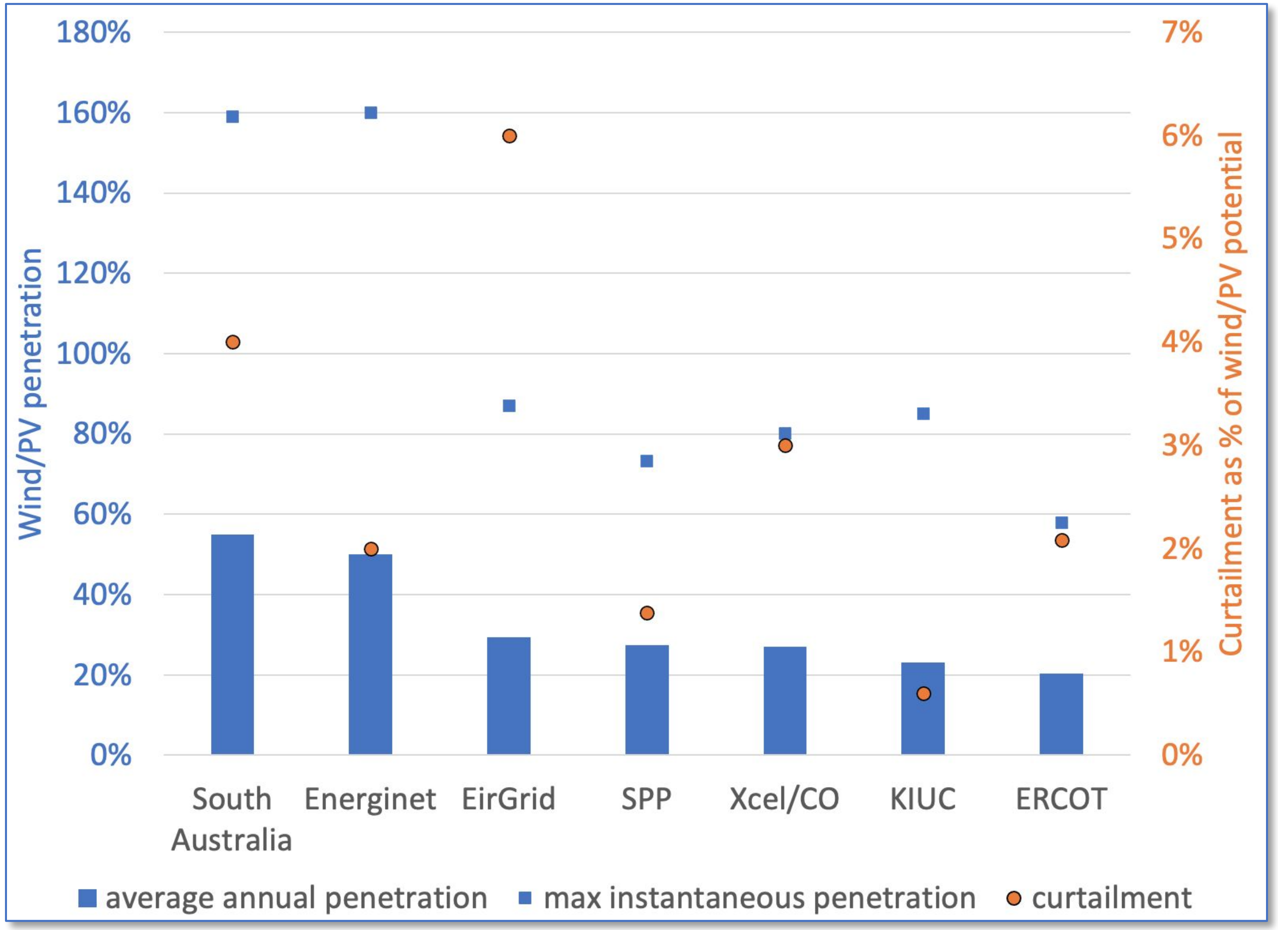
- Bottom line - meet NERC standards
- What's the product? (Are you managing 30 min ramp events? Do you have resources that take a long time to start up?)
- How much do you need? (Are you protecting against 90% of events? 95%?)
- Reserves should be dynamic (Don't hold reserves for solar at night)
- Hold reserves to protect against risk, not just for variability
- If you have a lot of fine control, you might not need as much coarse control



Source: Lew, et al, Secrets of Successful Integration, IEEE PES Magazine, Nov/Dec 2019; Lew, et al, Wind Integration Workshop, Ireland, 2019.

We know how to balance the system with high levels of wind and solar

These numbers do not include DERs



Adapted from Lew, et al, Secrets of Successful Integration, IEEE PES Magazine, Nov/Dec 2019

Six sources of flexibility help balance the system

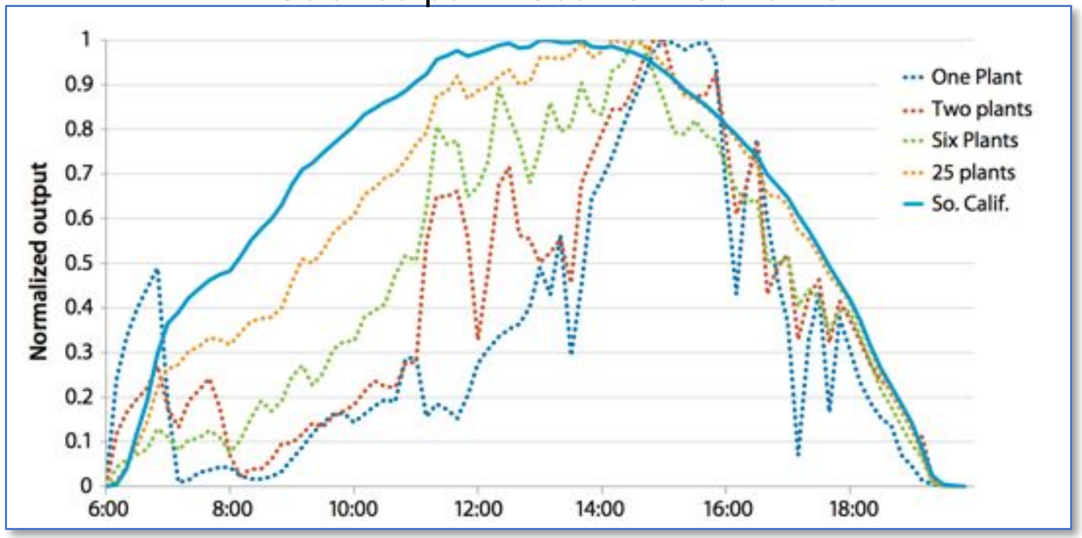
1. Faster trading over wider areas
2. Forecasting over different time horizons
3. Extract flexibility from non-variable generation
4. Wind/PV can provide essential reliability services
5. Responsive demand and integration of other energy sectors
6. Storage – electrical and thermal

