Flexible Ramping Uncertainty Calculation in the Western Energy Imbalance Market (WEIM)

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Short Term Forecasting
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Topics

- Executive Summary
- Flexible Ramping Uncertainty
- Current Calculation: Histogram (H)
- Weather Information
- Introduction to Quantile Regression
- Uncertainty in Load, Wind, and Solar
- Mosaic Model for Net Load Uncertainty (M)
- Simulation Study
- Daily Trends
- Performance comparison: H vs. M
- Other Considerations

Executive Summary

- Mosaic model can incorporate weather information into estimation of uncertainty requirement
- Compared to the Histogram approach, the Mosaic approach has:
  - similar coverages
  - less requirement on average
  - closer proximity to the observed uncertainty
  - comparable exceeding number
  - less impact of seasonality

Detailed Description of the Requirement Calculation

- In order to increase transparency on the proposed Quantile methodology and enable interested parties to replicate the calculation, CAISO posted the step-by-step description of the methodology. The document is available at

  http://www.caiso.com/Documents/BusinessRequirementsSpecifications10-FlexibleRampProduct-RequirementsEnhancements.pdf

Notation

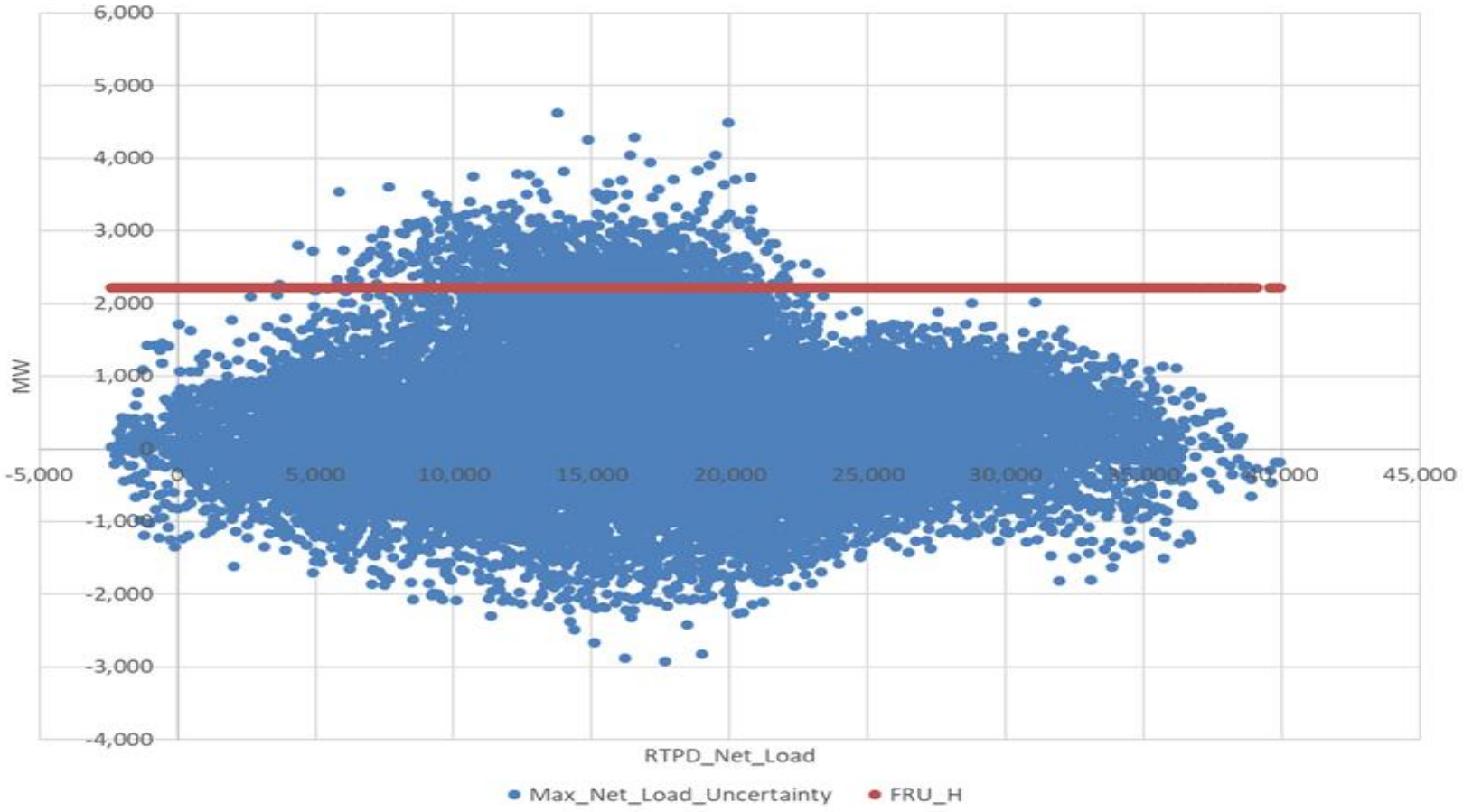
Term	Definition
FRD	Flexible Ramping Down
FRP	Flexible Ramping Product Requirements
FRU	Flexible Ramping Up
H	Histogram - The Histogram approach to estimate the requirements for L, W, S, and NL
L	Load Uncertainty = RTD Bidding Load - RTD Advisory Load
M	Mosaic Quantile - The mosaic quantile approach to estimate the requirement for NL
NL	Net Load Uncertainty = L - W - S
Q	Quantile - The quadratic quantile approach to estimate the requirements for L, W, and S
RTD	Real Time Dispatch
RTPD	Real Time Pre-Dispatch
S	Solar Uncertainty = RTD Biding Solar - RTD Advisory Solar
W	Wind Uncertainty = RTD Biding Wind - RTD Advisory Wind

