National Renewable Energy Laboratory
Innovation for Our Energy Future

Incorporating Variability and Uncertainty into Operating Reserves Modeling

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NREL Studies

- Reserve Requirement Method Determination: The WECC Operating Committee, along with member support from the Variable Generation Subcommittee (VGS), has created the Operating Reserve Task Force (ORTF)
  - The task force is looking at comparing reliability and costs metrics of using different reserve requirement methods with different penetrations of VG

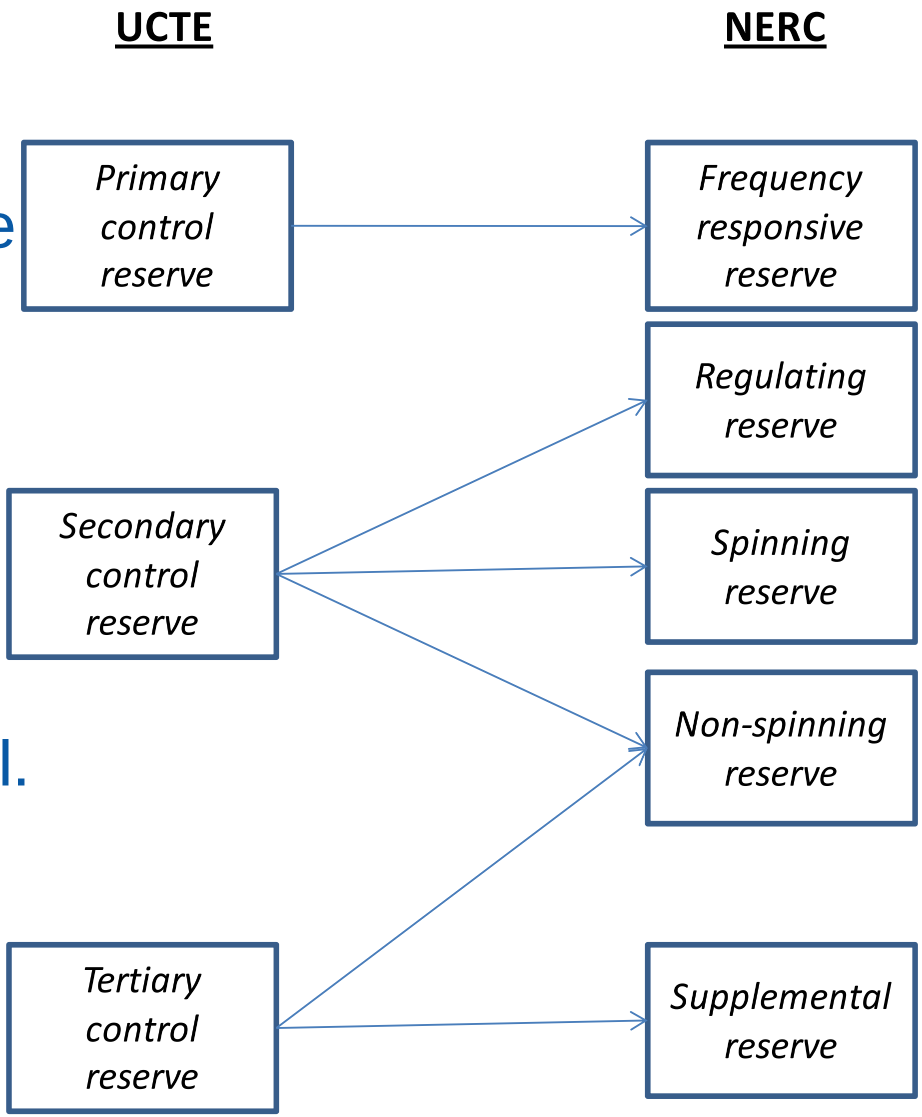
- Innovative Electricity Market Design: Evaluating current energy, capacity, and ancillary service market designs to look at ways to incentivize increased flexibility from the supplier

Practical Definitions

- **Operating Reserves**: Capacity above or below that which is scheduled for expected average demand and used within some time frame to maintain the active power balance of the system during operations
  - Upward and downward response at all time scales
- For multitude of reasons:
  - Maintain frequency at nominal level (60 Hz in U.S.)
  - Reduce Area Control Error (ACE) to zero
  - Assist neighboring balancing authority
  - Reduce over flow of transmission lines and transformers
  - Better economically prepare for variability and uncertainty
- Reactive Power Reserves: Reactive Power capacity to facilitate voltage control (*not discussed here*)
- Planning Reserves: Long term installed capacity to ensure system adequacy (*not discussed here*)