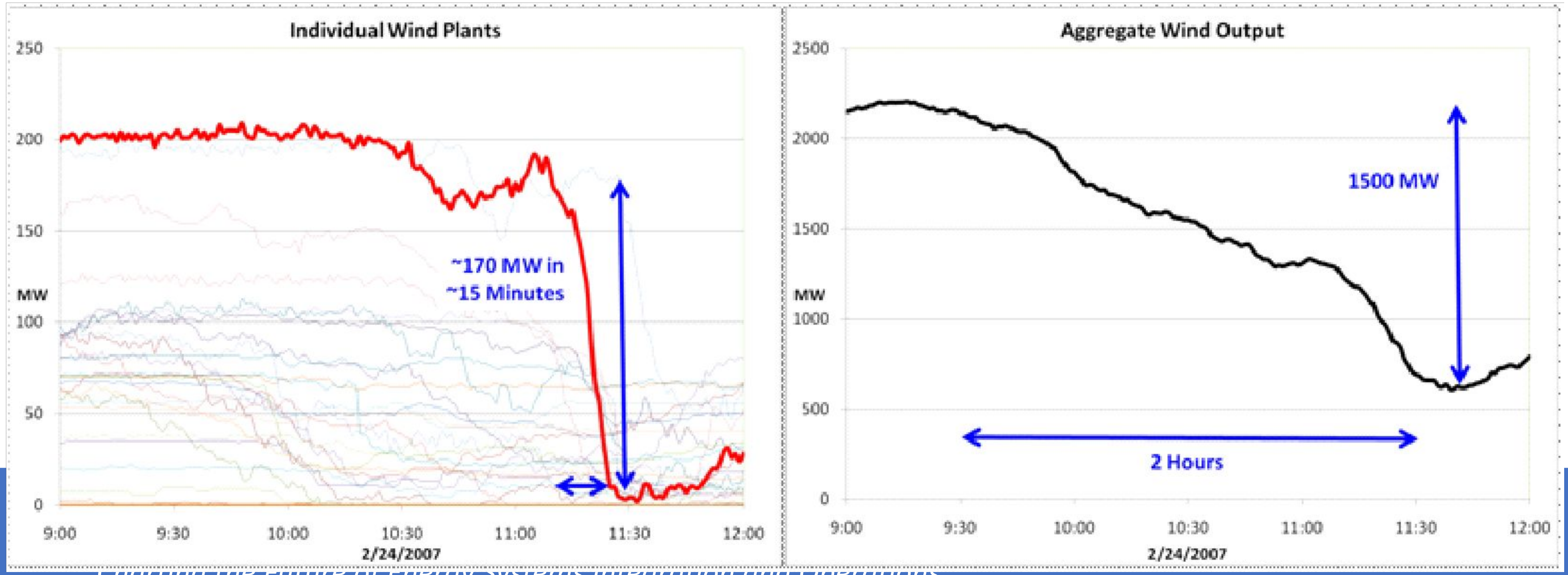
- Each tool can saturate
- The tools interact, e.g., demand response competes with storage
- The more constrained your system is, the more valuable these tools are
- We need them all

1 Geographic diversity over wide areas provides smoothing

- Geographic diversity smooths load, wind and solar
- And provides access to more resources providing reliability services
- Transmission and markets enable diversity

Solar output in Southern California

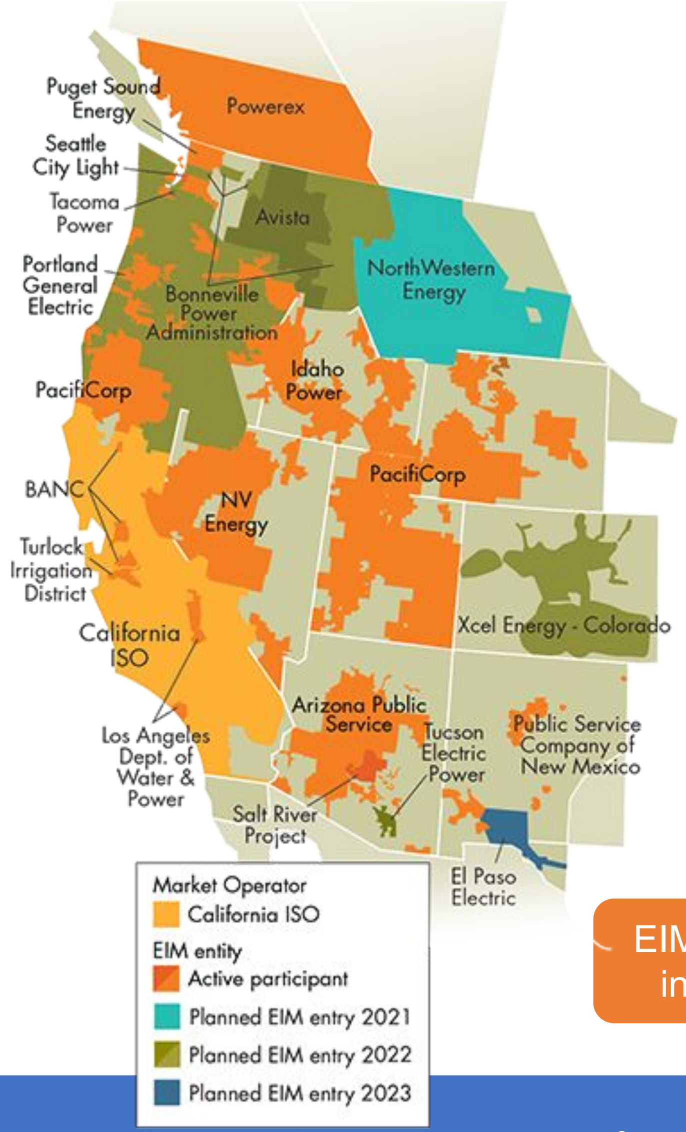




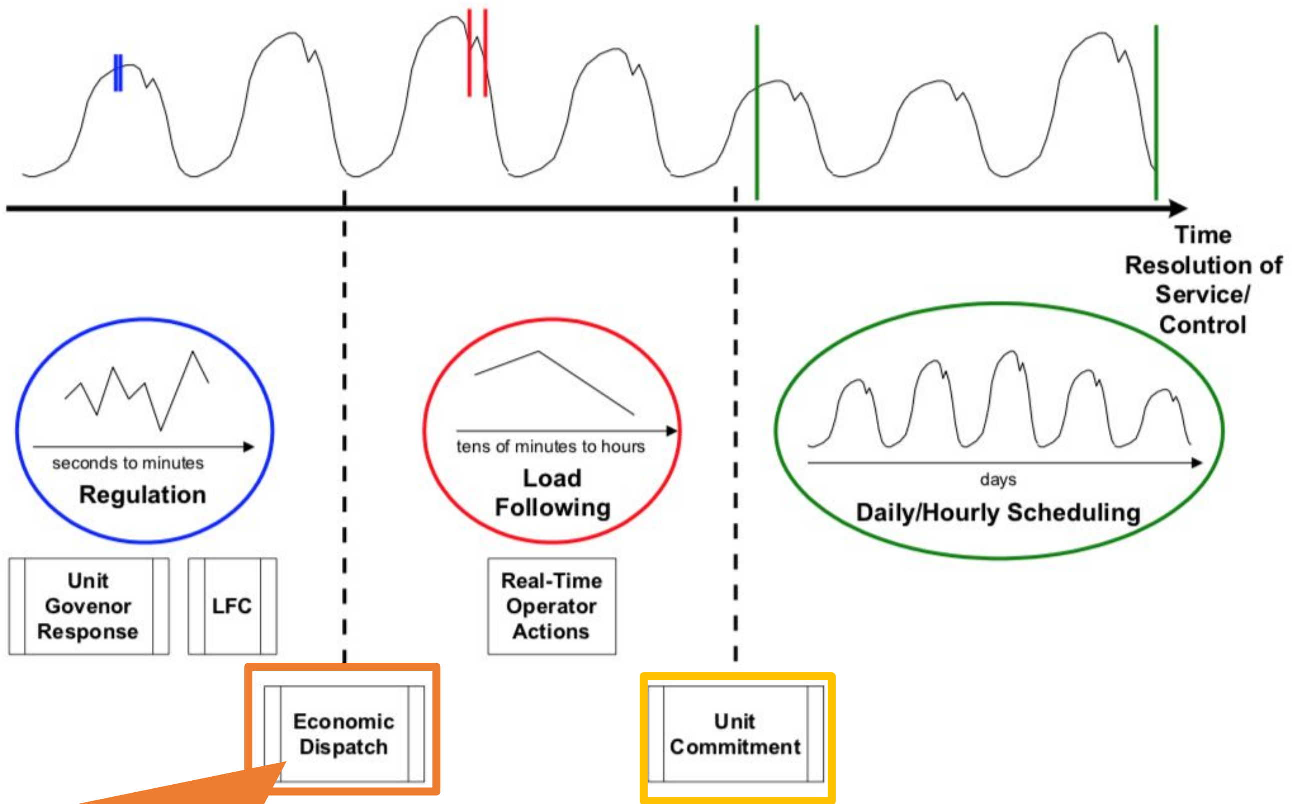
Geographic diversity takes your windy road and makes it straighter!

