Session 3 - Integration of Probabilistic Forecasts into the EMS and MMS – Status and Prospects

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Outline

1. Current operational paradigm in Energy Management System (EMS) and Market Management System (MMS) dealing with uncertainty
2. Commonly perceived rules of engagement in Dispatch functions – EMS and MMS control centers, North-American Electric Reliability Corporation (NERC) and Federal Energy Regulatory Commission (FERC)
3. Present improvements made to the system/market operations to account for uncertainty
4. Current perception of limitations in use of probabilistic forecast
5. Improvements under consideration
6. Future Improvements

Current Paradigm in Grid Operations

Grid planning functions: Uncertainty is represented by use of stochastic formulations for long term studies - month(s) and year(s) ahead studies (e.g., generation capacity and transmission adequacy, system protection design, energy policy review, Return on Investment (ROI) calculations for expansions)

Grid operations Functions: EMS and MMS Control Centers, engaged in daily operations and weekly planning to manage uncertainty by calculating and deploying the needed uncertainty products in the market optimization.

- Demand and renewable forecast calculated net load drives the generation/load dispatch using the procured reserves

Intent is to account for uncertainty in planning, and operationally manage by quantifying and paying for reserves, and release the reserves when needed and achieve the least possible operational cost

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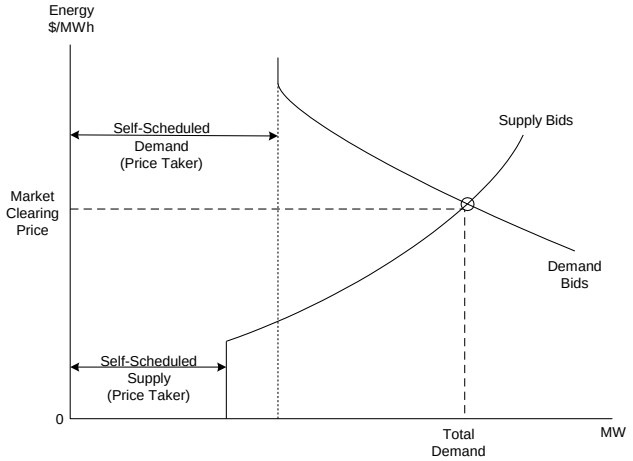
Market Products & Reliability (includes NERC mandated reserves)

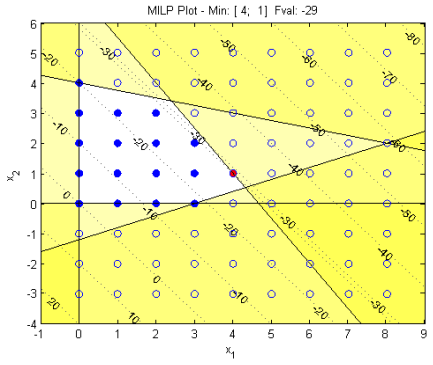
Market Products	Type of service	Reliability Aspect
Energy	Production, imbalance planned. Nodal prices w/ energy, congestion and loss components	Set dispatch targets, account for physical constraints of grid
Frequency Control	Responsibility for frequency control procured via annual contract. Large interconnected system gets assistance. Market product will be developed.	Primary control (governor) for frequency
Regulation Up/Down	4-second automatic generation control (AGC) Market reserve payment plus payment for mileage	Address demand variations (forecast vs. actual); Net load and Area Control Error driven corrections.
Flex Ramp Up Flex Ramp Down	Ten-minute ramping product	Address **net load** forecast variability (looking at wind, solar, and load forecast changes)
Spinning	Supplemental ten minute synchronized reserve	Address loss of generator to return grid to normal
Non Spin	Supplemental thirty-minute Non-synchronized	Address loss of transmission to return grid to normal
Voltage support	Outside Market (Tariff plus opportunity payment)	Reliability Must Run program
Black start	Outside Market (contract)	System restoration needs from a blackout or brownout

Energy Markets

Market Clearing Engine

Example: Day-Ahead Market Clearing Price for Energy – ignoring Marginal Losses & Congestion





Mixed Integer Linear Program based constrained optimization of operating cost

<u>Market Clearing Engine: Day Ahead, Fifteen Minute Market (FMM), Real Time (RT) Markets</u>

Computes nodal energy prices and regional Ancillary Service (AS) product (reserves) prices in a co-optimization formulation

Generator/Load commitment and dispatch for Energy (EN) and AS over a horizon of time

Grid constraints (generator, load, network, emission) constraints need to be met

Prices and quantities of EN and AS for generation/load for each node (hourly for a day, ¼ hour or 5 minute intervals for hours ahead)

Current Practice in EMS and MMS

Samples of types of uncertainties and associated counter measures in EMS and MMS solutions:

Outages: Contingency Analysis of "what if" simulations to:

- calculate preventive corrections to generation dispatch for selected contingencies
- preventive-corrective dispatch (simulate reserve based corrections and postpone dispatch expense if violations can be corrected in prescribed time)
- simulate and ensure system recovery after large disturbances and establish stability limits (generation, area, transmission) enforced by preventive dispatch
- post contingency voltage problems simulated via separate voltage security tool to facilitate voltage performance coordination.

Activate dispatch of energy from uncertainty market products and reserves as and when needed to manage:

- Demand variations: regulation reserves
- Generator outages: spin reserves
- Transmission outages: non-spin reserves
- Renewable variations: reserves and methods used to address uncertainties:
  - Ramp reserves, Fast regulation, Flexible Ramp, and Frequency Reserve products

