Evolution of Ancillary Services to Facilitate Integration of Variable Renewable Resources

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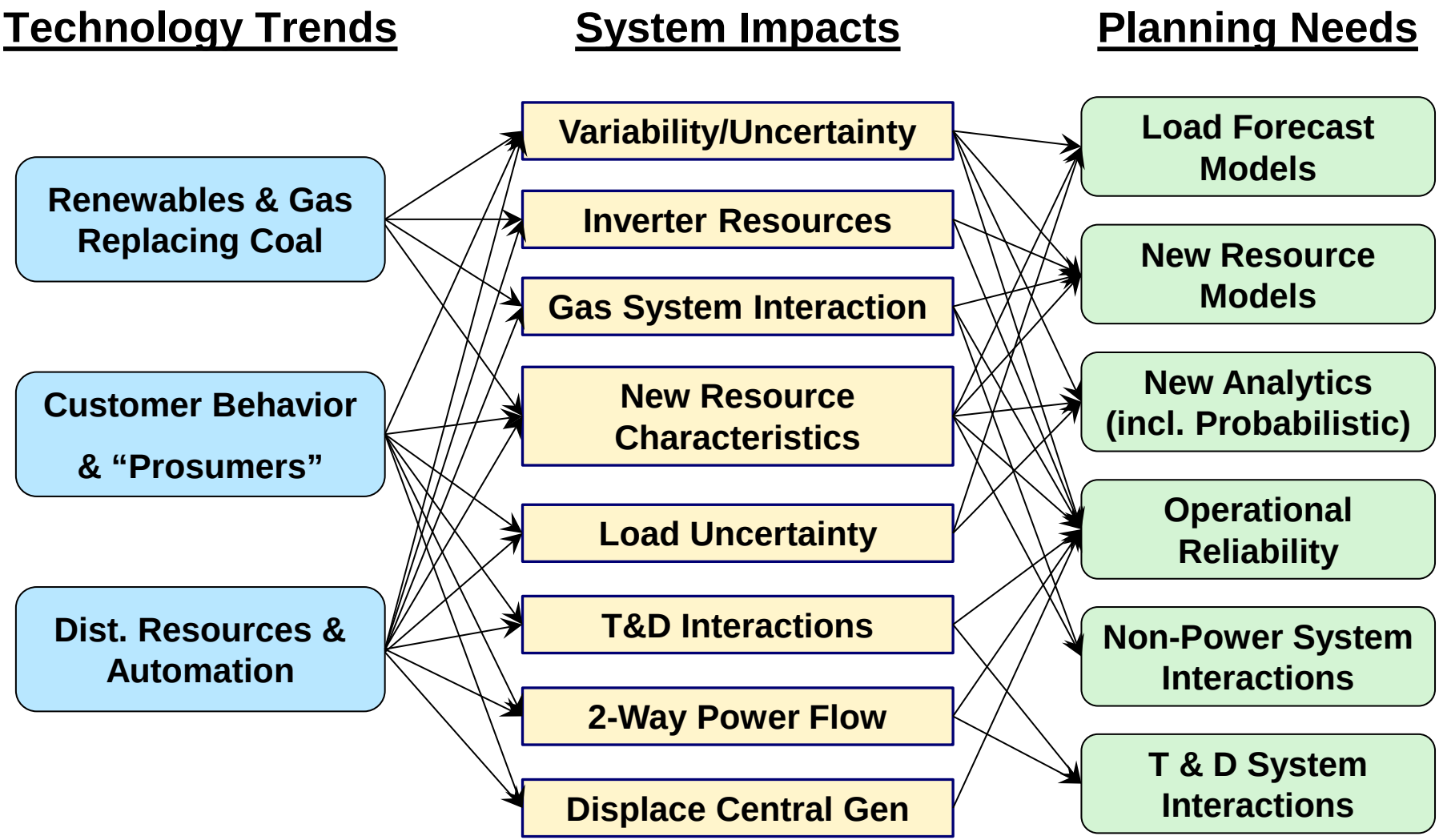
Agenda

- What is changing?
- Ancillary service overview
- Ancillary service and other market design initiatives in the United States
- Evolving ancillary service examples
  - Flexible capacity
  - Ramp products
  - Primary frequency response
  - Voltage control

Emerging System Characteristics & Planning Impacts



Characteristics of VER and Potential Impacts

DER Characteristic	Potential Benefits	Potential Challenges
Point of Interconnection	• T&D deferral • Congestion & losses • Supply capacity	• T&D expansion need • Congestion & losses • Protection • Voltage regulation • Disturbance ride-thru
Visibility & Control (DER)	• Increased potential to manage local issues	• Ops awareness/control • Power flow mgmt. • Balancing
Inverter Interface	• Voltage & frequency support	• Protection • Voltage & Frequency control • Power Quality
Variability & Uncertainty	• Increased diversity	• Forecast challenge • Other resource O&M • Reserves & Flexibility • Frequency and ACE control
Emissions & Fuel Costs	• Low fuel costs • Low emissions	• Revenue Sufficiency

Not all Benefits & Challenges apply to all VER resource types & locations

Ancillary Services (FERC)

1. **Scheduling, system control and dispatch**:

   Provided by the ISO or RTO, *not applicable* to this discussion.

2. **Reactive supply and voltage control from generation service**:

   Generally supplied as a **cost-based** service. **Lost Opportunity Costs** provided if applicable.

3. **Regulation and frequency response service**:

   Today, **regulation** is typically supplied and priced **by dynamic markets** in ISO/RTO regions. It is used to correct ACE. However, **frequency response**, as defined by the droop response of governors autonomously responding to frequency is generally **not included** in any dynamic markets **nor is it given cost-based rates**.