Flexible Ramping Uncertainty

- Forecasts
  - Two markets: RTPD and RTD
  - Three components: Load, Wind, and Solar
  - One focus: Net Load = Load – Wind – Solar

- Uncertainties
  - RTD forecast – RTPD forecast
  - Load, Wind, Solar, and Net Load

Current Calculation: Histogram (H) is a fixed requirement for any level of net load

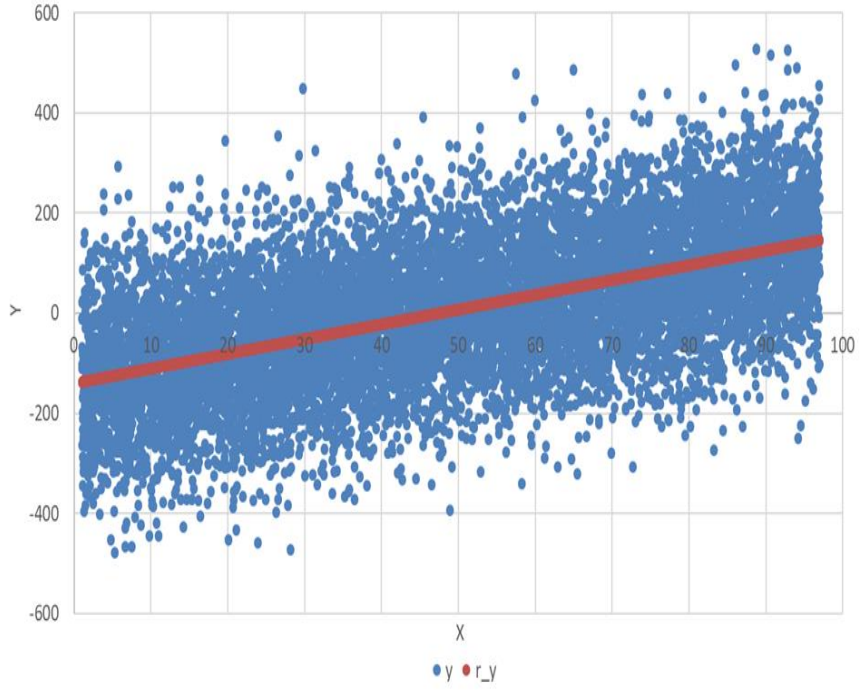


Weather Information

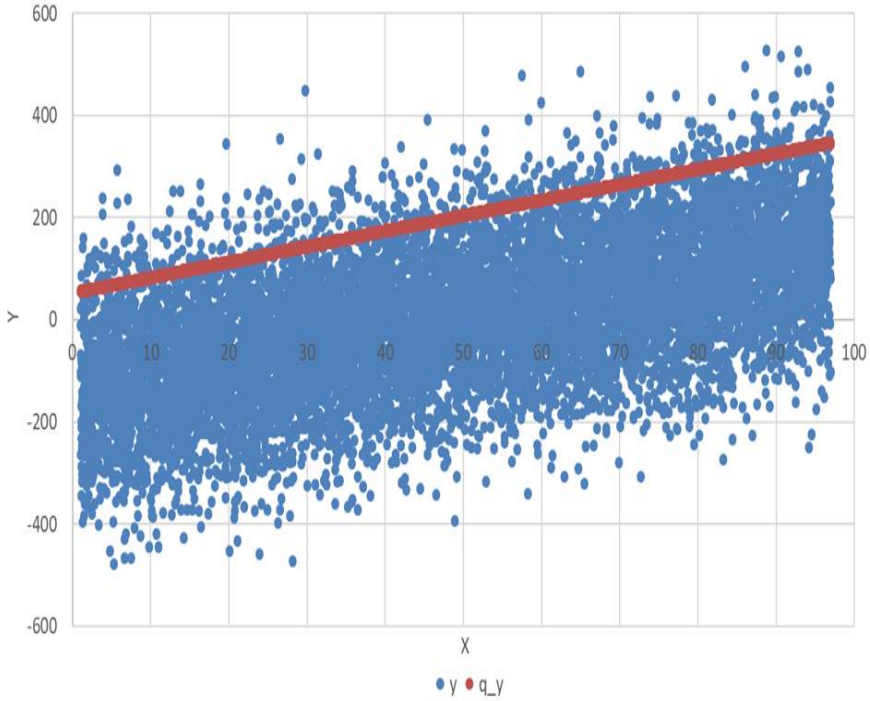
- Latest Numerical Weather Prediction information is utilized in formulating the megawatt (MW) forecast.