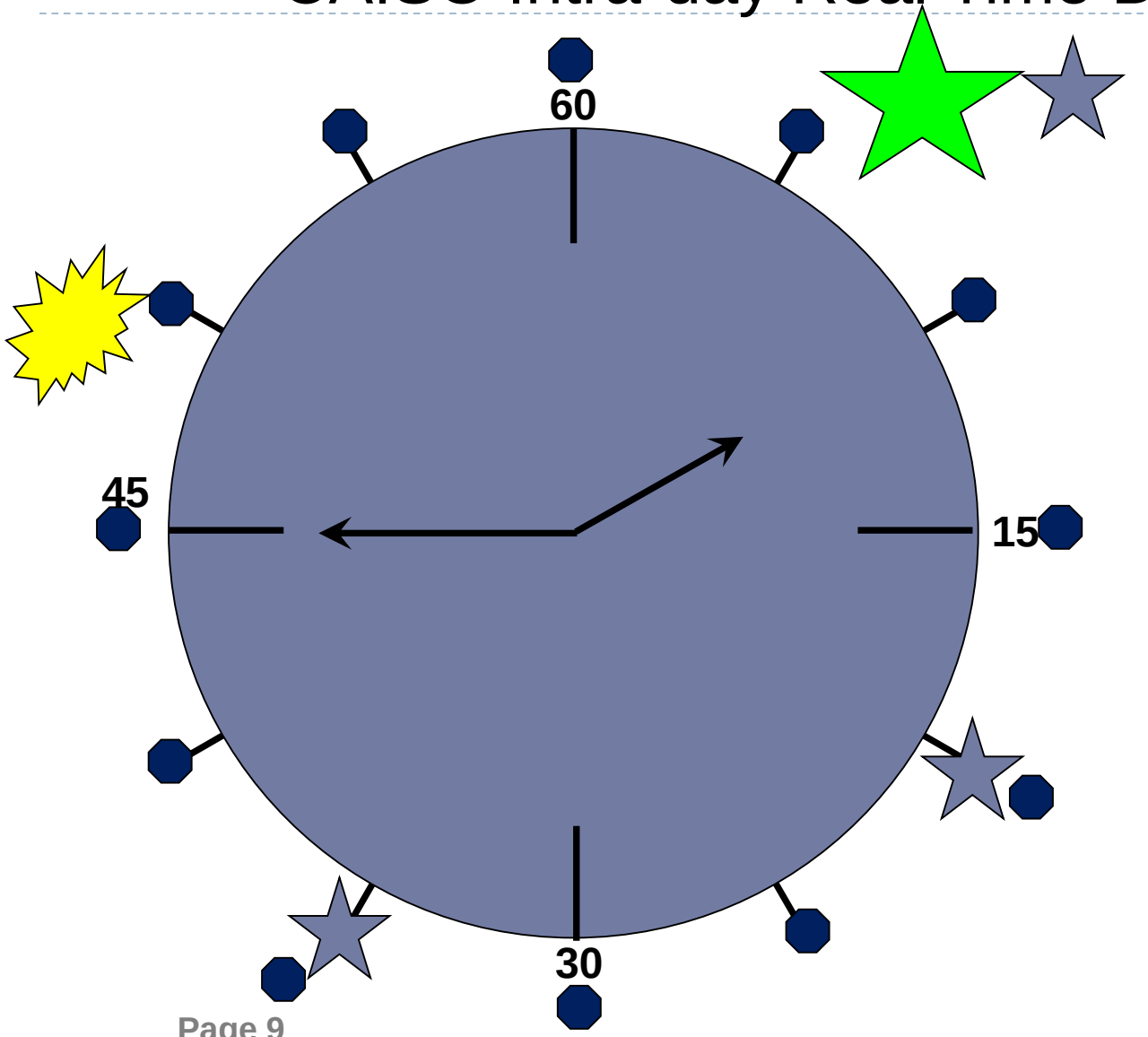
EMS Functions and use of probabilistic forecast

Function	Current Use	Use of Forecast	Use of Probabilistic Forecast
EMS SCADA	Real Time measurements every few seconds	Yes, for a time series of estimated values	No
EMS State Estimator	Uses real time measurements and runs every minute	Yes, with SCADA use above	No
EMS Contingency Analysis	Uses State Estimator solution as base case, and runs every 5 minutes	Yes, in a Look-Ahead formulation	Yes, in a Look-Ahead formulation
EMS AGC (Vertical or Market based)	Uses real time values of generations and flows. Load Frequency Control - every 6 seconds. Dispatch every 1 - 3 minutes	Yes. Could use very short term forecast.	No

MMS Functions and use of probabilistic forecast

Function	Current Use	Use of Forecast Scenarios	Use of Probabilistic Forecast
Day Ahead Market	Uses demand and renewable forecast.	Some systems use scenarios for advisory purposes (e.g.,+5% and -5% of forecast)	Yes. For calculation of reserve requirements
Real Time Market	Uses demand and renewable 5" forecast , more reserves are being added to address net load variations	Yes	Yes, for Flexible Ramp Product and Reserve Req' calculations.
Voltage support and Outage Evaluation (for planning)	Outside Market	Yes	Yes
Black start (year ahead for planning)	Outside Market	No	No. Selected grid locations is more important

CAISO Intra-day Real Time Dispatch (FMM, RTD)



Hour Ahead
8x 15’
SCUC
2 hours

STUC
18 x 15’
SCUC
4.5 hours

RTPD
6 x 15’
SCUC
1.5 hour

RTD
12 x 5’
SCDD
1 hour

Successive Refinement of dispatch trajectory:

Repetitive Look Ahead runs (every 15” and 5”)

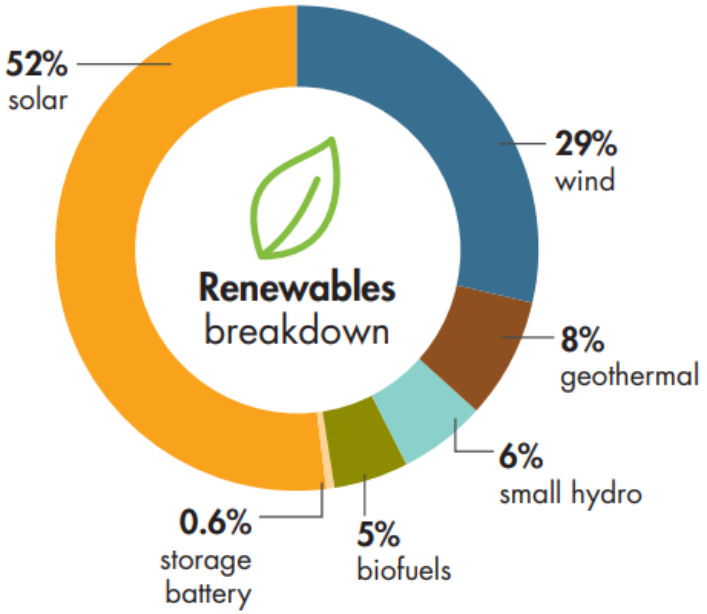
Driven by very short term net load forecast updates of future intervals

Refinements used to re-adjust the trajectory

SCUC: Security Constrained Unit Commitment
SCDD: Security Constrained Dynamic Dispatch

ISO renewable resource mix

Installed renewable resources *(as of 04/09/2018)*



	Megawatts
Solar	11,439
Wind	6,295
Small hydro	1,238
Geothermal	1,790
Biofuels	997
Storage battery	134*
TOTAL	**21,893**

Record peaks

SOLAR
10,412 MW
March 5, 2018, 10:18 a.m.

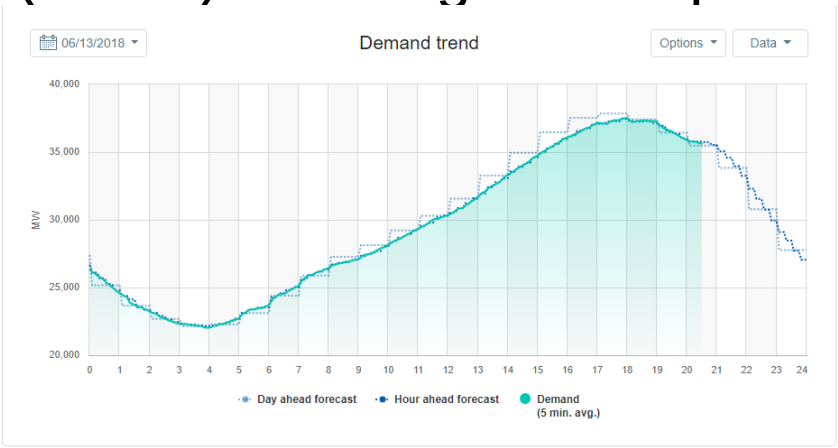
WIND
4,985 MW
May 16, 2017, 5:26 p.m.