4. **Energy imbalance service**:

   Energy imbalance is typically the service of the real-time markets balancing out the imbalance from the forward markets, and therefore is **priced by the real-time energy markets**. However, some areas have **implemented or proposed new market mechanisms** to support **ramp products** for energy imbalance.

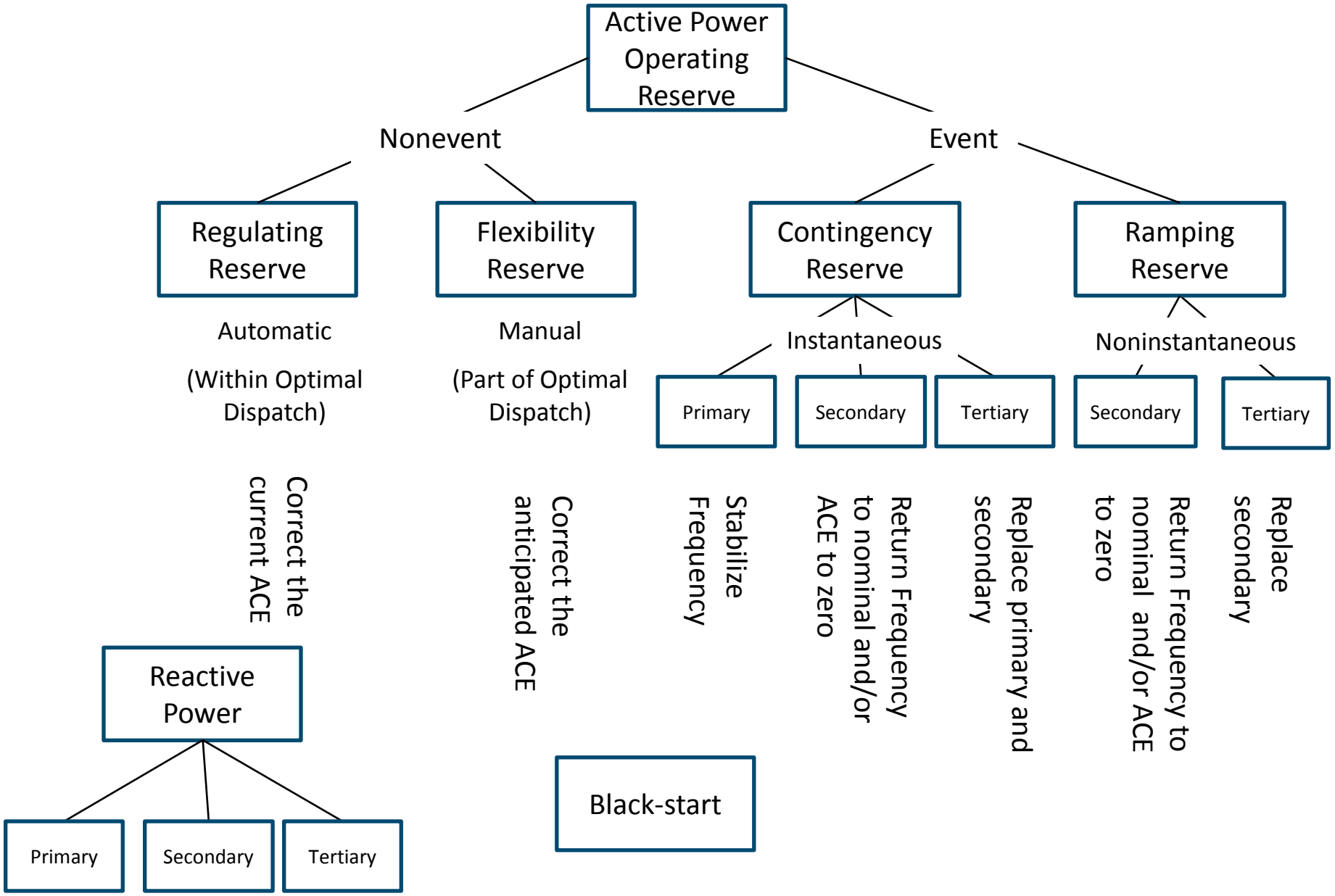
5. **Operating reserve – synchronized reserve service**:

   This service is typically supplied and priced by **dynamic markets** in ISO/RTO regions.

6. **Operating reserve – supplemental reserve service**:

   This service is typically supplied and priced by **dynamic markets** in ISO/RTO regions.

E. Ela, B. Kirby, N. Navid, and J.C. Smith, "Effective ancillary services market designs on high wind power penetration systems," *In Proc. IEEE PES General Meeting,* July 2012.



E. Ela, M. Milligan, and B. Kirby, *Operating Reserves and Variable Generation,* Technical Report, NREL/TP-5500-51978, Aug. 2011.

Y. Rebours et al., "A survey of frequency and voltage control ancillary services—Part I: Technical Features", *IEEE Trans. Power Syst.,* vol. 22, no. 1, Feb. 2007.