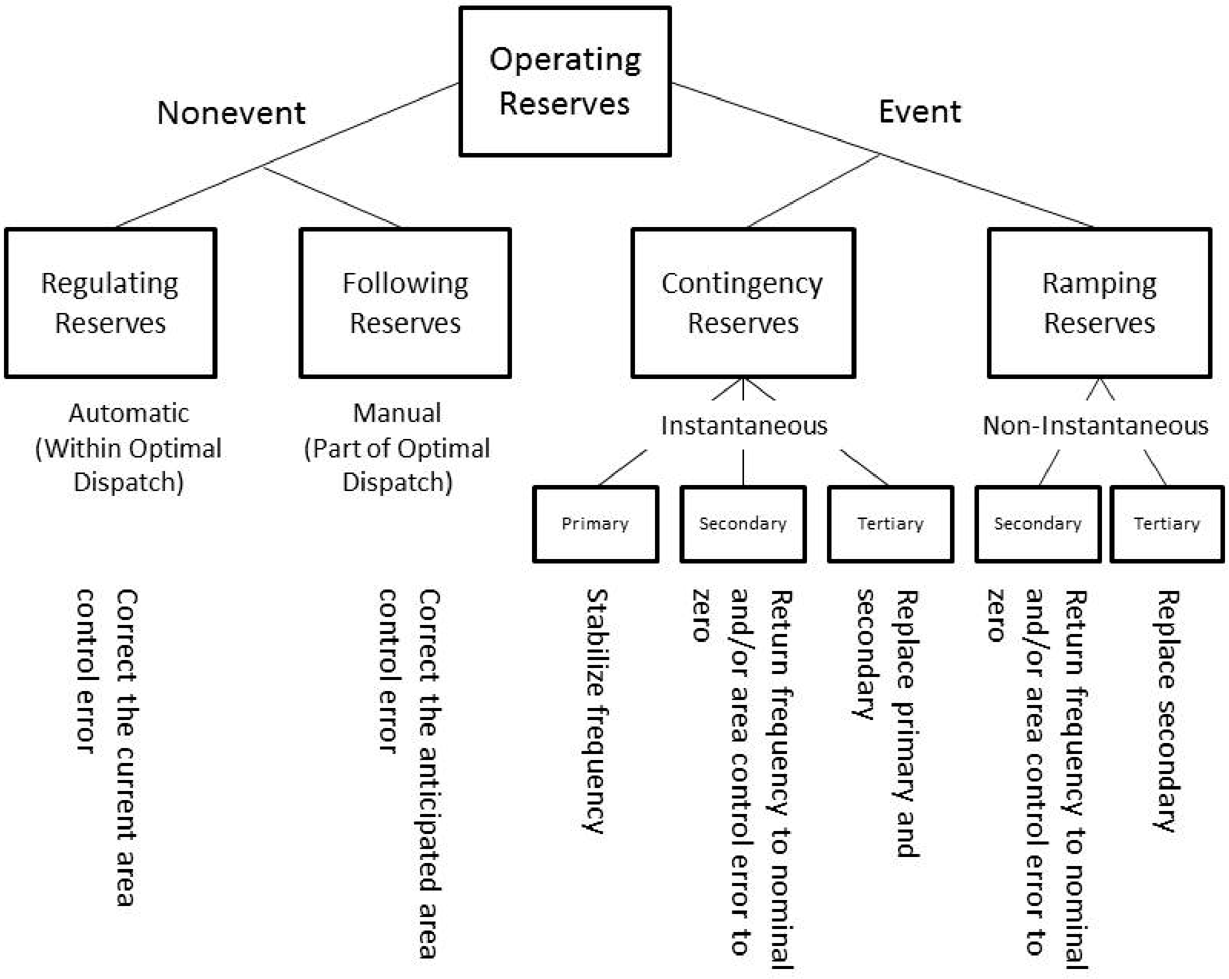
Modeling Definitions

- **Operating Reserves**: Capacity above or below the energy used to meet the expected average demand, implicitly or explicitly held in one time frame and scheduling model, and deployed in a future time frame and scheduling model.