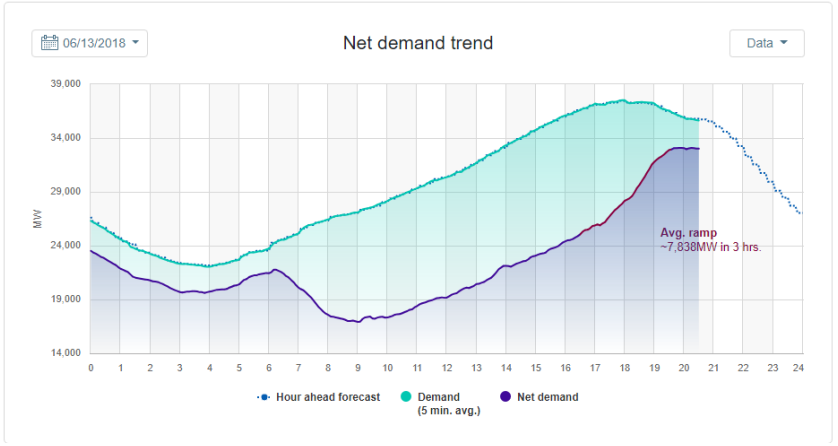
PREVIOUS SOLAR RECORD **9,914 MW** set on June 17, 2017, 12:13 p.m.

Forecasts at CAISO

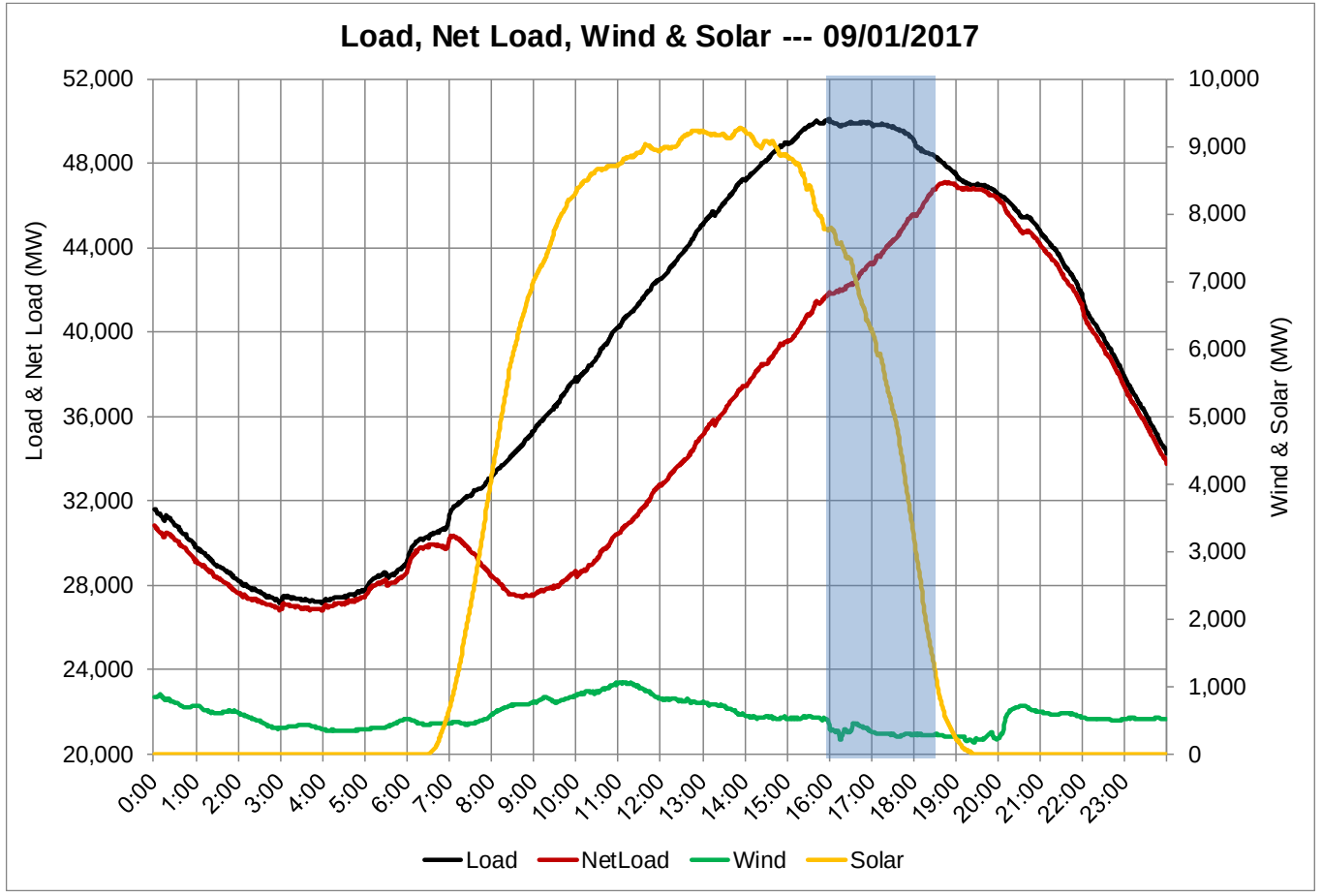
- The ISO Automatic Load Forecasting System (ALFS) is configured to provide the following forecasts:
  - Demand (Load):
    - Day Ahead – Hourly Forecasts out 9 days
    - Real Time – 5 Minute Forecasts rolling out 24 hours
  - Renewables (Wind/Solar):
    - Day Ahead – Hourly Forecasts out 4 days
    - Real Time – 5 Minute Forecasts rolling 9 hours

http://www.caiso.com/TodaysOutlook/Pages/default.aspx





In 2017, the ISO peak load was 50,116 MW and occurred at 15:58:24 on September 1st



15:58 to 18:44

- Net Load peaked 2 hours and 46 minutes after peak demand
- Peak load decreased by 2,148 MW
- Solar production decreased by 7,199 MW
- Net Load increased by 5,258 MW

Managing Supply and Demand

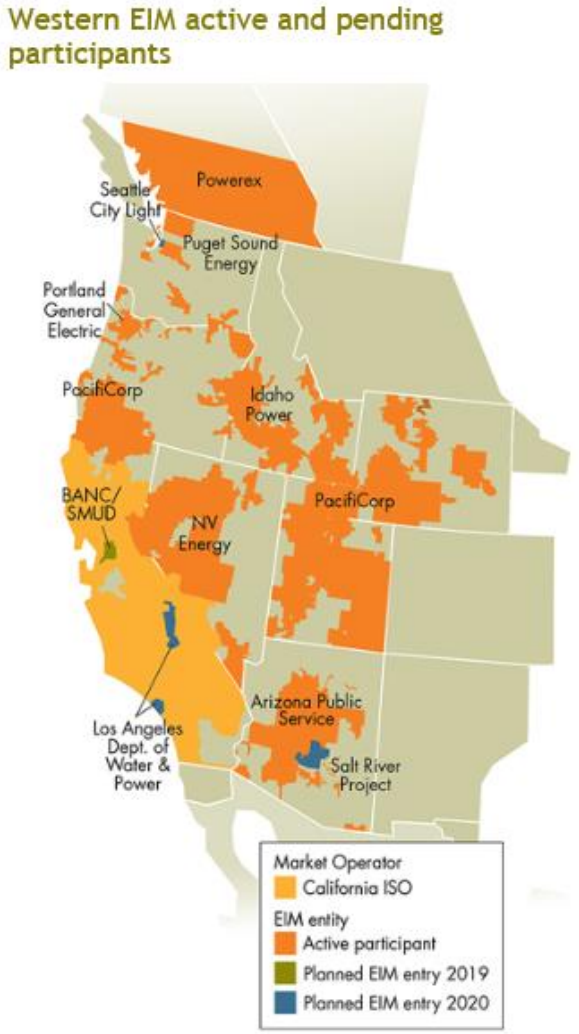
Reserve products assist grid dispatch to a certain degree