ISO/RTO Comparison

	ISO-NE	NYISO	PJM	MISO	SPP	ERCOT	CAISO
Regulation							
Product name	Regulation	Regulation	Regulation	Regulation	Regulation up, Regulation down	Regulation service	Regulation up, Regulation down
Performance component name (details in Table 3-12)	Regulation service	Regulation movement	Regulation performance	Regulating mileage	Regulation-up mileage, Regulation-down mileage	N/A	Regulation mileage up Regulation mileage down
Day-ahead procurement		✓		✓	✓	✓	✓
Real-time procurement	✓	✓	✓	✓	✓	✓*	✓
Contingency Reserves							
Product name—spinning reserve	Ten-minute spinning reserve (TMSR)	Spinning reserve	SR	Spinning reserve	Spinning reserve	Responsive reserve	Spinning reserve
Product name—non-spinning reserve and supplemental reserve	Ten-minute non-spinning reserve (TMNSR); Thirty-minute operating reserve (TMOR)	Non-spinning reserve	Non-synchronized reserve (NSR)	Supplemental reserve	Supplemental reserve	Non-spinning reserve	Non-spinning reserve
Forward (pre-day-ahead) procurement	✓						
Day-ahead procurement		✓	**	✓	✓	✓	✓
Real-time procurement	✓	✓	✓	✓	✓	✓*	✓
Other products							
Product name—ramp reserve				Ramp capability			Flexible ramping product
Ramp reserve—when procured				DAM and RTM			FMM and RTM (not DAM)
Voltage control—payment mechanism provision and capability	Lost opportunity cost and American Electric Power (AEP) method	Lost opportunity cost and fixed tariff rate	Lost opportunity cost and AEP method	Lost opportunity cost and AEP method	Compensation rate for provision	Lost opportunity cost for provision	Provision payment based on lost opportunity cost or contract
Black start service payments	Paid standard black start rate or station-specific rate	Paid cost-based rates	Receive revenue based on 110% of annual black start costs	Receive cost-based rate after committing to 3-year period	Not procured through SPP	Procured through bi-annual competitive process	Contracted through reliability contracts

*ERCOT reserve can be procured as an optional feature as a supplemental ancillary services market (SASM), during the adjustment period only when it is determined that additional regulation is needed

**day-ahead scheduling reserve procured but not identical to synchronized reserve

Common and Unique U.S. Market Design Initiatives

	Common or Similar Initiatives	Unique Initiatives
Energy Markets	• Improved coordinated transaction scheduling (NYISO, ISO-NE, PJM, MISO, SPP, and CAISO) • Combined Cycle Modeling Improvements (PJM, MISO, SPP) • Virtual spread product (e.g., up-to-congestion, or point-to-point) (NYISO, MISO, CAISO) • Pricing of fast start resources (ISO-NE, NYISO, MISO, CAISO)	• Do-not-exceed limits for wind generation (ISO-NE) • Flow control resources as market participants (MISO) • 15-minute three settlement market (CAISO) • Integrated day-ahead market (CAISO)
Ancillary Service Markets	• Regulation pay-for performance improvements (PJM, SPP, CAISO) • Ramp products (MISO, SPP, CAISO) • Primary frequency response (MISO, ERCOT, CAISO)	• Synchronous Inertia service (ERCOT) • Gas system limitations on reserve provision (NYISO) • Reserve product for voltage (MISO)
Financial Transmission Rights	• FTR funding issue resolution and shortfall allocation methods (PJM, MISO, CAISO) • Long-term FTR (ISO-NE, MISO, CAISO) • Incorporating transmission outages into FTR auctions (SPP, CAISO)	• Third-party FTR clearing (ISO-NE) • Rights for PAR-controlled lines (NYISO)
Capacity Markets	• Sloped demand curves (ISO-NE, MISO) • Locational capacity market improvements (ISO-NE, NYISO, MISO) • Performance incentives (ISO-NE, NYISO, PJM) • Locational price hedging (NYISO, PJM, MISO)	• Flexible capacity procurement (CAISO) • Changing from annual to seasonal markets (MISO)

Ancillary Service Market Initiatives

ISO/RTO	Market design topic
ISO-NE	Additional 30-minute reserve requirements Regulation market – energy neutral AGC signal Forward Reserve Market Changes Day-ahead energy and reserve co-optimization Price responsive demand participation
NYISO	Improving shortage prices Recognition of gas system limitations when scheduling reserve
PJM	Revisions to RegD product Replacement of Day-ahead Scheduling Reserve to Real-time Reserve Regulation Market Performance Impacts Synchronized Reserve Tier 1 Compensation
MISO	30 minute reserve product (or other pricing mechanism) for accounting voltage and local reliability rules AGC Enhancement for Fast Ramping Resources Short-term capacity reserve Frequency Response Service Compensation for Restoration Energy Recognize supplemental reserve to provide reserve when starting up Eliminate Guarantee Payments to Deployed Spinning Reserves
SPP	Ramp-constrained shortage pricing Regulation mileage calculation Ancillary Service product substitution assignment changes
ERCOT	Design of new products: Primary Frequency Response Service, Fast Frequency Response Service, Synchronous Inertia Service, Fast Responding Regulation Service Other refinements to ancillary service products Co-optimization of energy and ancillary services in real-time
CAISO	Flexible ramping constraint and Flexible Ramping Product Pay for performance regulation implementation 30-minute contingency requirement and pricing Frequency Response requirements and incentives Contingency Reserve Locational Requirements Contingency Reserve Cost Allocation Reactive Power Compensation