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

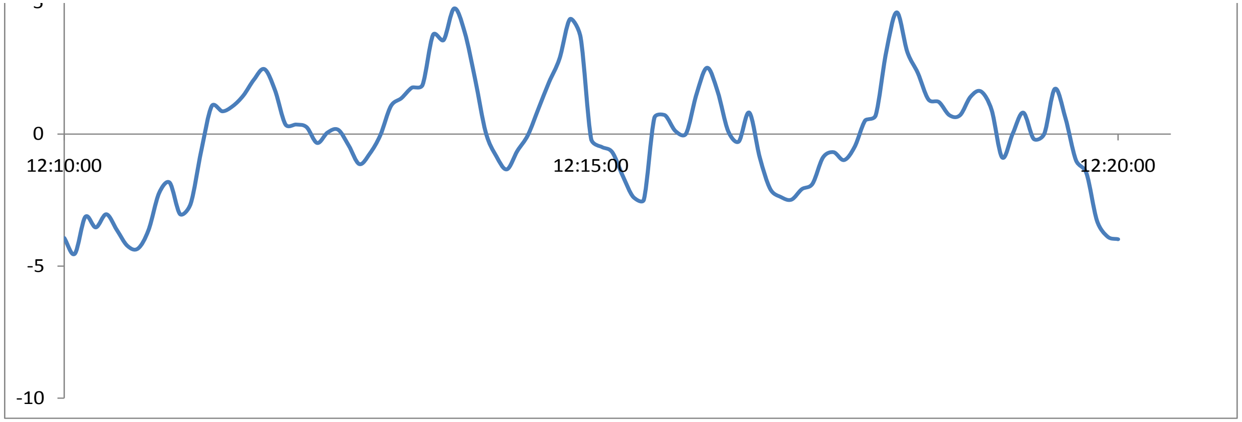
Operating Reserve Categorization



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

Why does one need operating reserve

1. Hold now to meet the **variability** that occurs **faster** than the **current** scheduled time interval.

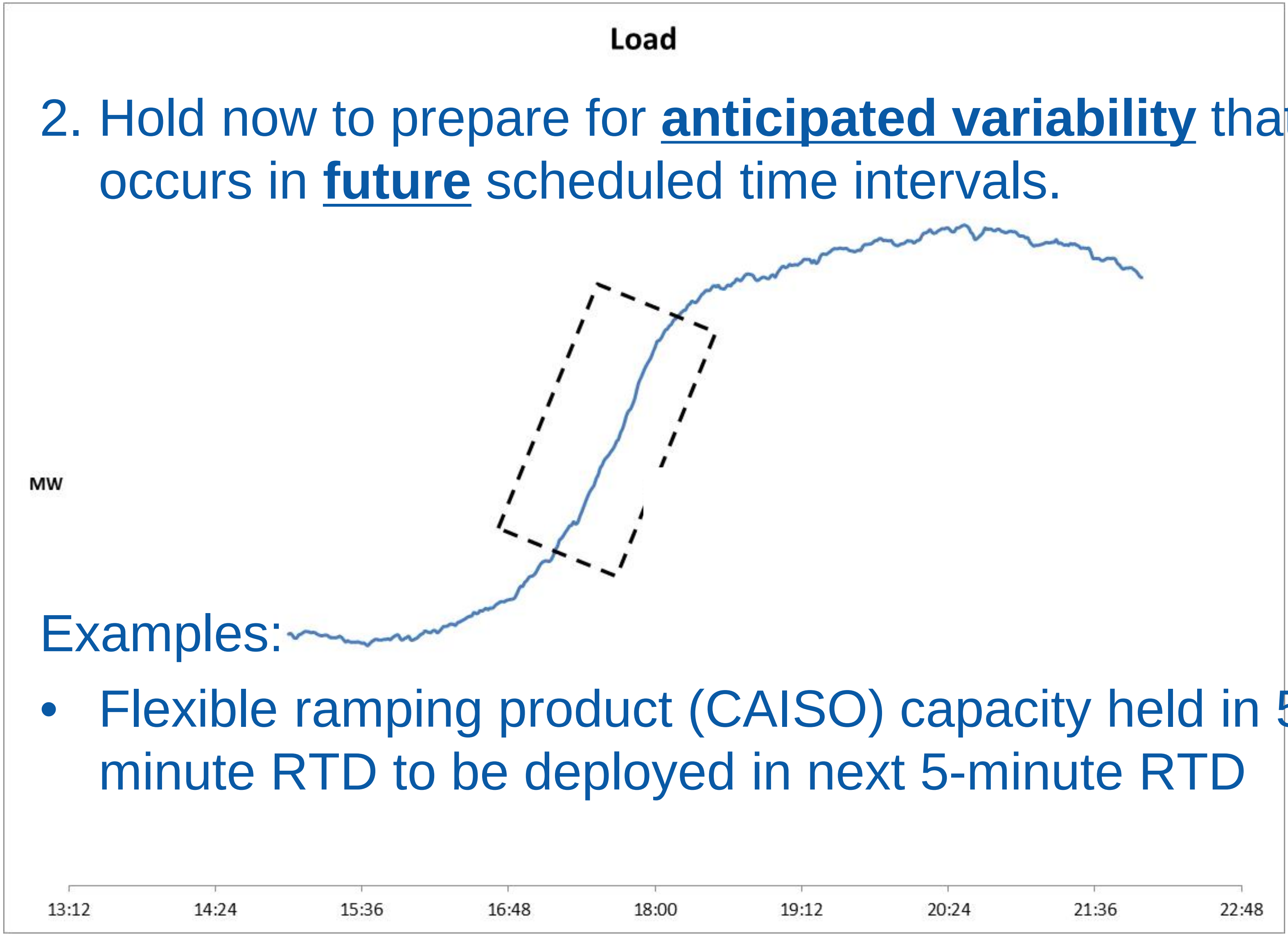


Examples:

- Regulation (NERC/FERC) capacity held in hourly DASCUC, and 5-min RTSCED to be deployed in 4-second AGC
- Flexible ramp constraint (CAISO) capacity held in 15-minute RTPD to be deployed in 5-minute RTD

Why does one need operating reserve

2. Hold now to prepare for **<u>anticipated variability</u>** that occurs in **<u>future</u>** scheduled time intervals.

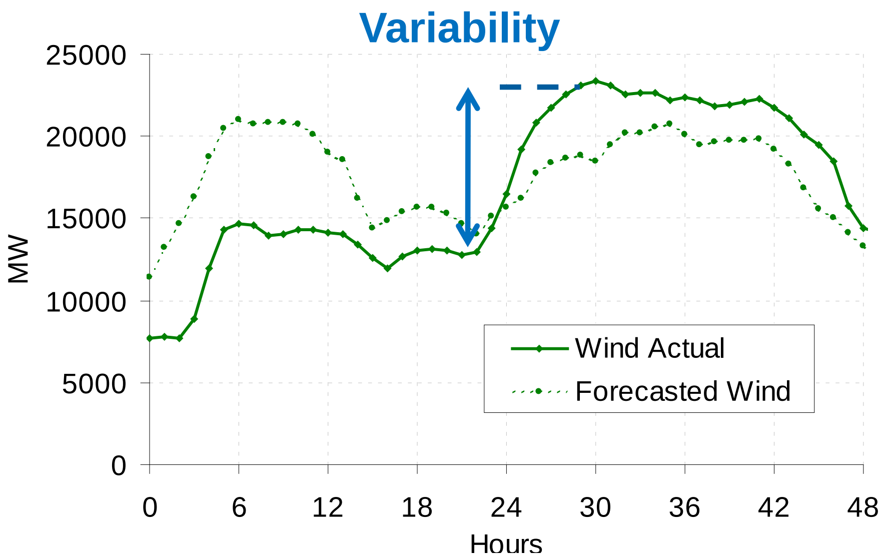


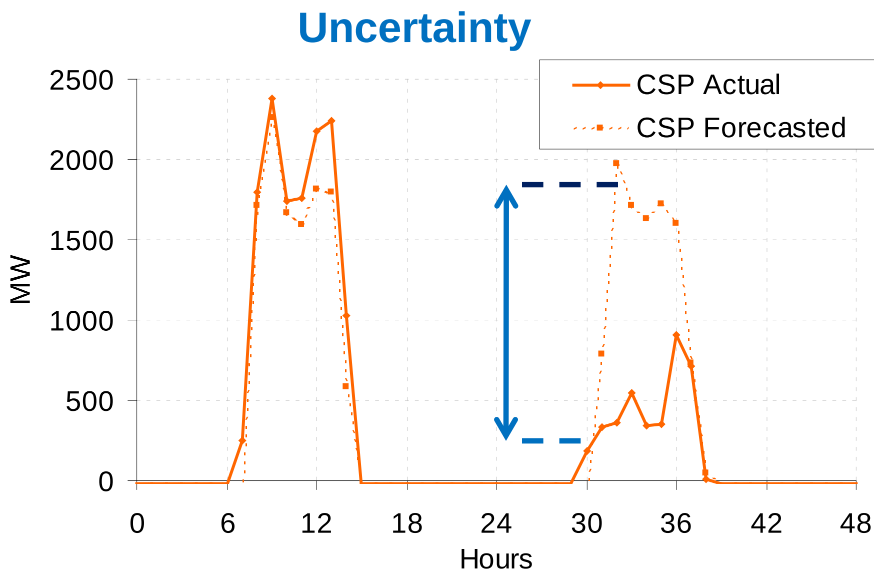
Examples:

- Flexible ramping product (CAISO) capacity held in 5-minute RTD to be deployed in next 5-minute RTD

Why does one need operating reserve

3. Hold now to prepare for **uncertain outcomes** that occur in **current or future** scheduled time intervals.

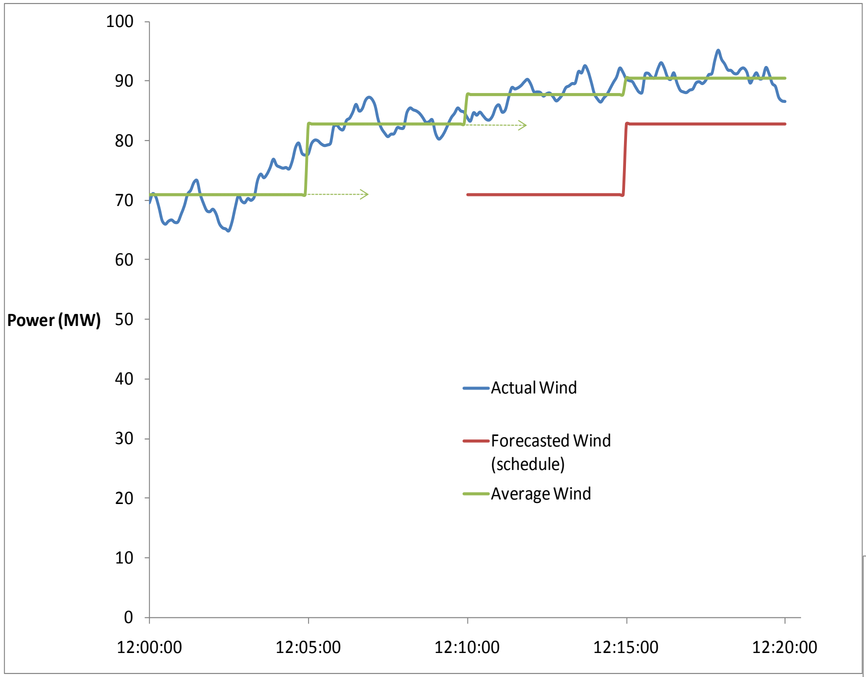




Examples:

- Contingency reserve held in all normal scheduling models and deployed in reserve pick ups due to uncertain contingencies
- (everything else)

Regulation Reserve



Why does one need operating reserve

1. Hold now to meet the upcoming **variability** that occurs **faster** than the **current** scheduled time interval

2. Hold now to prepare for **anticipated variability** that occurs in **future** scheduled time intervals

3. Hold now to prepare for **uncertain outcomes** that occur in **current or future** scheduled time intervals

Explicit vs. Implicit

1. Hold now to meet the upcoming **variability** that occurs **faster** than the **current** scheduled time interval
   A. Reserve constraint vs. faster scheduling time resolution

2. Hold now to prepare for **anticipated variability** that occurs in **future** scheduled time intervals
   A. Reserve constraint vs. multi-period optimization and longer horizons

3. Hold now to prepare for **uncertain outcomes** that occur in **current or future** scheduled time intervals
   A. Reserve constraint vs. scheduling toward multiple scenarios

Explicit vs. Implicit

- When the market clearing engine has the following:
  - Time resolution that approaches 0
  - Time horizon that approaches ∞
  - Number of scenarios that are modeled approaches ∞
- Then there are no explicit operating reserve requirements

Explicit vs. Implicit

- If done correctly, the implicit model for all three reserve needs is more efficient and more reliable than the explicit reserve constraint model, but…

- It has greater computational difficulties
- It requires more data, which is often unavailable and sometimes unattainable
- It requires more complicated pricing
  - i.e., there is no longer the reserve constraint dual variable

- If the needs and costs are correctly included, explicit reserve requirements can get us very close

"Build what's most efficient and reliable first, then worry about how to create the markets and incentives to get it."