Operating challenges that need effective counter measures

- Over supply (negative energy prices)
- Avoiding curtailment of solar energy during day time
- Net Load Peak: Ability to have the generation and operational preparation to operate large ramp at sunset

Successful counter measures of CAISO of (2015 – 2018)

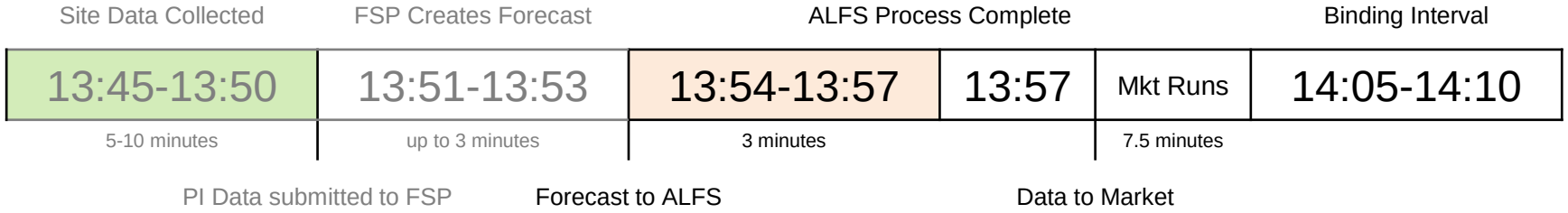
- Energy Imbalance Market (EIM)
  - Ability to use geographic diversity, exchange excess solar and wind energy with neighboring states for the regional benefit
  - Storages initiatives of CPUC (1325 MW in 2020)
- Implementation of Flexible Ramp Product
- Implementation of Renewable Persistence Methodology
- Regulation Reserve Requirement Methodology Changes
- DERP initiatives of CPUC under implementation to manage demand side and storages
  - DERP's bundle the roof-tops, storages, DR and offer to wholesale
- Demand Response Model within Market Optimization
- Non-Generating Resource (NGR) Models
  - Used by Battery Participants



Market System: Persistence-based Renewable forecast

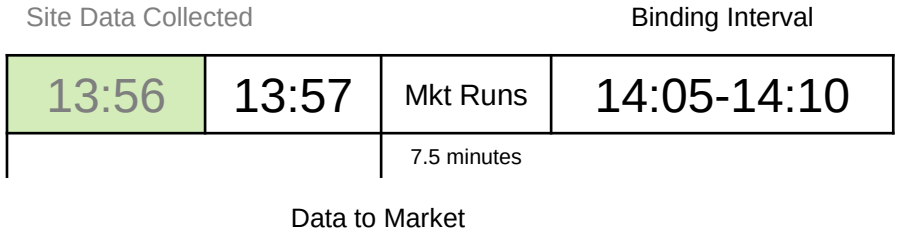
Why Is the Persistence Method needed?

Current:



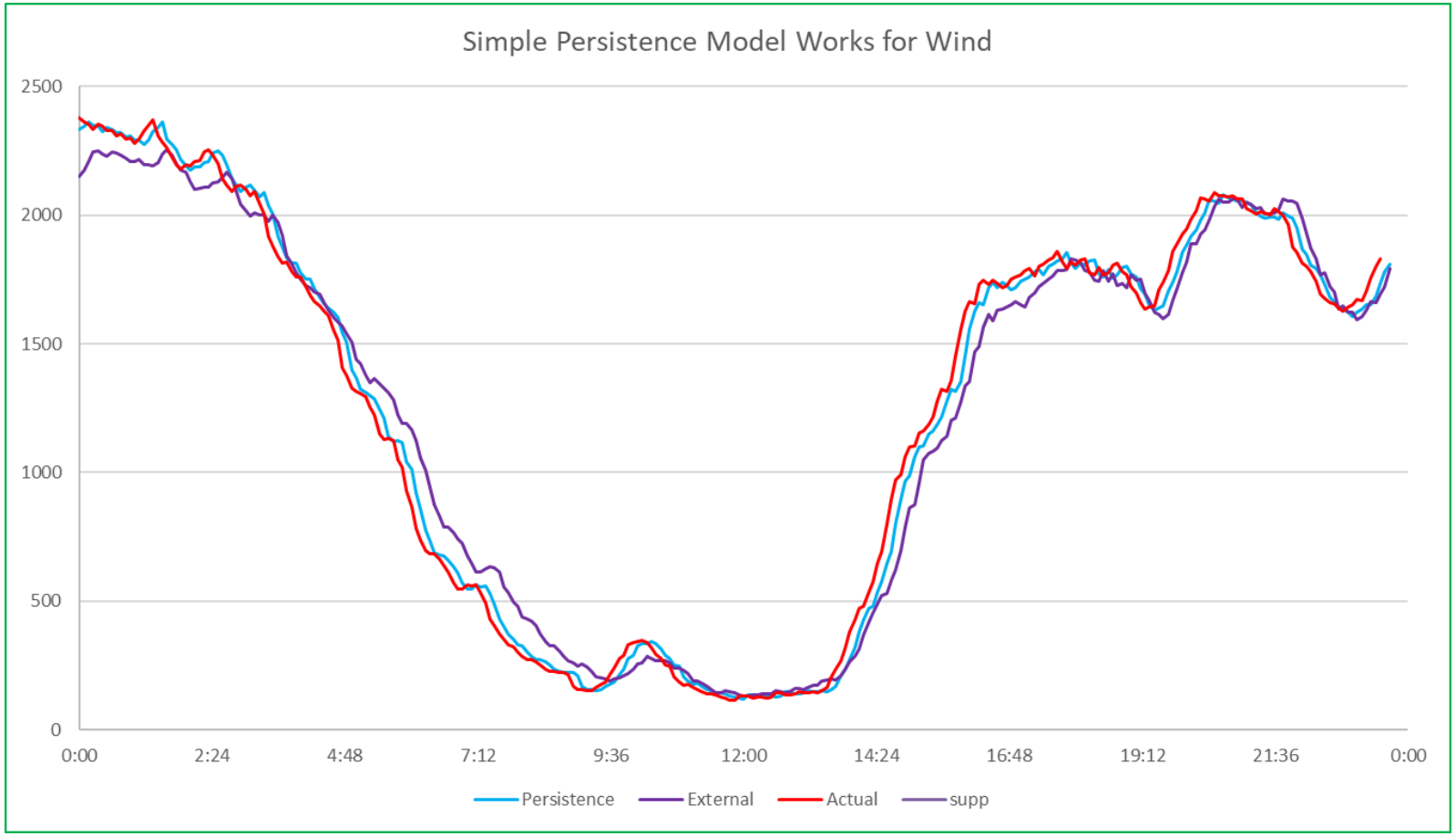
Persistence Method:

- More recent actuals are used in forecast
- 6+ minutes are eliminated from lag

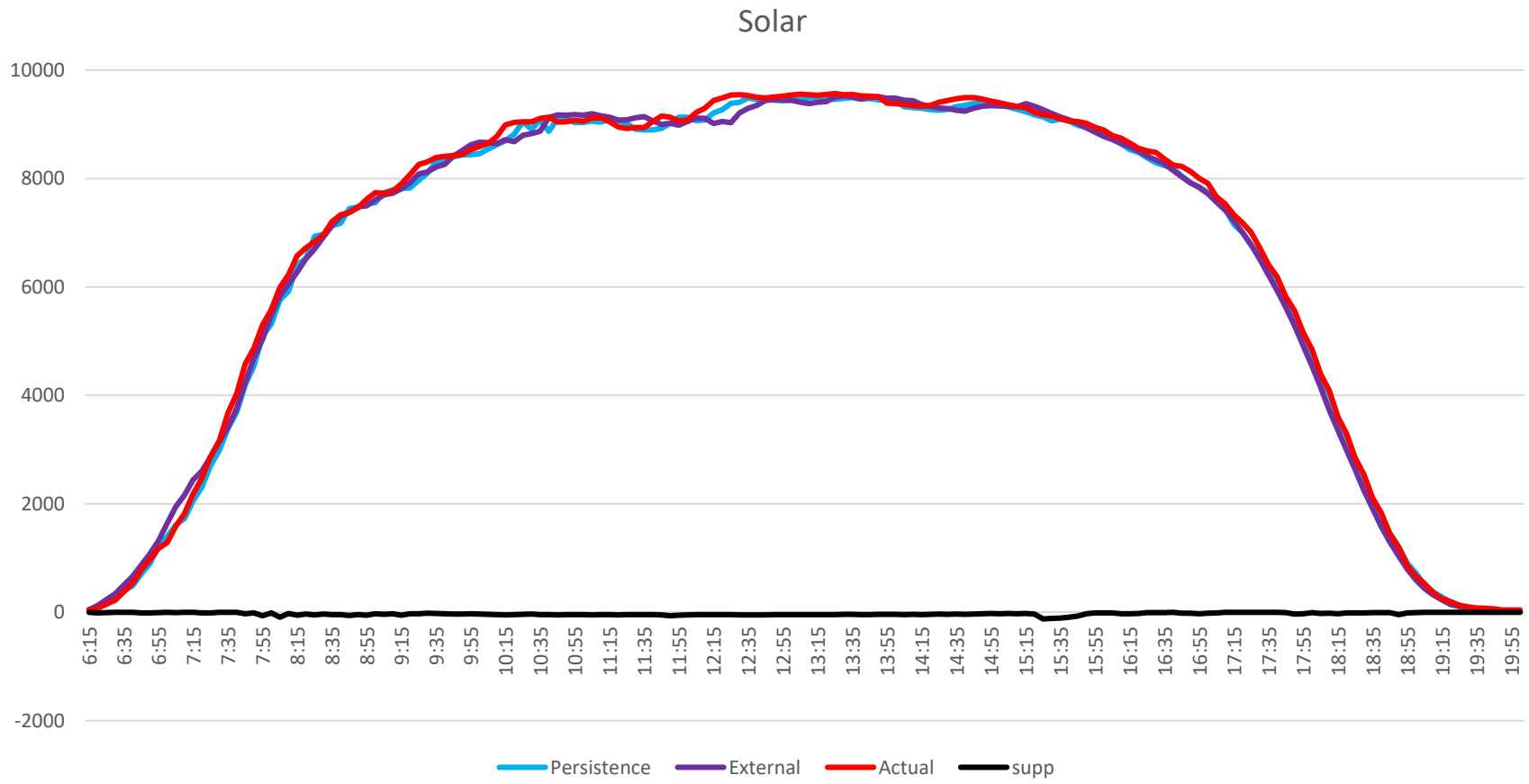


Forecast calculated in market, eliminating ALFS & processing time needed outside of CAISO

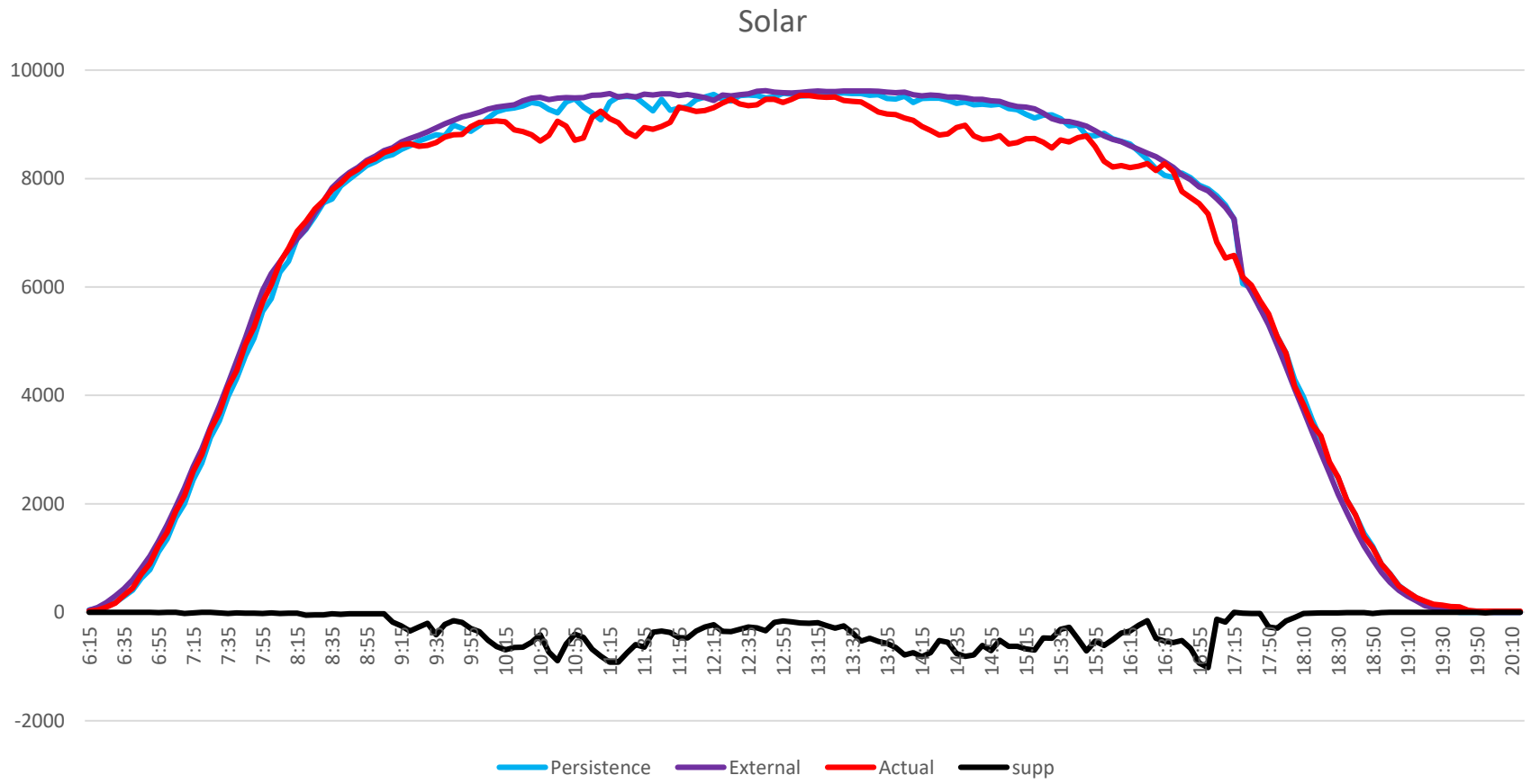
Impact of Shortened Processing Time for Wind