New and Evolving Ancillary Services

Industry Relevance

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  - Flexible ramp product
  - Flexible capacity procurement
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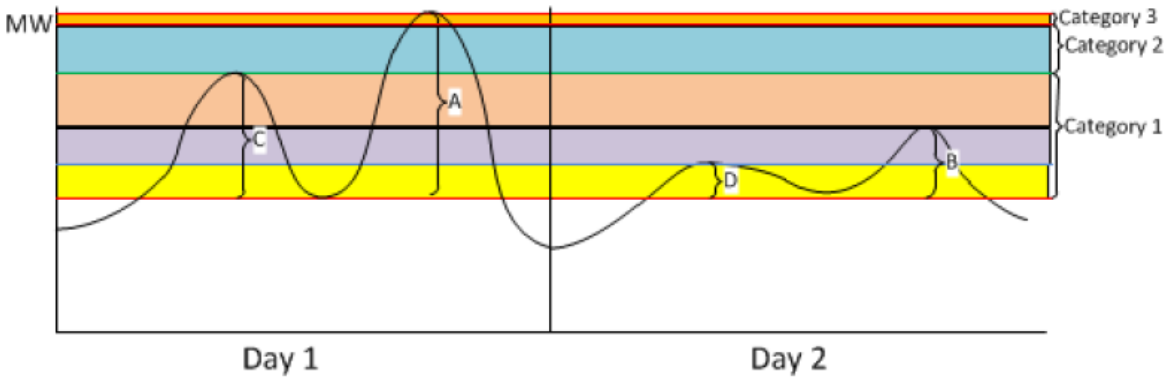
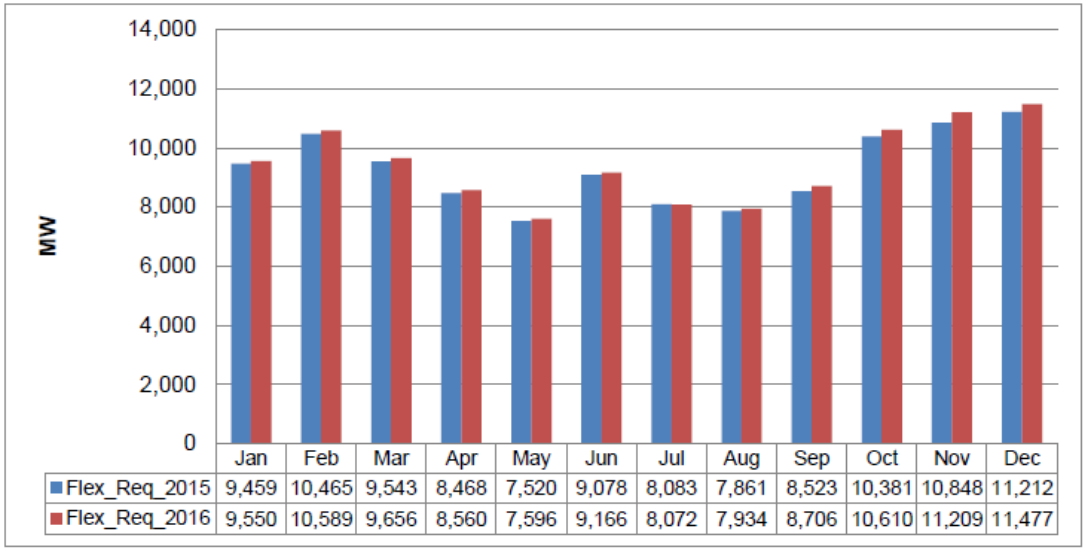
  - Ramp capability product
  - Voltage and Local Reliability Service
- 

  - Reserve for long-term wind ramps that are not regulation or contingency
-
  - Wide scale reorganization of ancillary service products
  - Primary frequency response, fast frequency response, inertia service
  - Regulation requirements based on forecast error characteristics
- Performance-based regulation service (*FERC Order 755*)

California Flexible Capacity Procurement

- Flexible ramp need: Max 3-hour ramp rate per month + contingency reserve
- Three types:
  - Base flexibility
  - Peak flexibility
  - Super-peak flexibility
- Allocation to system flexibility capacity needs allocated to LSEs based on contribution to 3-hour net load ramp





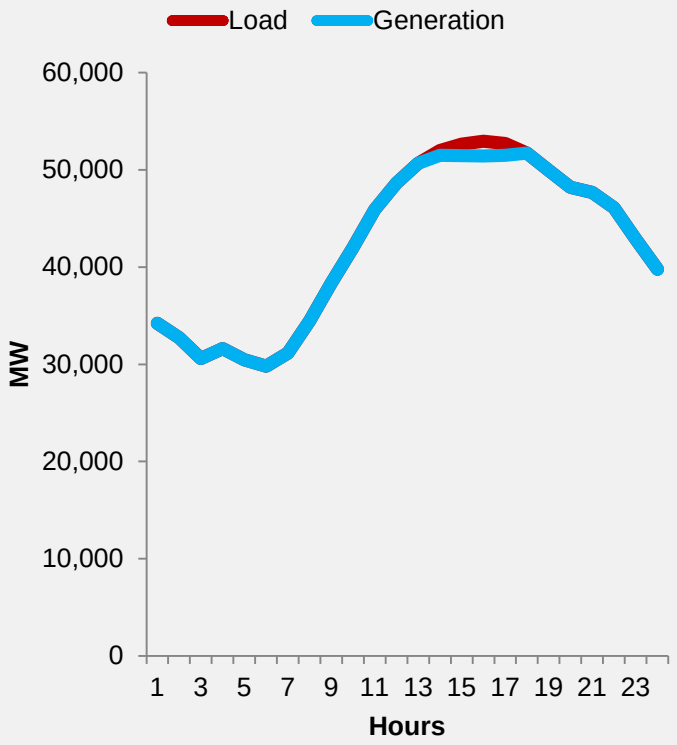
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flex_Req_2015	9,459	10,465	9,543	8,468	7,520	9,078	8,083	7,861	8,523	10,381	10,848	11,212
Flex_Req_2016	9,550	10,589	9,656	8,560	7,596	9,166	8,072	7,934	8,706	10,610	11,209	11,477

Definitions of Existing and New Reliability Metrics

Traditional "Generic Capacity" Metrics

$LOLE_{GENERIC-CAPACITY}$

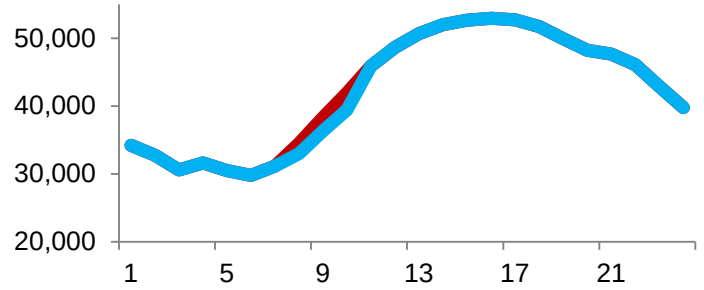
Traditional metric to capture events that occur due to capacity shortfalls in peak conditions