Top: Lew et al, Western Wind and Solar Integration Study Phase II, NREL, 2013; Bottom: Ela, 2008. http://www.nrel.gov/docs/fy08osti/43373.pdf

Energy Imbalance Market (EIM): fast, automated trading over wide areas



Real-time energy imbalance market (EIM) being transitioned to extended day-ahead market (EDAM)



EIM allows trading partner to dispatch down in real-time, in order to buy lower cost generation from a neighbor

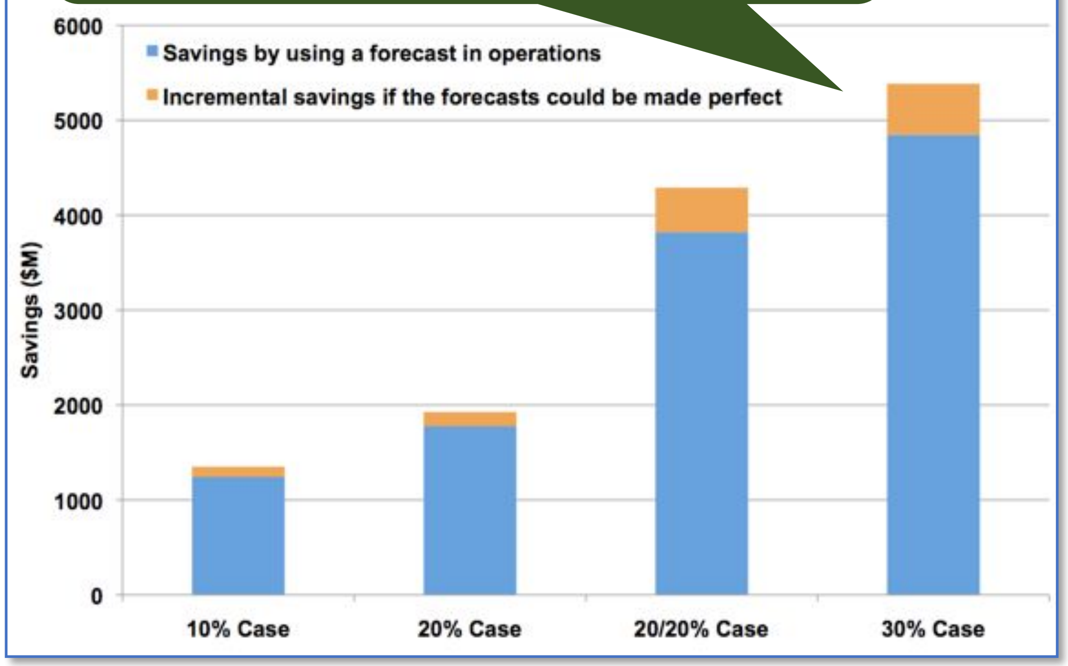
EDAM enables trading partner to not startup a generator, in order to buy lower cost generation from a neighbor

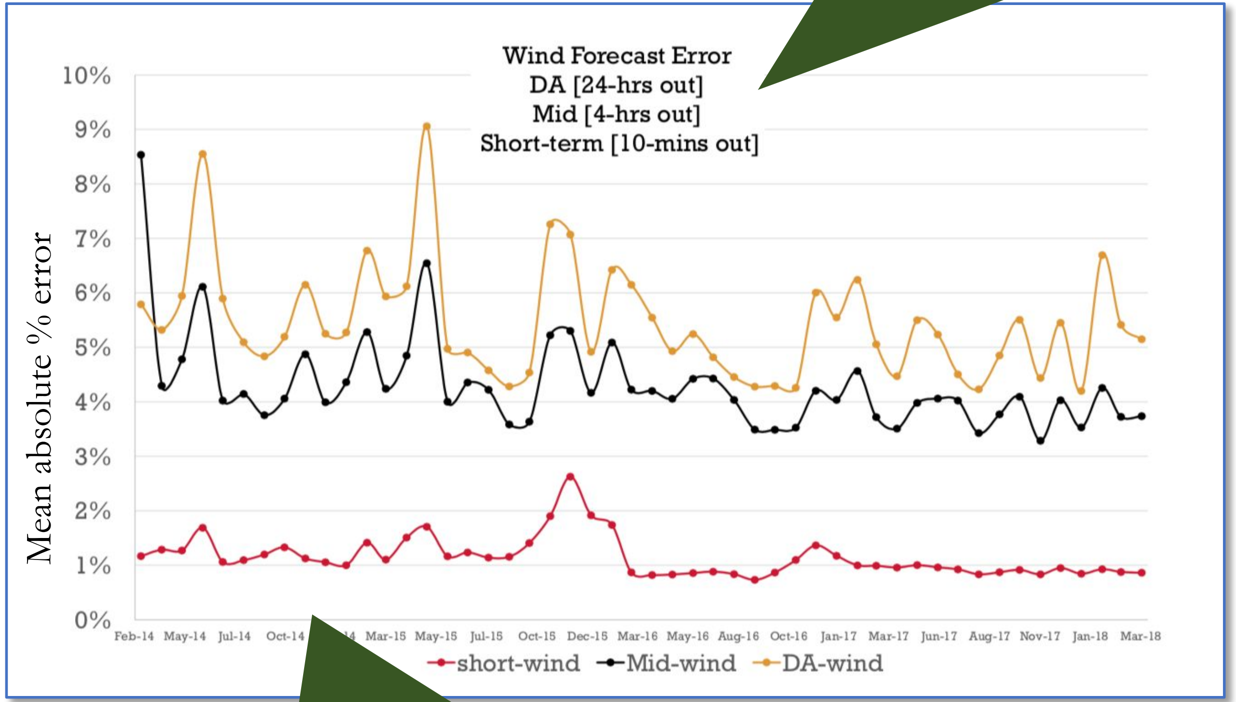
Left: www.westerneim.com; right E. Ela, EPRI, ESIG Forecasting workshop, 2018

Forecasting allows you to look-ahead and position your system

Forecasts are synchronized to decisions: day-ahead scheduling; committing gas generators; real-time dispatch

Forecasting saves up to 14% in annual operating costs. If forecasts were perfect, an additional 1-2% could be saved.