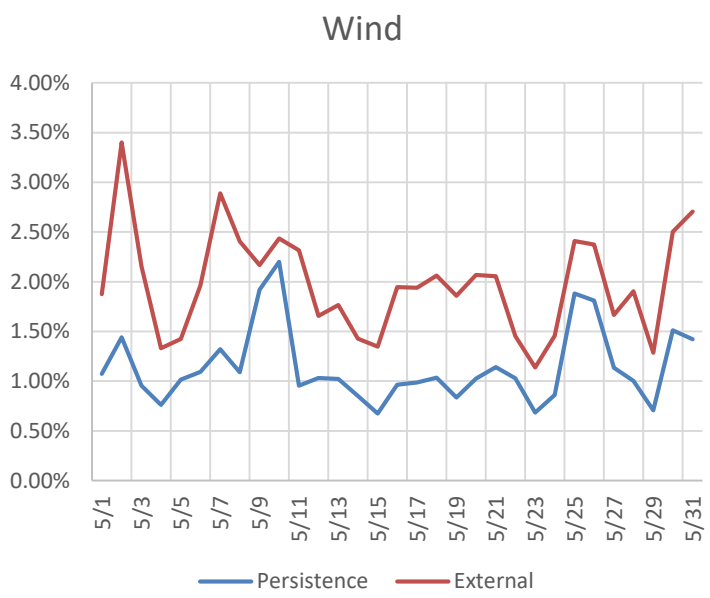
Results: Contour Persistence Works for Solar

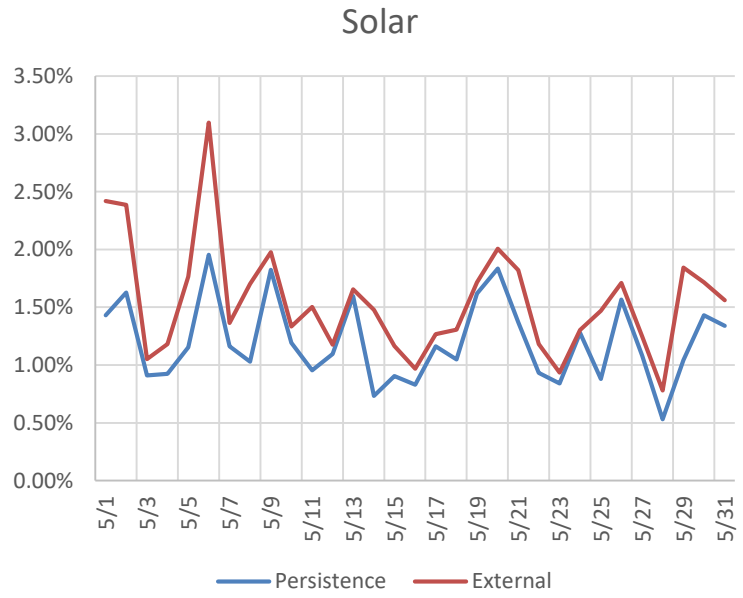


Results: Contour Persistence Method when Heavy Supplemental Dispatches are Present