New "Flexible Capacity" Metrics

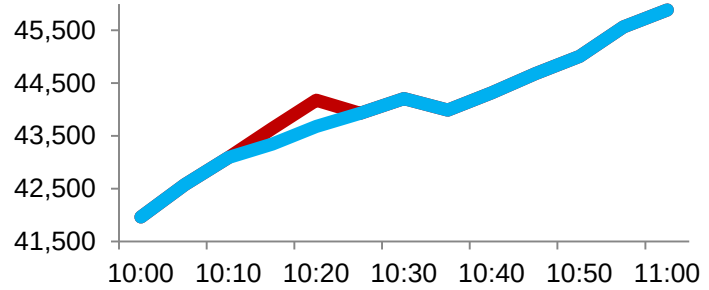
$LOLE_{MULTI-HOUR}$

New metric to capture events due to system ramping deficiencies of longer than one hour in duration



$LOLE_{INTRA-HOUR}$

New metric to capture events due to system ramping deficiencies inside a single hour



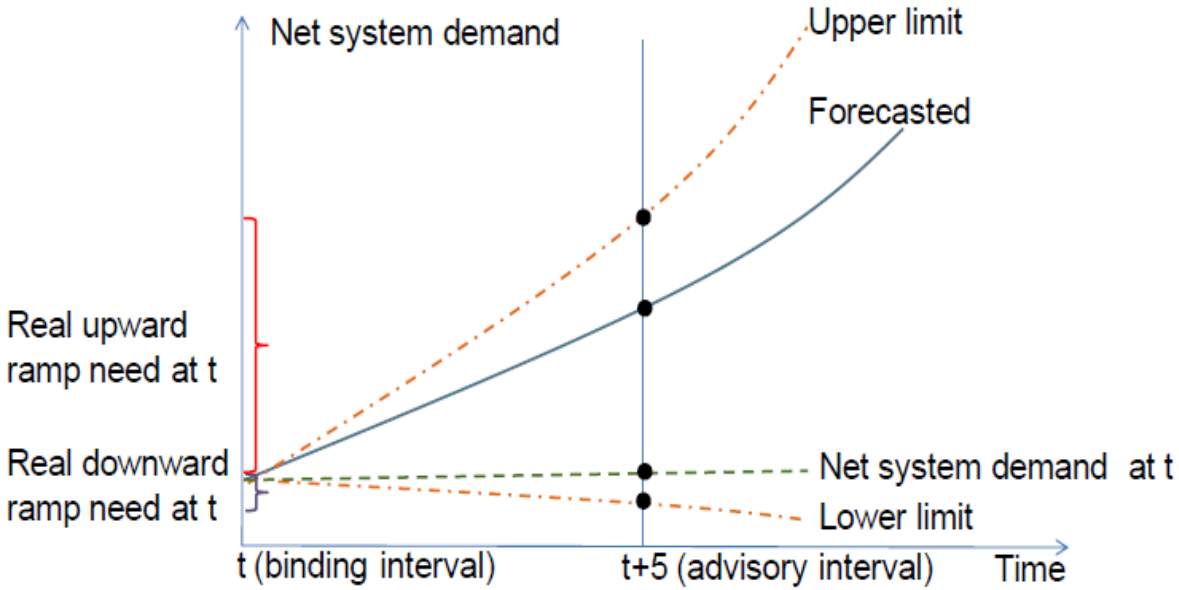
CPUC Workshop – Draft

Flexible ramping reserves

- Requirements based on short-term variability and uncertainty
  - Confidence intervals inform requirements
  - Low-priced demand curves
- **MISO**: Went live May 1, 2016
- **CAISO**: Approved by Board, not submitted to FERC yet
  - Flex ramp constraint live since 2012

California ISO
Shaping a Renewed Future

Net system demand = load + export – import – internal self-schedules - supply deviations



Real ramping need:
Potential net demand change from interval t to interval t+5
(net system demand t+5 – net system demand t)

FIGURE 2: REAL RAMPING NEED

Ramp products compared to other ancillary services

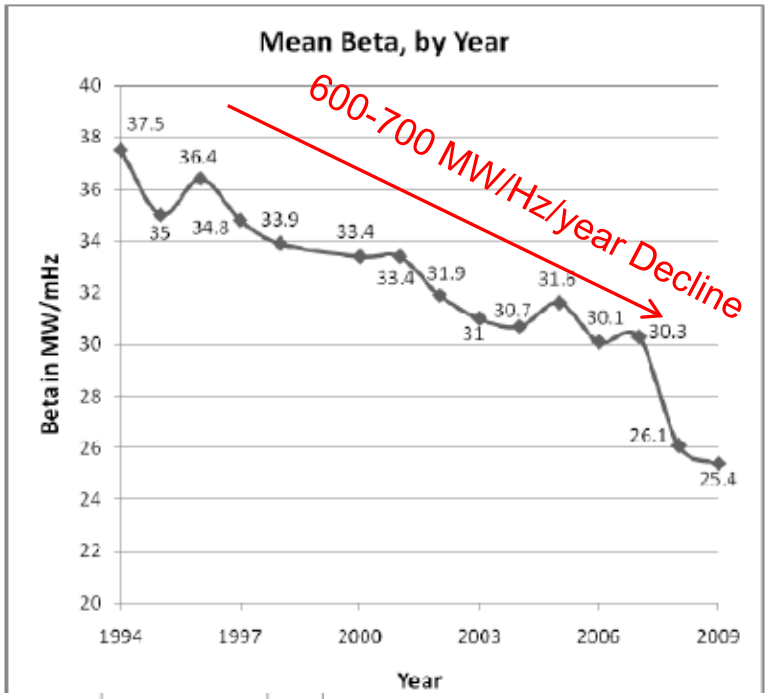
	Regulation	Spin and non-spin	Ramp product
What Guides Response	Automatic (AGC)	Operator-directed	SCED
Frequency of Use	Every interval	Rarely	often
What it is used for	Short-term changes in load and VER	Contingencies	Forecast errors and (several minutes timeframe) ramp events
Penalty Price	$80-$600 /MW-h (medium)	Typically >= $500 /MW-h (high)	Between $5 and $250 /MW-h (low)
Non-zero Bids Allowed	Yes: wear and tear and efficiency costs	Sometimes	No
When Deployed	After dispatch interval (in between RTSCEDs)	After dispatch interval (sometimes through new dispatch, e.g., RTD-CAM RPU, RTCD)	Part of dispatch interval