- FERC Software Conference 2013

Objectives

- If possible, model implicitly for better efficiency/reliability
- 5-minute SCED and multi-period SCED and SCUC is now the norm in every ISO

- **Goal 1**: See what other forms of variability and uncertainty can be modeled implicitly in the market clearing engine
- **Goal 2**: See how pricing and incentives can follow the implicit model
- **Goal 3**: Where implicit modeling is not possible, determine the appropriate explicit reserve requirement need and costs

Variability within the dispatch

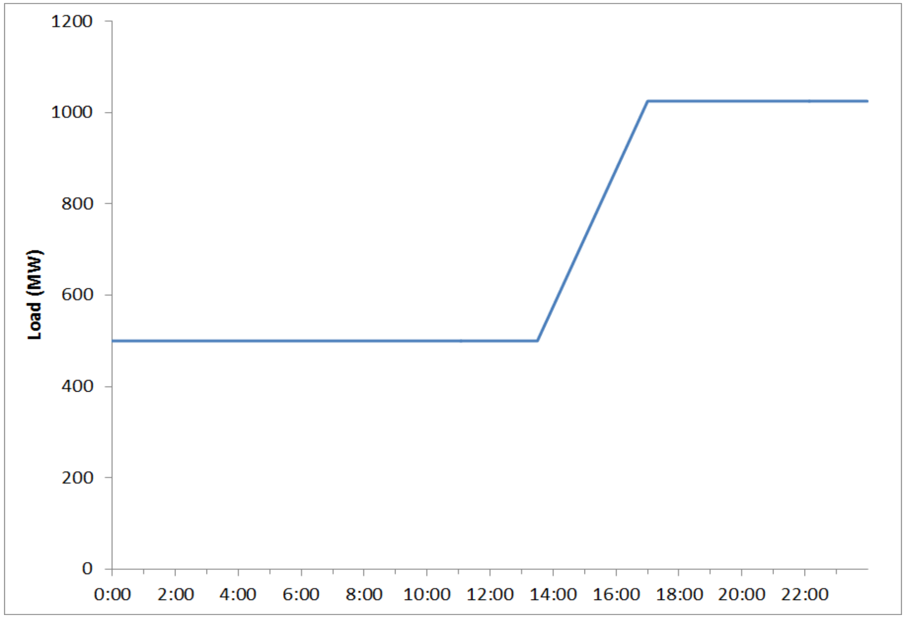
- Using FESTIV Model
- Perfect forecasts in all time frames, hourly day-ahead SCUC, 30-min real-time SCUC, 20% wind penetration, 6-second AGC, 24 hour simulation.

	Dispatch at 5-minute intervals	Dispatch at 1-minute intervals
Regulation Reserve	Regulation reserve at 1% load	No regulation reserve
Abs ACE (MWH)	94	59
Cost ($)	$909,852	$909,878
Revenue ($)	$1.636M	$1.396M

- Improved reliability, same costs, but significantly less payments. Missing money?

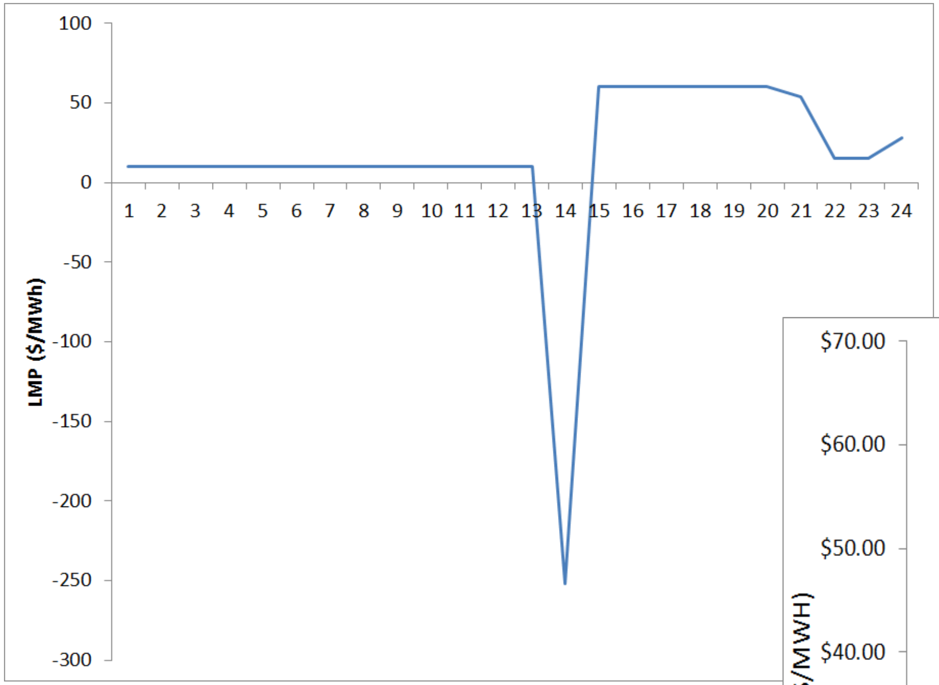
FESTIV Model:
Ela, O'Malley, "Studying the variability and uncertainty of variable generation at multiple timescales," IEEEE Trans. Power Syst., 2012