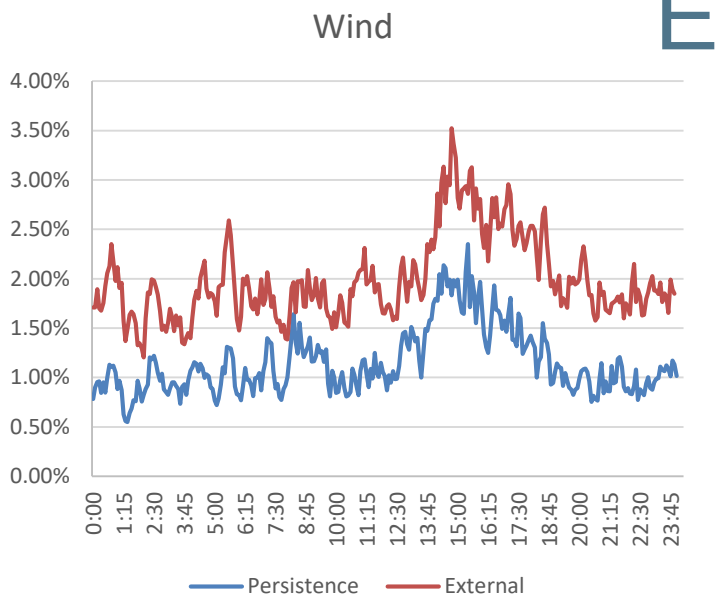


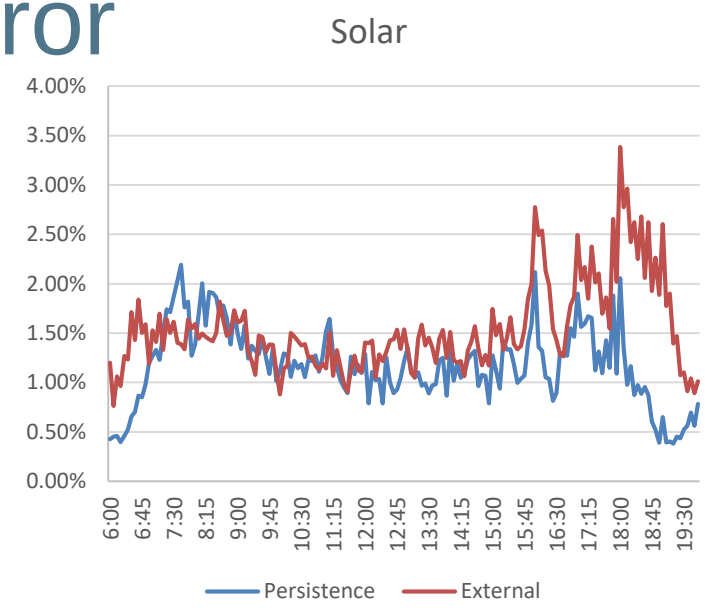
Persistence Method: Daily Error





Persistence Method: Time Interval Error





Summary

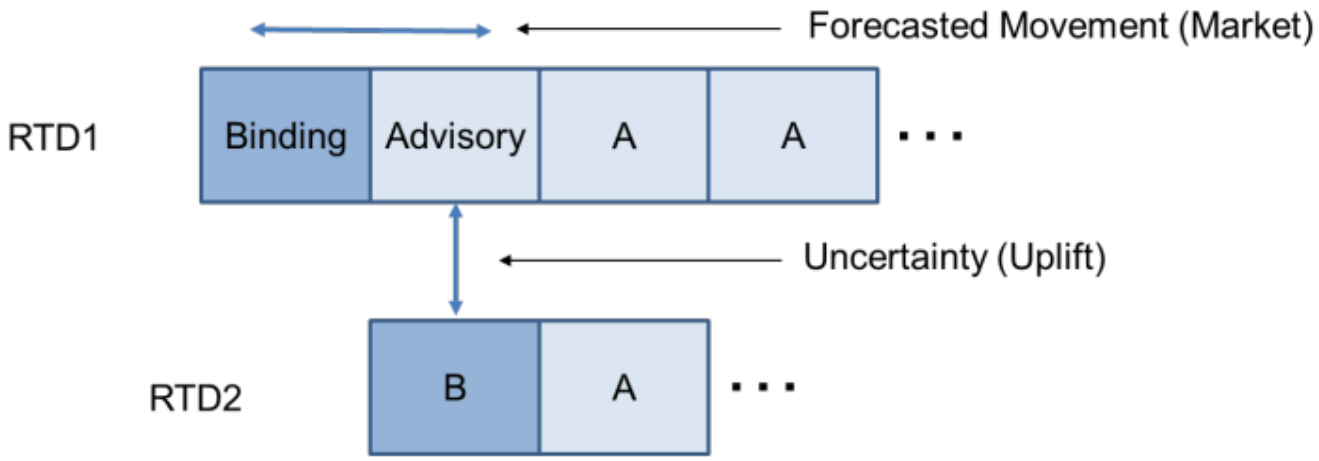
- Persistence Implemented on 4/18/2018
- Monthly Performance Review for 5/1-5/30, 2018
- Mean Absolute Percentage Error (MAPE) improvement

FUEL_TYPE	Persistence	External
SOLAR	1.22%	1.56%
WIND	1.15%	1.98%

Managing Forecast Uncertainty

Current Flexible Ramping Product Market Design:

RTPD and RTD Markets– histogram approximation of probability distribution of forecast error



RTD Net Load Forecast Error for this product is defined as the difference between the binding interval net load forecast and the prior market run first advisory net load forecast

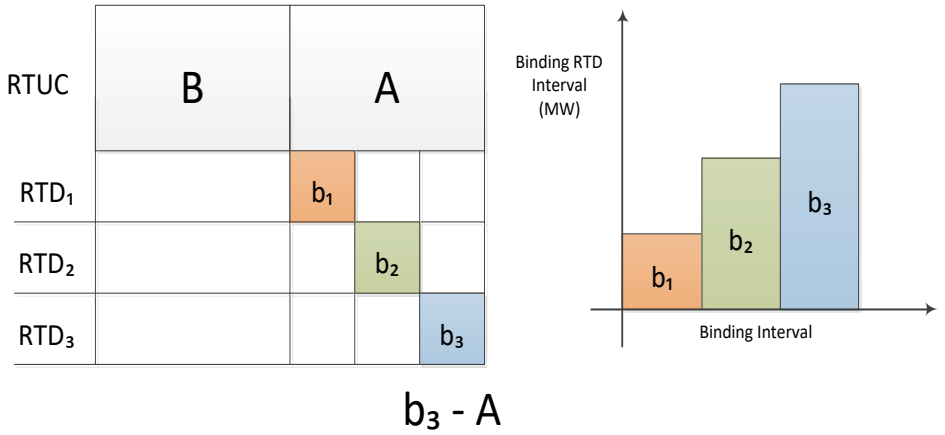
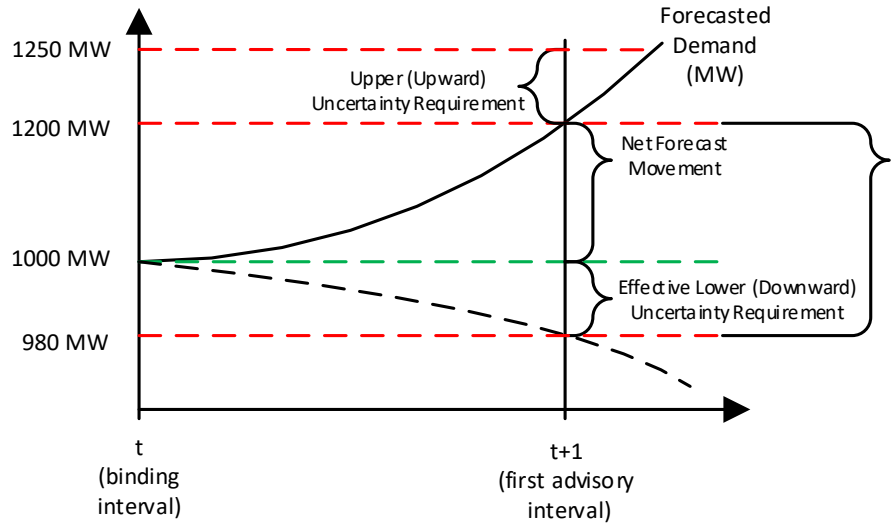