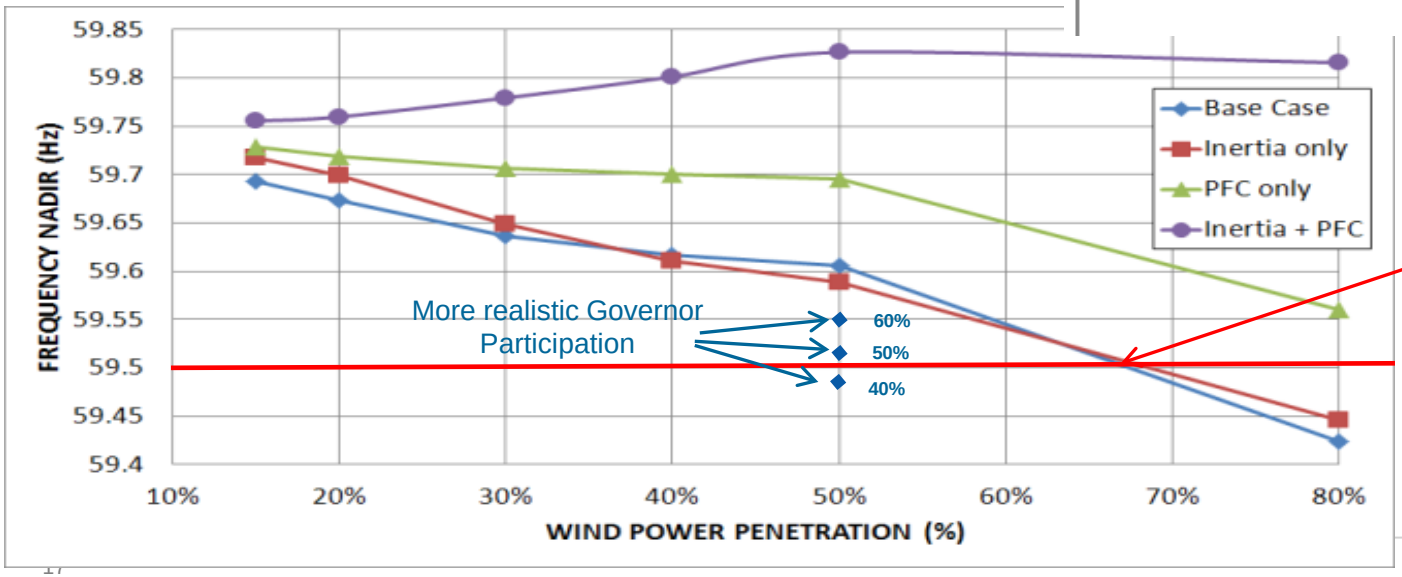
CAISO and MISO approach comparison

	MISO	CAISO
Ramp horizon time	10 minutes (2 RTSCED intervals)	5 minutes (1 RTSCED interval)
Insufficiency cost (scarcity price for ramp product)	$5/MW-h	Stepped demand curve ($11 to $250/MW-h for upwards)
Requirement	Expected Variability + 2.5σ (uncertainty)	Expected variability + 95th percentile (uncertainty)
Markets	DAM, LAC, and RTM	FMM and RTM (not DAM)
Deliverability	Post-deployment deliverability constraints	

Frequency Control

- Current issues exist
  - Governor dead bands
  - Blocked governors
  - Operational modes (e.g., sliding pressure)
- Variable renewables (wind and PV) are non synchronous resources and do not inherently provide inertia or frequency control