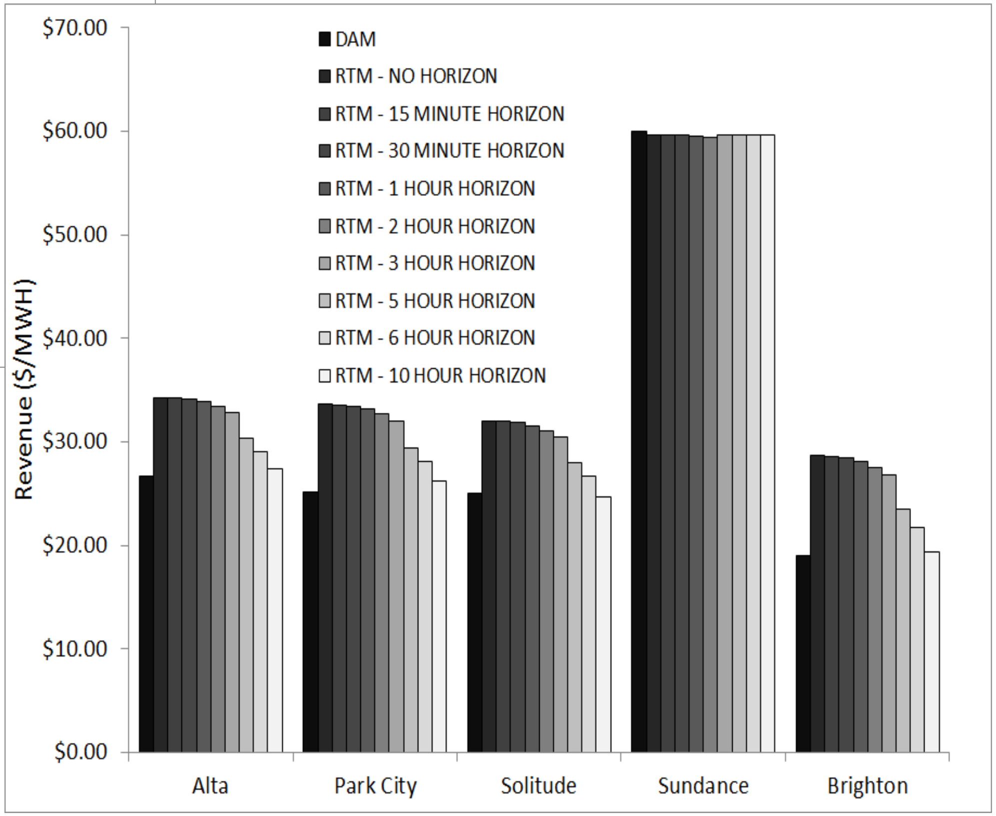
Anticipated Variability and Multi-period Look-ahead



	Cost ($/MWh)	Capacity (MW)	Ramp Rate (MW/Minute)	Start-up time
Alta	14	110	0.5	3 hours
Park City	15	100	0.5	3 hours
Solitude	30	520	0.5	3 hours
Sundance	60	200	10	10 minutes
Brighton	10	600	0.5	6 hours