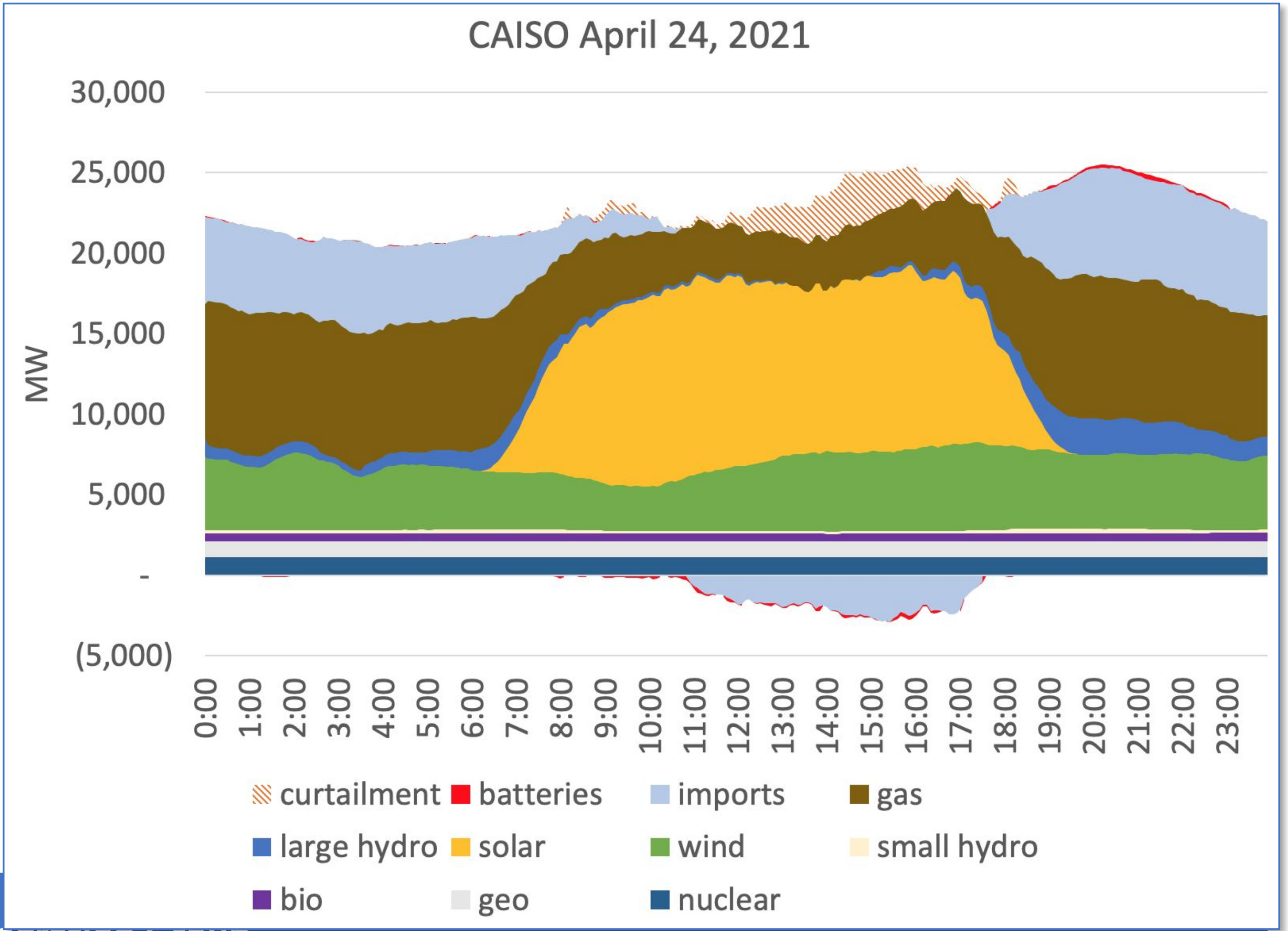
Forecasts are more accurate, the closer they are to real-time. Make decisions as close to real-time as possible.

Forecasting is like turning on your high beams in your car!

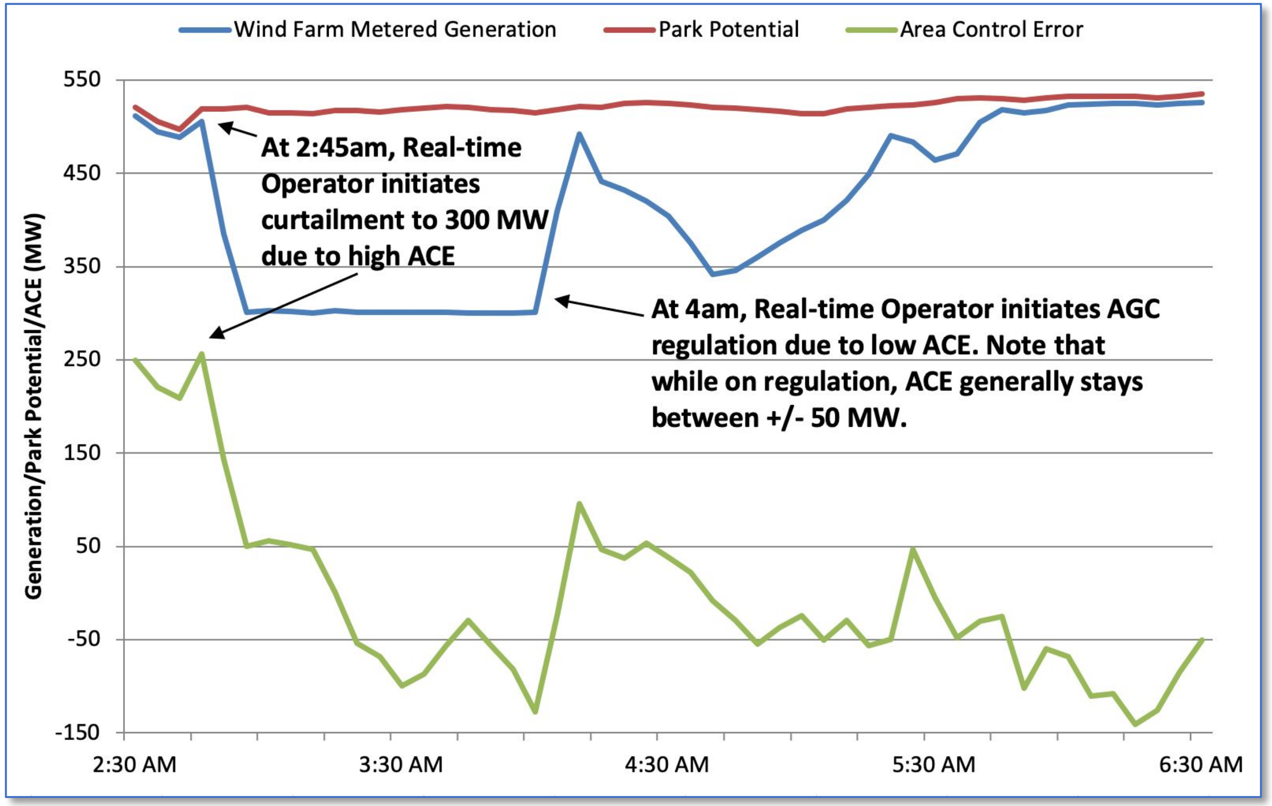
Left: GE Energy, Western Wind and Solar Integration Study, 2010; Right: T. Miller, SPP, ESIG Forecasting Workshop, June 2018

3

Flexibility of non-variable generators



Wind/PV can provide Essential Reliability Services (ERS)



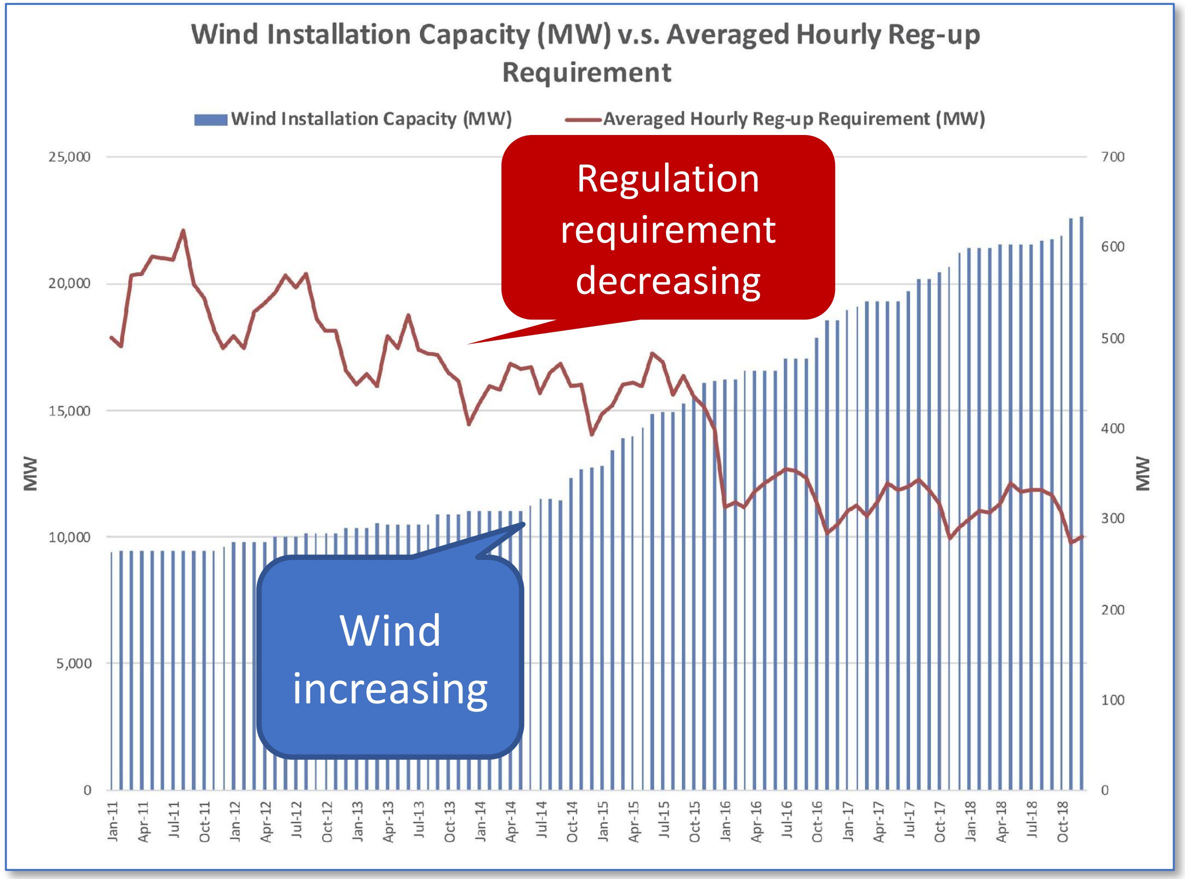
Think of curtailed wind/solar as a *resource*