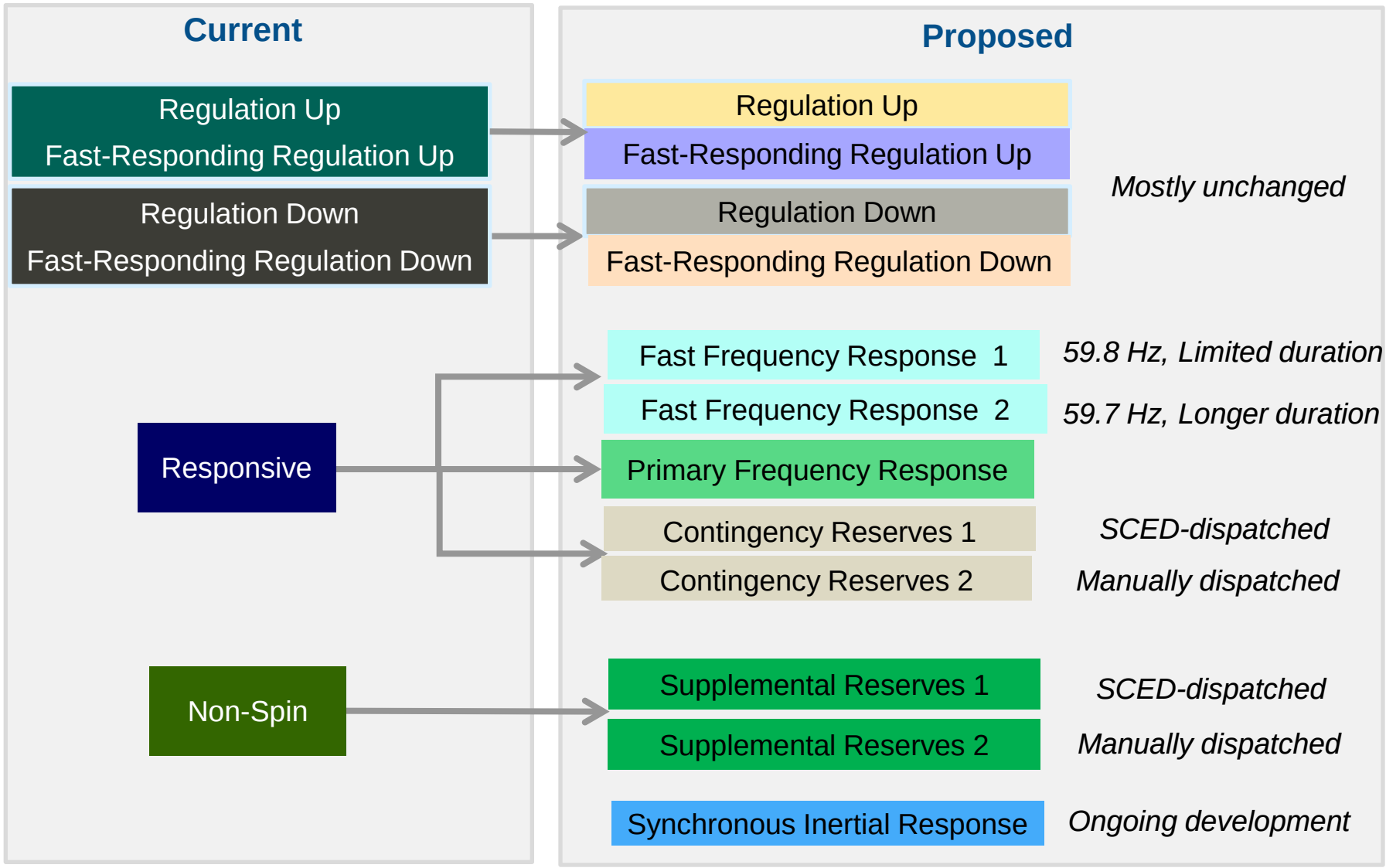




J. Ingleson and E. Allen, "Tracking the Eastern Interconnection Frequency Governing Characteristic," IEEE Power and Energy Society General Meeting 2010.

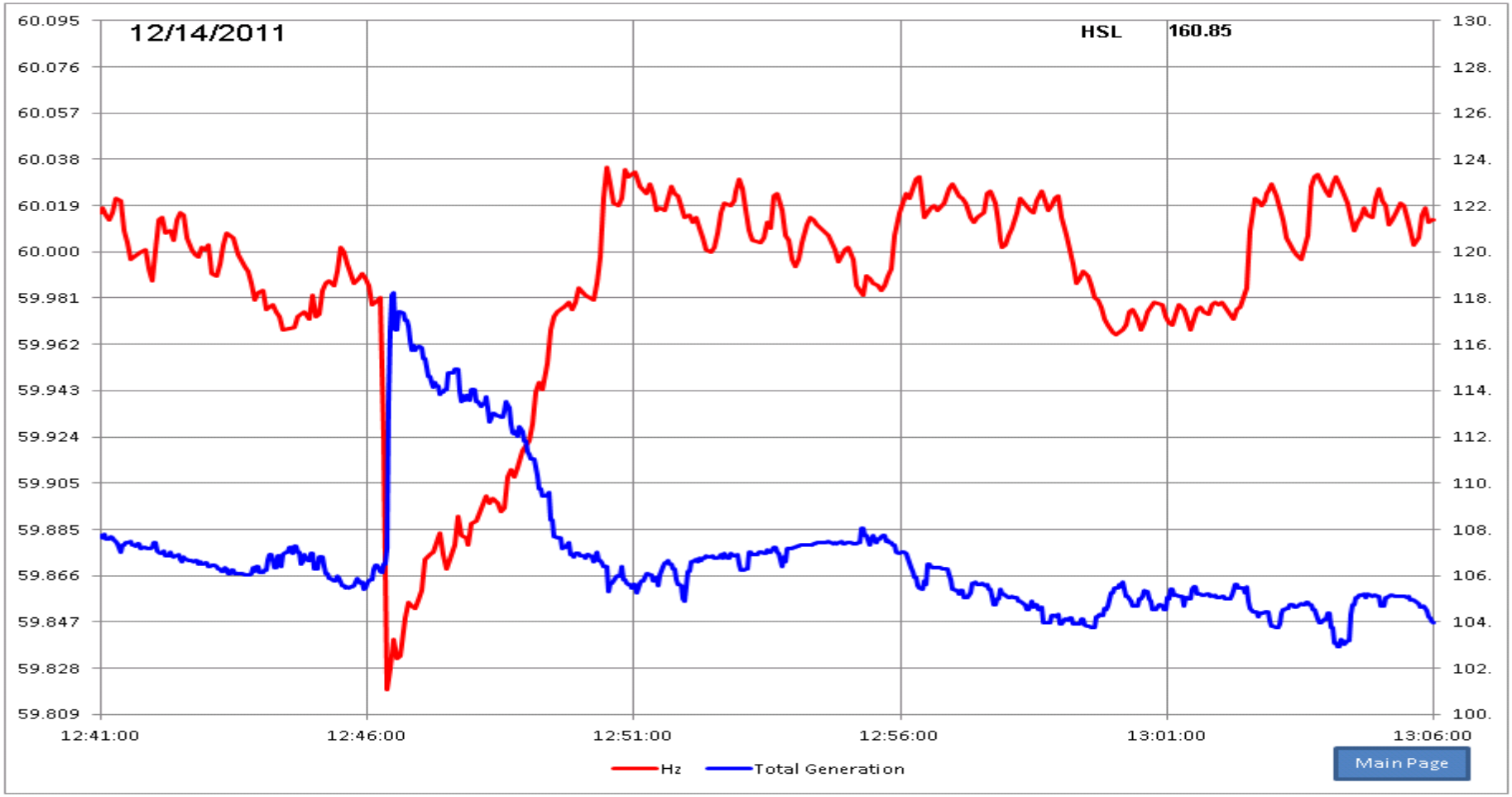
E, Ela et al., *Active Power Control from Wind Power: Bridging the Gaps,* NREL Technical Report, December 2013.