Anticipated Variability and Multi-period Look-ahead





RTM needs a 10-hour horizon to match DAM pricing

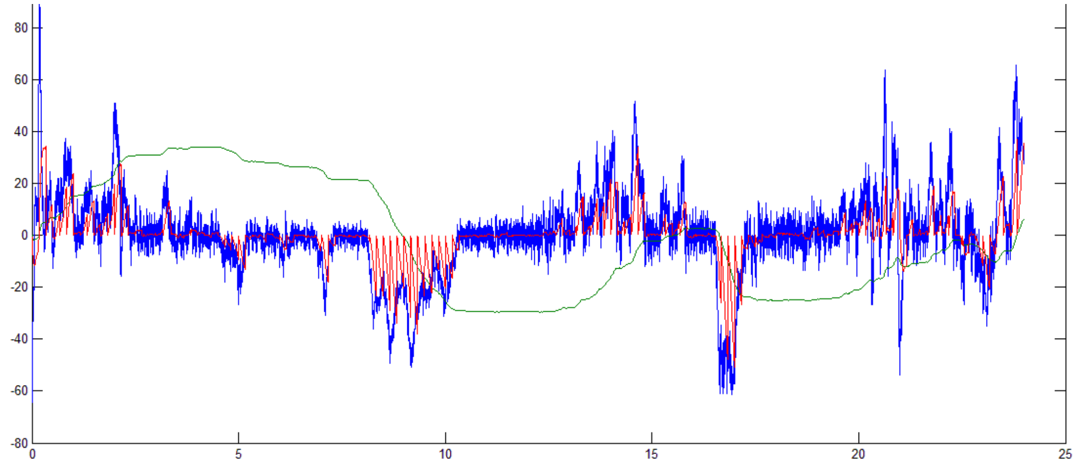
Uncertainty and probability-weighted LMP

Using FESTIV model, 2-stage STSCUC

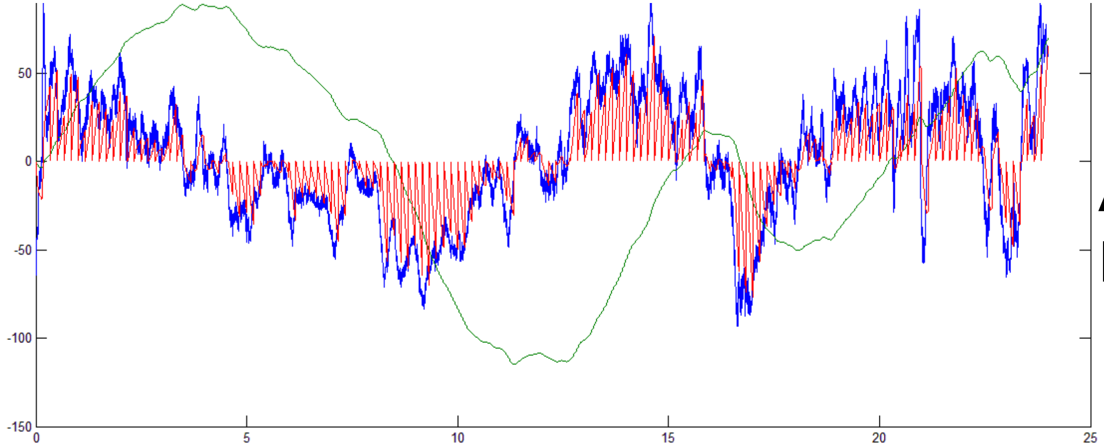
	Unit-hours with negative profit		Total $ of negative profit	
	LMP based on single scenario	Probability weighted LMP	LMP based on single scenario	Probability weighted LMP/RCP
August	77	43	-$9,252	-$4,180
April	73	42	-$6,357	-$4,724

Ela, O'Malley, "A probability-weighted lmp and rcp for day-ahead energy markets using stochastic security-constrained unit commitment," PMAPS 2012.

Reserve Requirement Method Comparisons



ACE with Regulating Reserve



ACE without Regulating Reserve

Case	CPS2 score	AACEE(MWh)	σ_{ACE} (MW)	Costs ($)
Case 6: Imperfect real-time forecasts at 5-minute intervals ,regulation reserves = 1.5% of load	27 violations 96.3%	3027	46.6	$13.237M
Case 7: Imperfect real-time forecasts at 5-minute intervals, with WWSIS2 regulation reserves	19 violations 97.4%	3610	43.5	$13.313M

Questions and Comments??

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http://www.nrel.gov/electricity/transmission/