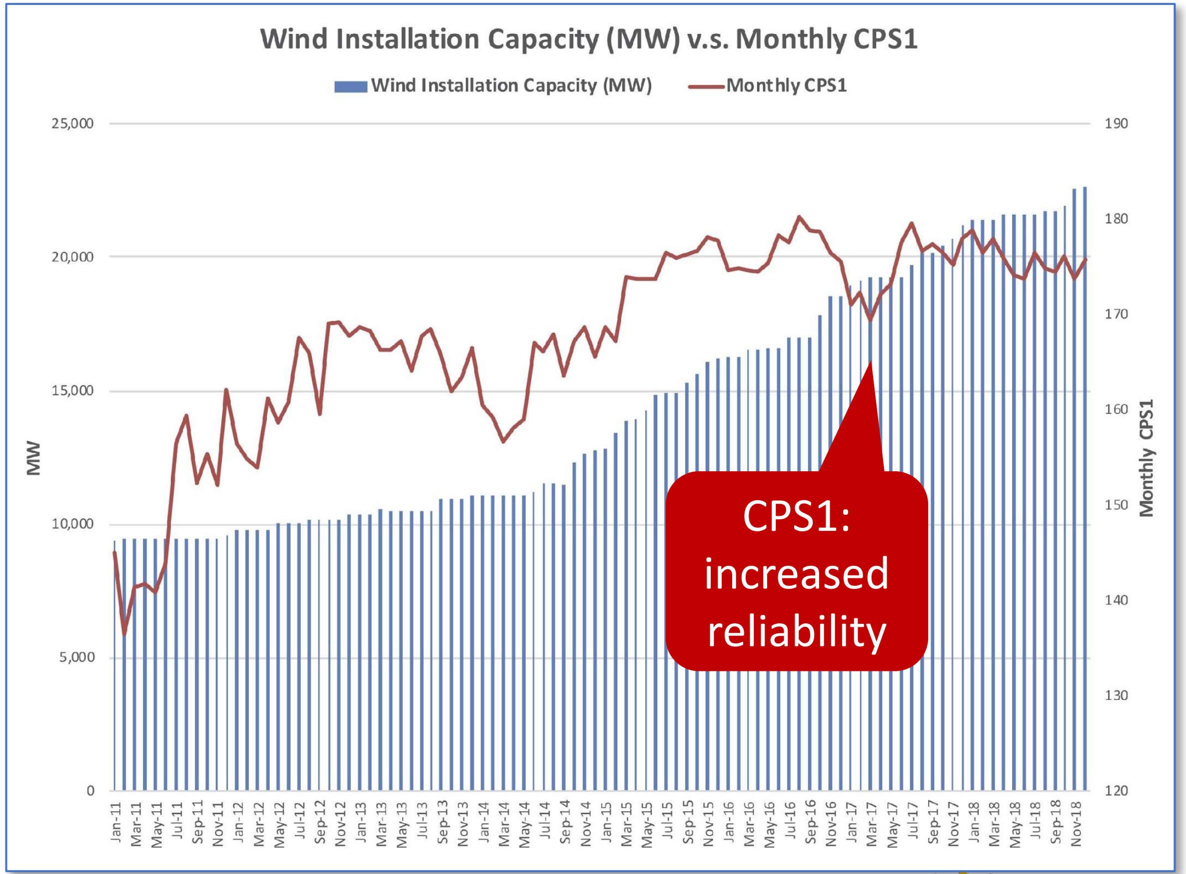
ERS support grid stability. ERS from wind/PV can avoid reliability-must-run thermal resources.

- Dispatch wind/PV to real-time forecasts (as opposed to 'must take' resources and manual curtailment)
- Regulation reserves: Xcel has used wind for regulation reserves for the last decade
- Spinning contingency reserves: Xcel working on this
- Primary frequency response: ERCOT/Quebec/Ontario has required wind/PV to provide this response for several years
- Fast frequency response/synthetic inertia: Quebec/Ontario requirement
- Voltage regulation: wind/PV can provide
- Disturbance ride-through: wind/PV can provide

Lew, et al, "Getting to 100% renewables: operating experiences with very high penetrations of variable energy resources", IET Renewable Power Generation Dec 2020

ERCOT reduces regulation while increasing wind





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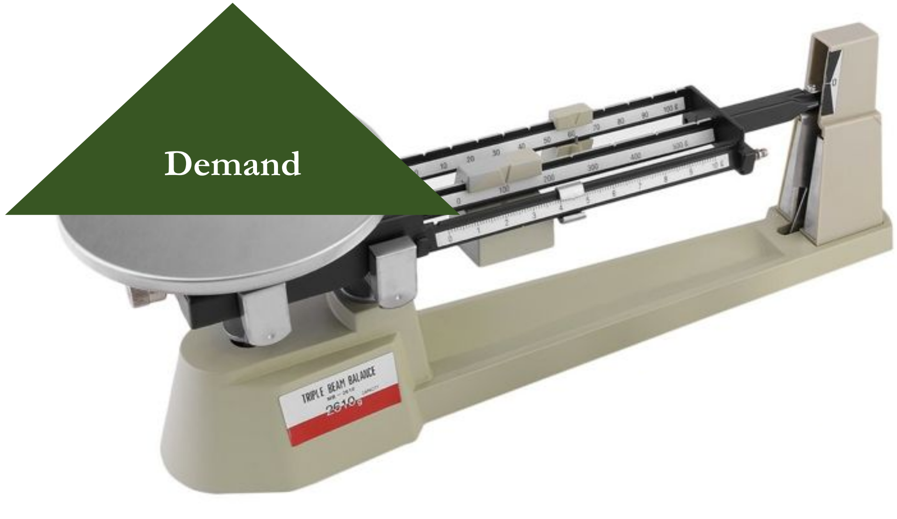
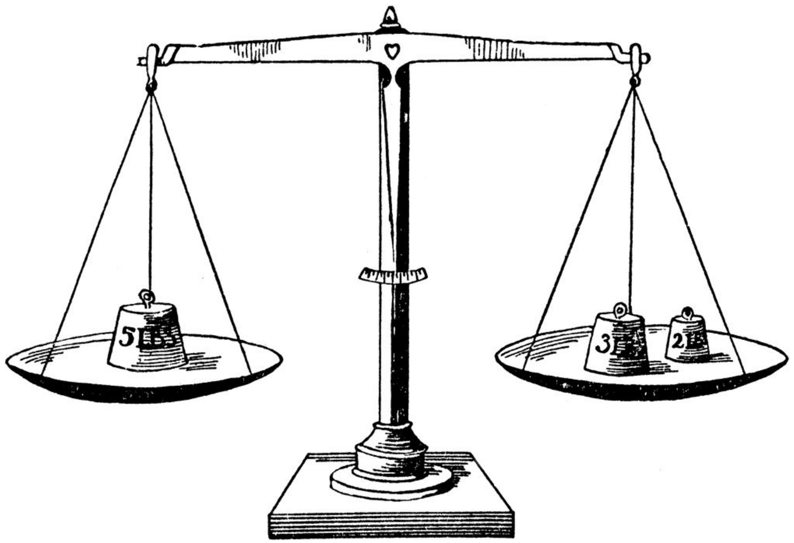
Responsive demand is a game-changer for flexibility