ERCOT Proposed Ancillary Services



www.ercot.com

VG can be a solution

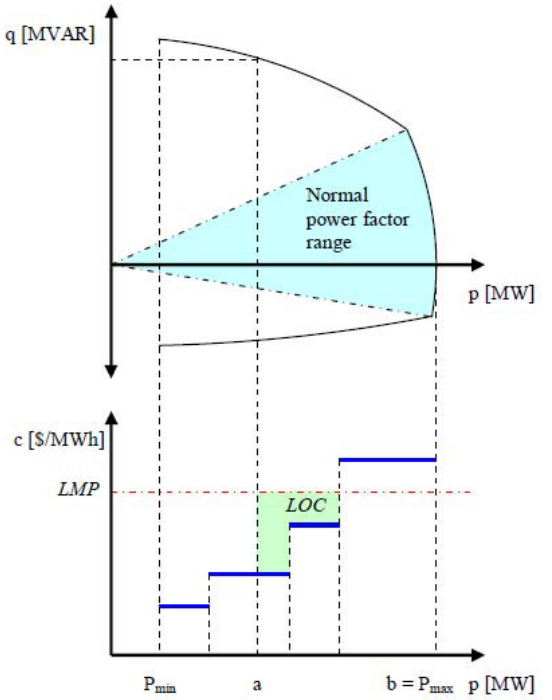


Wind (and solar) can provide many of the services they displace– need to enable controls and compensation/requirements

SOURCE: Sandip Sharma, ERCOT, "Frequency control requirements and performance in ERCOT ISO," presented at EPRI/NREL/PJM Inverter Generation Interconnection Workshop, Apr 11-12, 2012.

Volt/VAR Compensation

- Volt/VAR service, as a FERC rate schedule is compensated mostly through cost-based rates
- Lost opportunity cost: The profit a supplier foregoes by not selling a product, because it sold a separate product
  - Used for generally all active power ancillary services in all markets in the U.S. (synch. reserve, non-synch reserve, regulation, ramp product)
- Compensation scheme for reactive supply in ISO markets in addition with fixed cost recovery



K. Abdul-Rahman et al., "Considerations of Reactive Power/Voltage Control in CAISO Market Operations," 2011 PES GM.

Decrease P

LMP=$50/MWh

Offer_Cost=$40/MWh

P_economic=100MWh

P=80MWh (due to reactive support)

LOC=(100-80)*(50-40)=$200

Increase P

LMP=$50/MWh

Offer_Cost=$60/MWh

P_economic=30MWh (mingen)

P=50MWh (due to reactive support)

Payment=(50-30)*(60-50)=$200

MISO VLR Market Design

- Voltage and Local Reliability (VLR) needs in MISO have increased dramatically since MISO-South integration
  - About $90M in uplift increase with addition of MISO-South, mostly based on VLR
- MISO Forward Reliability Assessment Commitment incorporates series of binary constraints that ensure VLR in specific areas
  - Improves scheduling and reduces need for manual actions
  - Still does not necessarily provide price separation or incentives
- MISO's IMM recommending a 30-min reserve product to represent VLR as an ancillary service to provide incentives for quick-start generation
  - Would provide price incentives for the service in those locations that need it

KV1 Units

	U3 + U2 + U1	U3 + U1	U3 + U2	U1 + U2	U3	U1	U2	0/3
4/4 Committed	.....	.....	.....	.....	.....	.....	.....	L6
3/4 Committed U4+W5+W6	.....	.....	.....	L6	L6	L5	L5	L4
3/4 Committed U5+W5+W6	.....	.....	.....	L6	L6	L5	L5	L4
3/4 Committed U4+U5+W5	.....	L6	L6	L6	L6	L4	L4	L4
3/4 Committed U4+U5+W6	.....	L6	L6	L6	L6	L4	L4	L4
2/4 Committed U4+W5	L5	L4	L4	.....	.....	.....	.....	.....
2/4 Committed U4+W6	L5	L4	L4	.....	.....	.....	.....	.....
2/4 Committed U5+W5	L5	L4	L4	.....	.....	.....	.....	.....
2/4 Committed U5+W6	L5	L4	L4	.....	.....	.....	.....	.....
2/4 Committed W5+W6	L5	L4	L4	L4	L4	.....	.....	.....

Y. Chen et al., "Voltage and Local Reliability Commitment under Electricity Market Operation," *IEEE PES General Meeting,* 2016.

Together…Shaping the Future of Electricity

Questions?