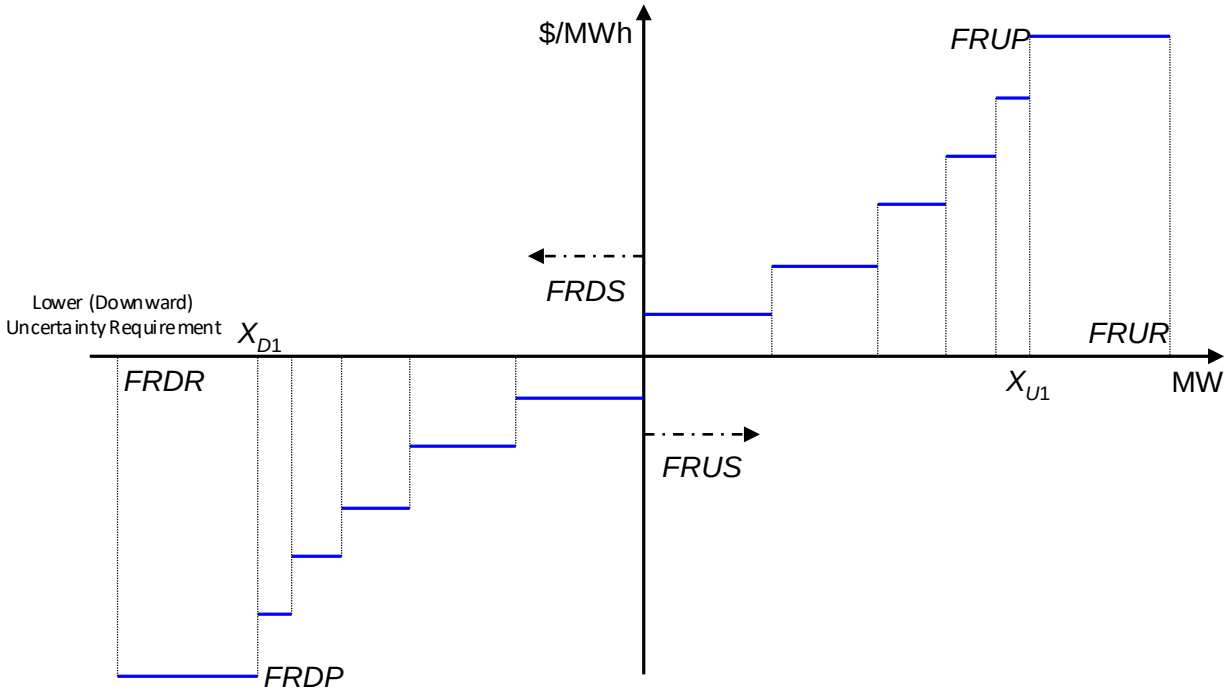
Figure 4: Histogram construction in FMM

Flexible Ramp Product

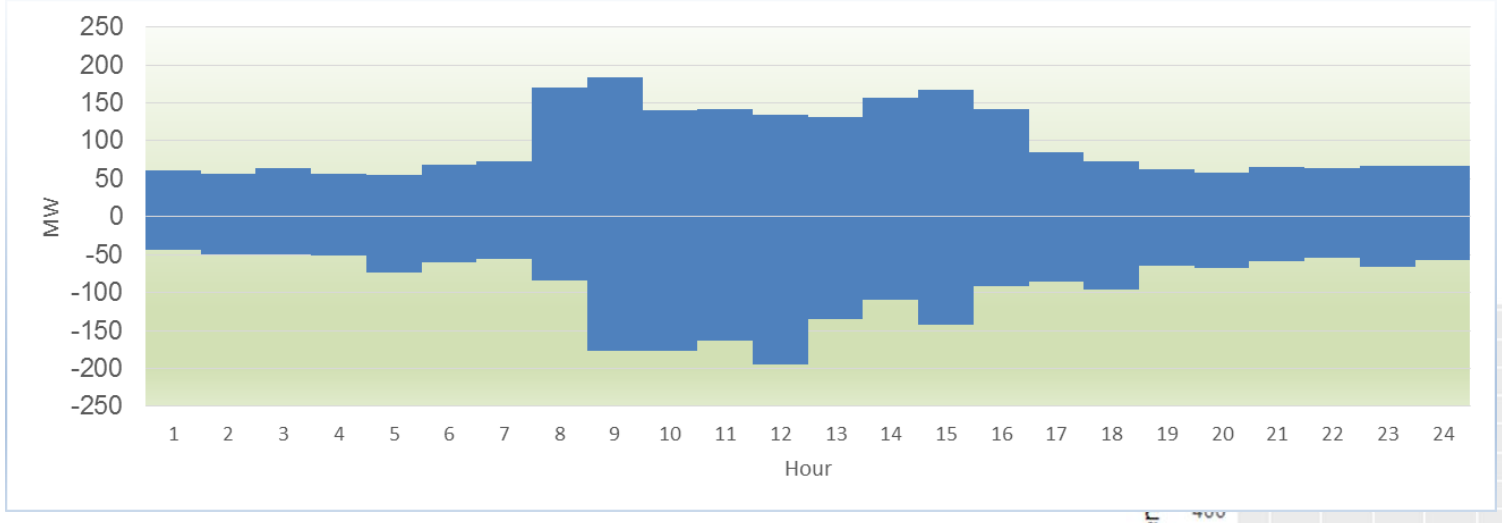
Flexible Ramping Product Uncertainty Requirements

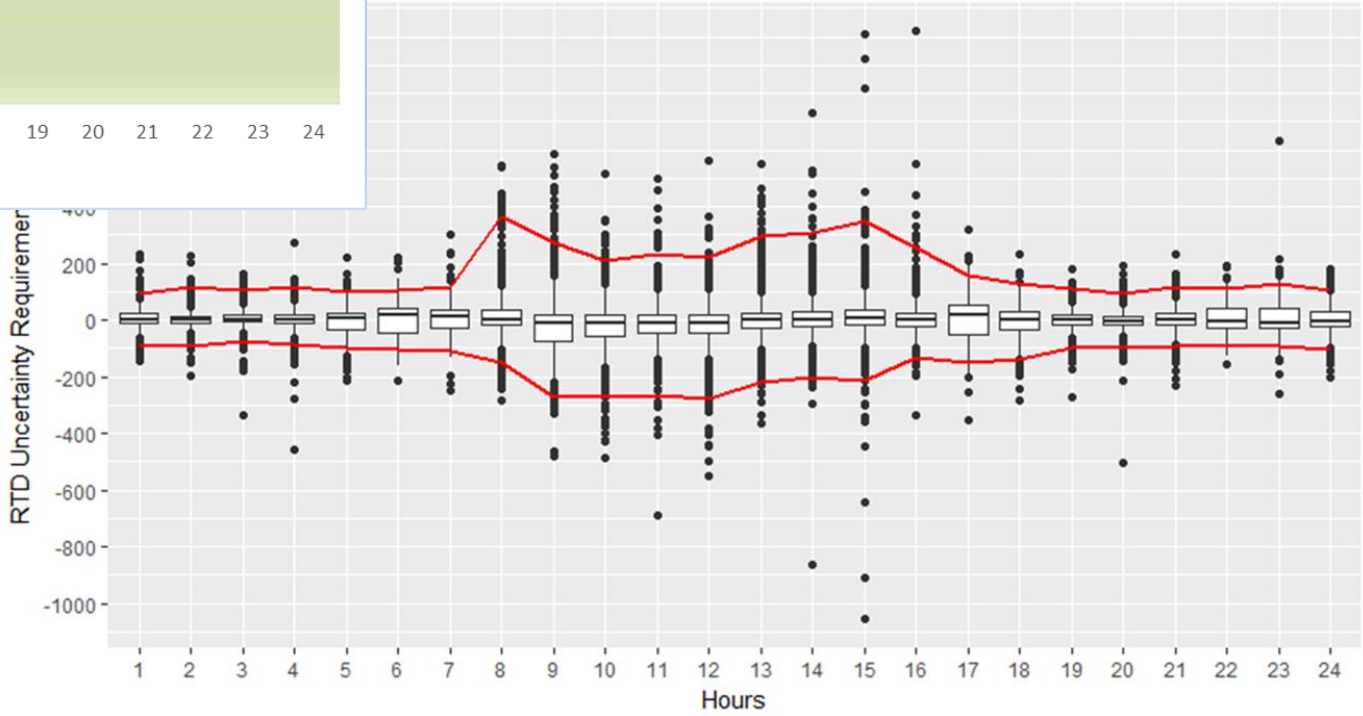


Flexible Ramping Surplus Demand Curves (Upward and Downward)



RTD Expected Average Flexible Ramp Product Cleared Awards for EIM_Area – January 23, 2018





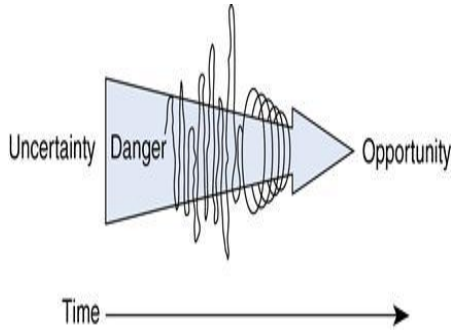
Closing Remarks

The more accurate we are able to make the deterministic and ensemble forecasts the better to formulate Day Ahead and Real Time prices.

Uncertainty forecasts for calculating reserve requirements to pay for reserve capacities are already here (e.g., Flex Ramp Product, Imbalance Reserve)

Tuning Ensemble Numerical Weather Prediction Models for Solar and Wind Forecasting is beneficial to the market operator to use in uncertainty market products.

With the expansion of market products probabilistic forecasting can be beneficial to the market operators for uncertainty products in multiple timeframes.



EMS Look Ahead Contingency Analysis, and Daily Scheduled Outage Evaluations will immensely benefit from use of probabilistic forecast

Larger regional diversity and broader regional coordination better position the grid. above and beyond vulnerability from forecast errors.