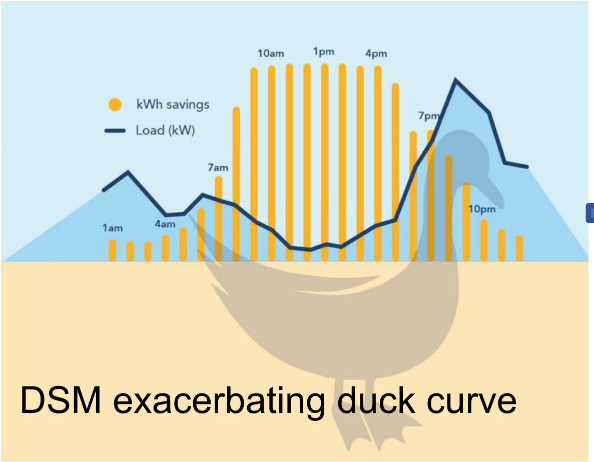
We used to control a portfolio of generators to balance a fixed demand

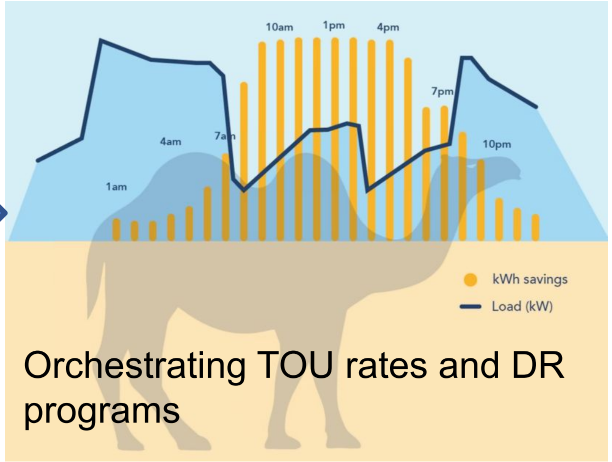
In the future, we'll control **both** demand and generation to balance the system

Instead of using generation to balance demand, will we use demand to balance generation?

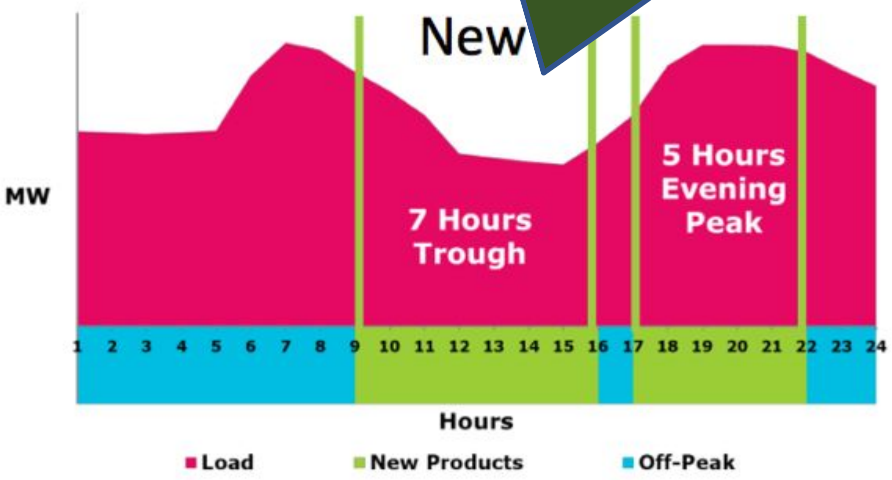
Slide from Lew, Western Interstate Energy Board, Tutorials May 2020

APS orchestrates demand through prices and programs





APS sells cheap midday power to manage the duck curve

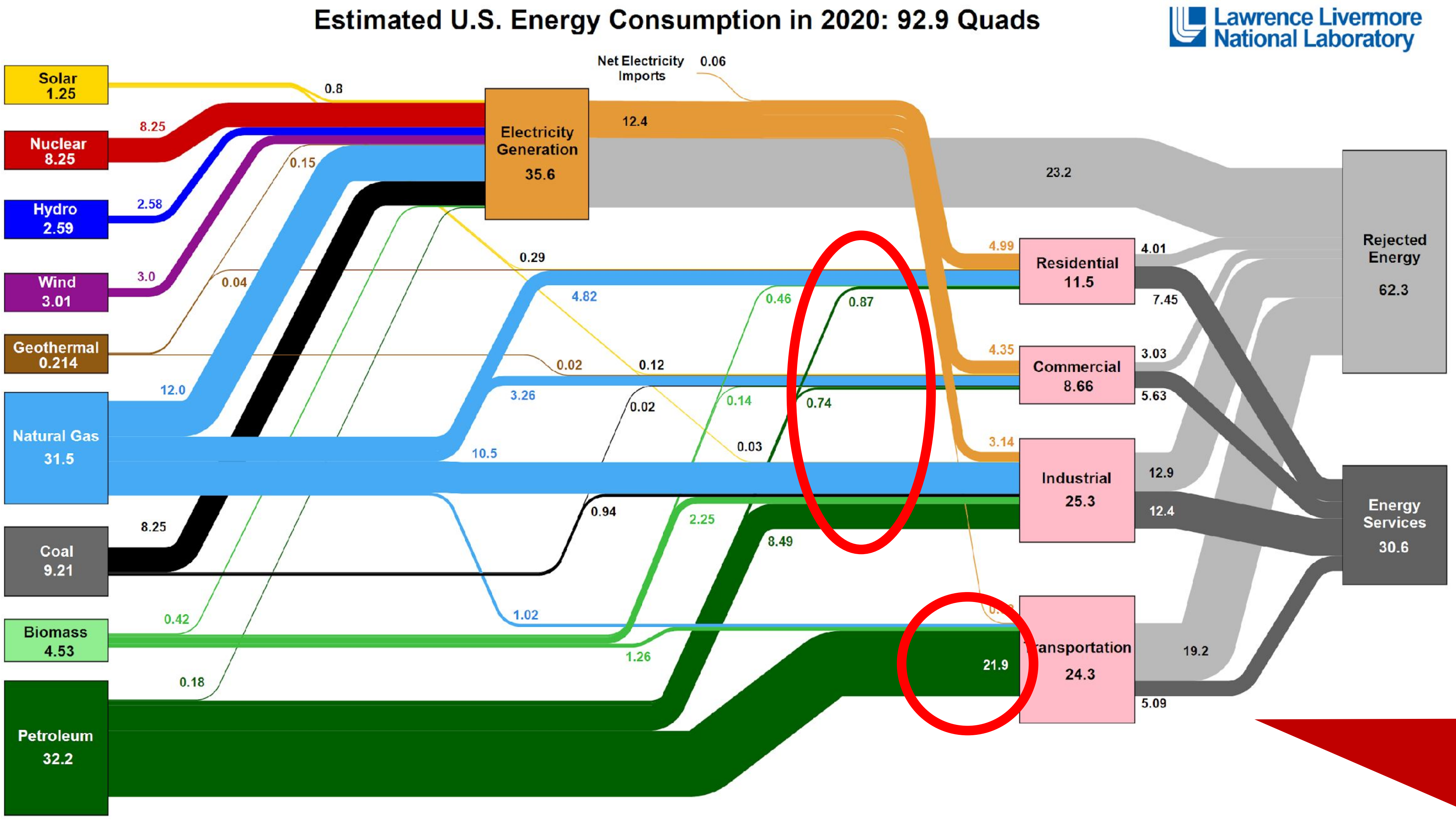


- Prices
- Schedules
- Signals
- Autonomous response

Time-of-use rates can act like storage
Critical peak pricing can act like a gas peaker

Hines, Tierra Resource Consultants, PLMA, Apr 2020; Thompson, APS, "What if Your Neighboring Utility Goes to 100% Renewables," CREPC April 2019

Energy systems integration is key to demand flexibility



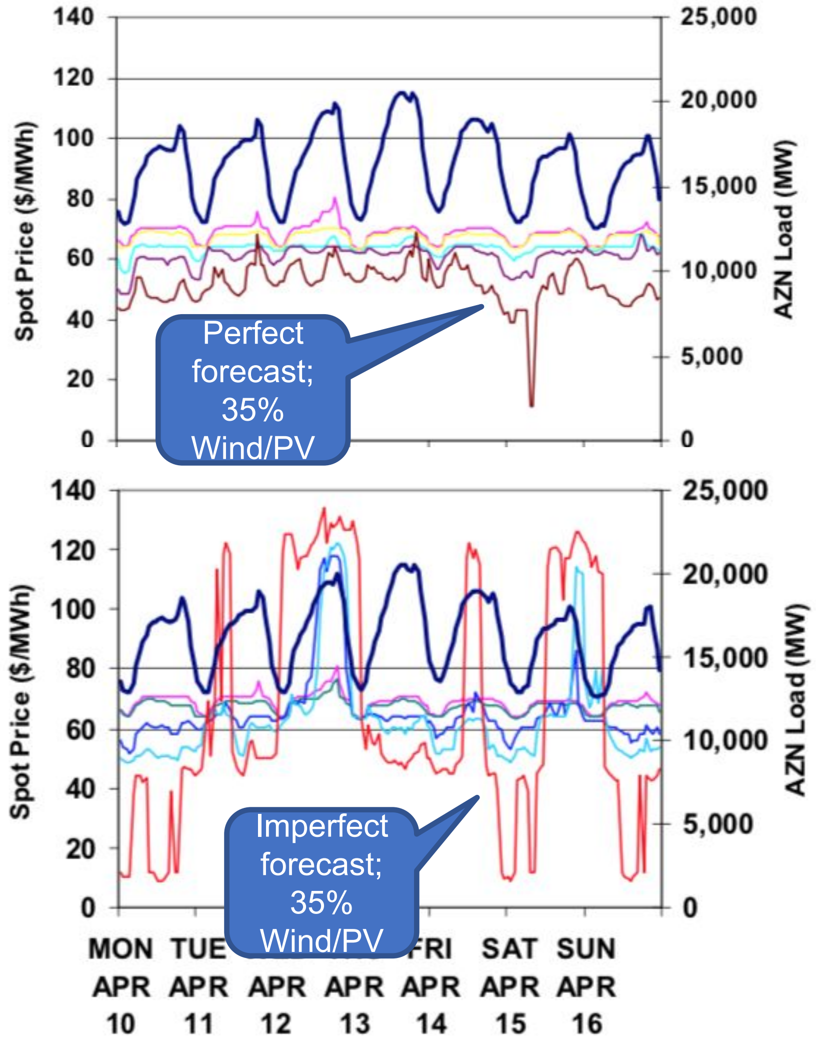
High levels of variable renewables require flexibility that may be cost effectively sourced from the existing fuel-based heating and transportation sectors

https://flowcharts.llnl.gov/content/assets/images/charts/Energy/Energy_2020_United-States.png

6

Thermal and electrical storage provide flexibility

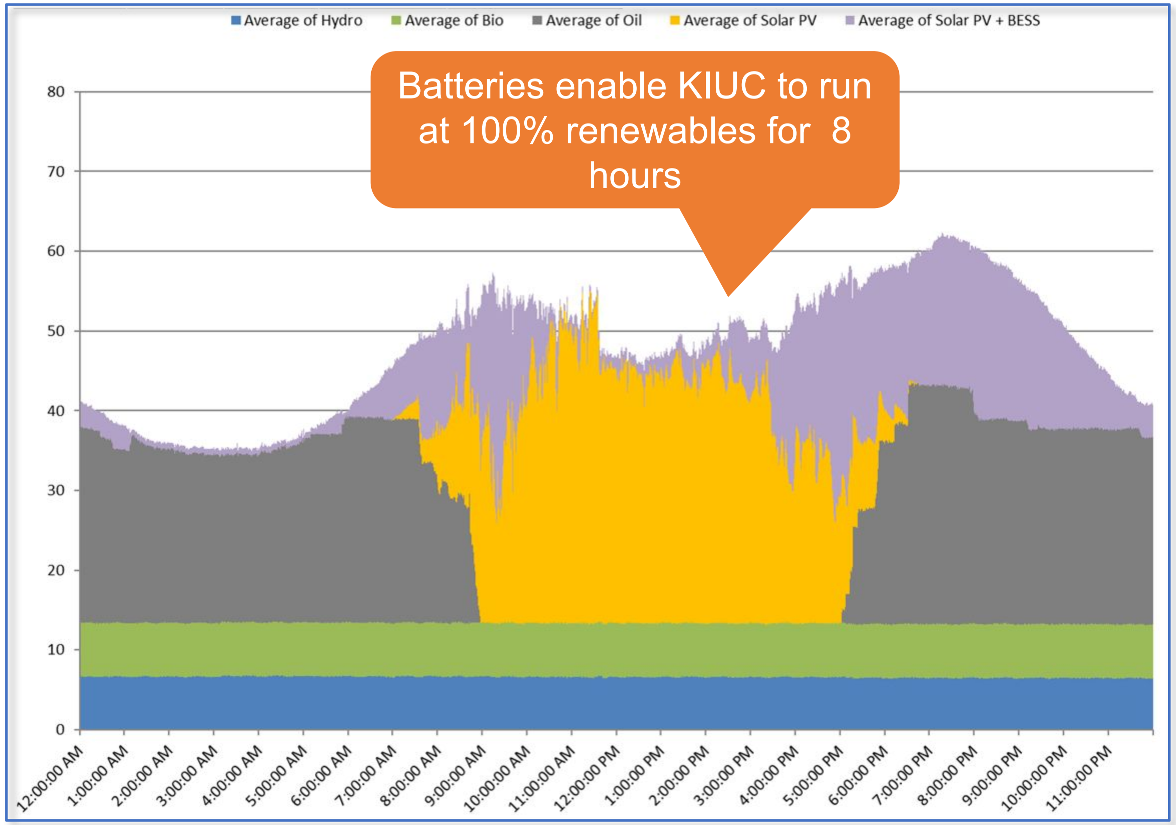
- Synergy between medium-term storage and PV
- A portfolio of storage resources is likely in our future
  - Thermal storage including space/water heating/cooling
  - Long-duration storage (e.g., hydrogen) for resource adequacy
- Forecasting is very important for positioning of storage!



GE Energy, Western Wind and Solar Integration Study 2010.

Kauai pioneered PV/battery hybrid plants

- 78 MW peak demand; 100MW PV; 40 MW storage; zero interconnections
- Ample quick-start diesel reciprocating engines
  - But can't start up fast enough (seconds not minutes) for cloud events
- PV/battery hybrids enable 100% renewables (85% PV) for 8 hours
  - Batteries provide spinning contingency reserves for those PV plants
  - Hold headroom equal to 50% of real time PV output for PV that is not backed by batteries



Lew, et al, "Getting to 100% renewables: operating experiences with very high penetrations of variable energy resources", IET Renewable Power Generation Dec 2020

Conclusions

- Law of large numbers – the bigger the region, the more smoothing of variable renewables and load. This drives the needs for transmission and markets.
- Flexible, responsive demand is the "low hanging fruit". Electrification of other energy sectors can provide this demand flexibility.
- Changes can be made in operations, at low cost, to cost-effectively integrate variable renewables.
- Wind and solar can provide essential reliability services – if you ask them to!

Wind, solar, DERs make it harder to "drive", but we have the tools to manage this!

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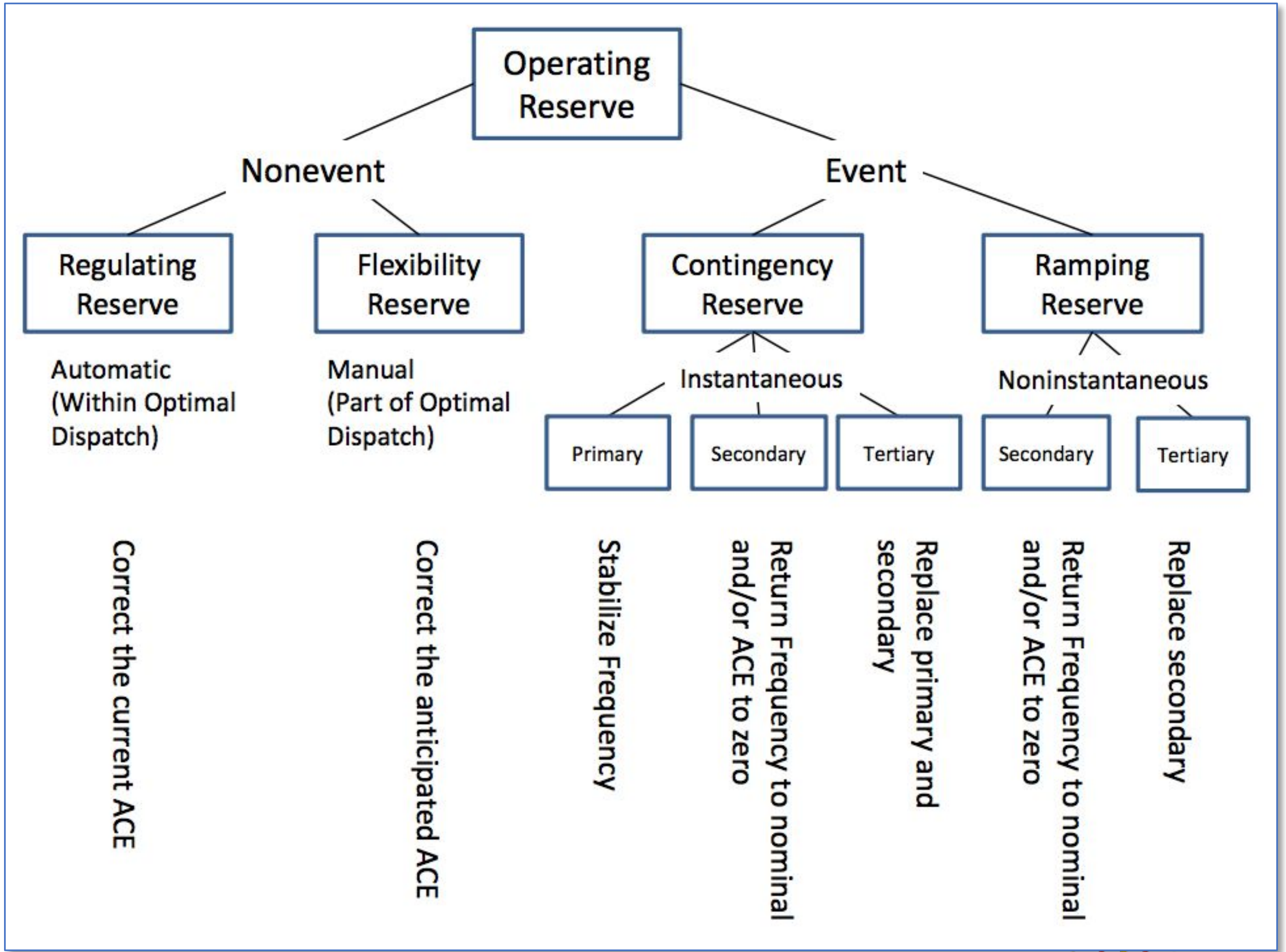
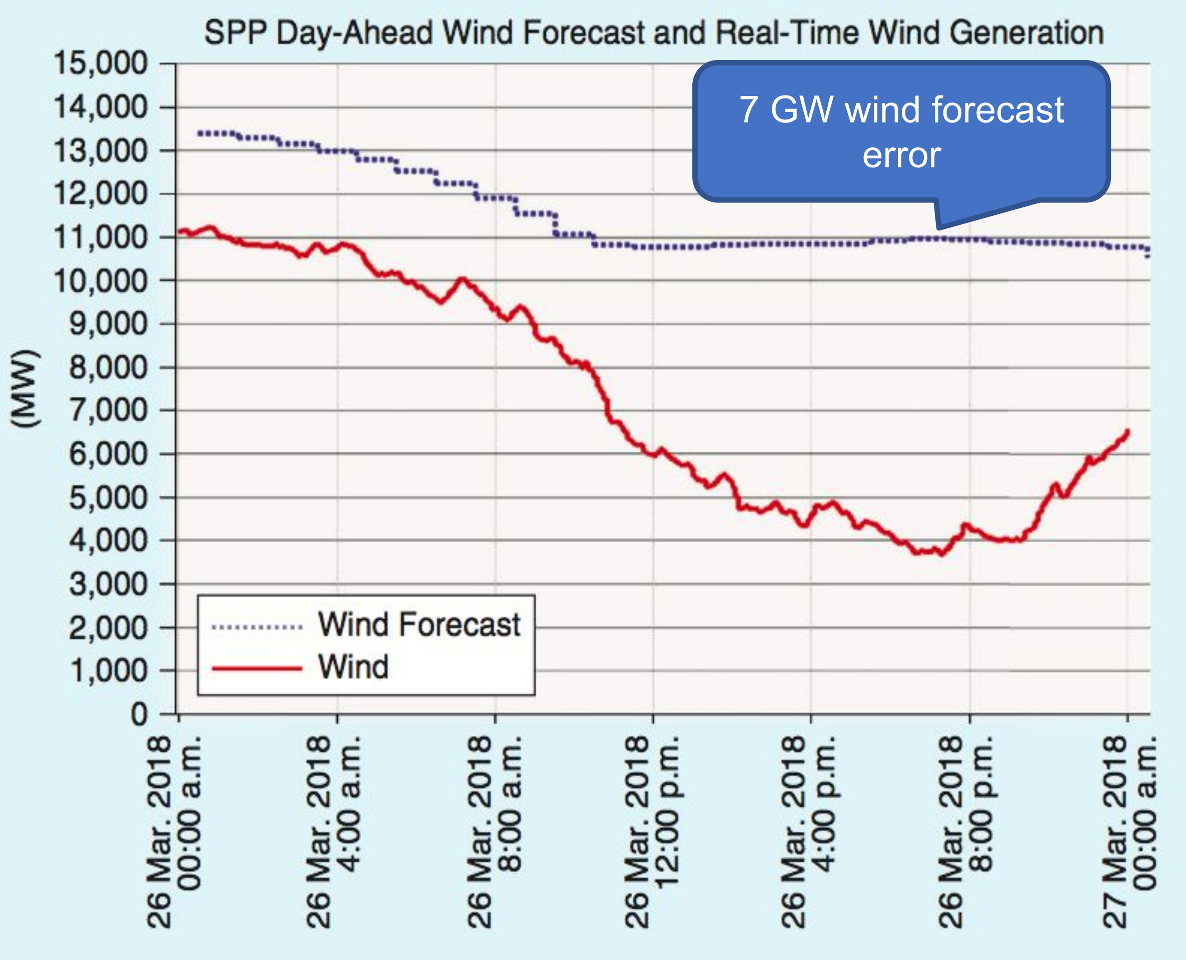
Reserves provide fine control and respond to events



Source: Ela, et al, NREL, 2011 https://www.nrel.gov/docs/fy11osti/51978.pdf

SPP manages large forecast errors

- SPP has 21.4 GW wind, 50.6 GW peak demand, 72% instantaneous penetration
- Low pressure systems cause instabilities and low-level jet stream significantly impacts wind
- Largest wind down ramp was 16.1 GW in 21 hours (was forecast). Largest one-hour ramp was 4 GW
- SPP has 5 GW that can start-up within 1 hour
- What if a forecast error occurred during May 2018 when all quick-starts were committed in DAM? Or during largest wind ramp?
- Uncertainty response team assesses risk in 1, 4, and 8 hour look-ahead horizons over next 7 days



Source: B. Rew, SPP, 2019; Lew, et al, Secrets of Successful Integration, IEEE PES Magazine, Nov/Dec 2019