- For RTD-RTPD uncertainty, wind, solar, and load, the RTPD forecast serves as the surrogates for the weather information.
- However, for load other factors contribute to uncertainty such as human activity, covid lock-downs, wild fires, etc. also contribute to uncertainty.

Introduction to Quantile Regression

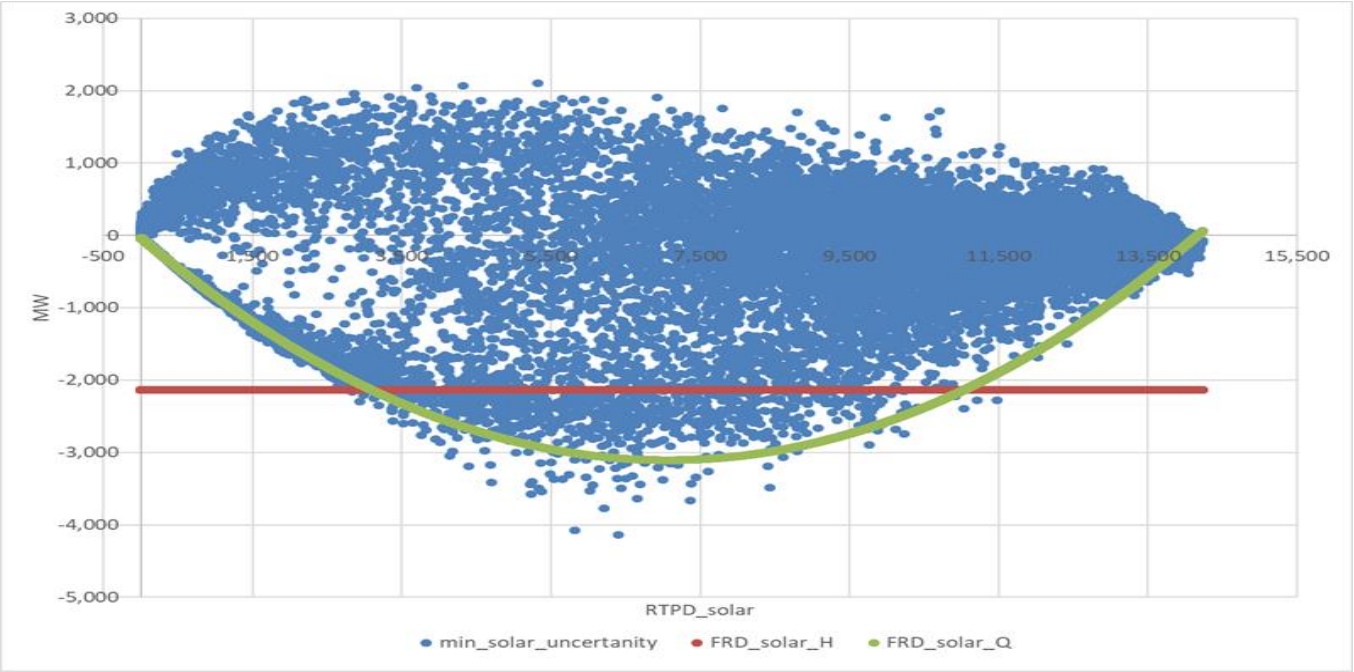
Ordinary Regression:
estimate relationships in average



Quantile Regression:
estimate relationships in percentile

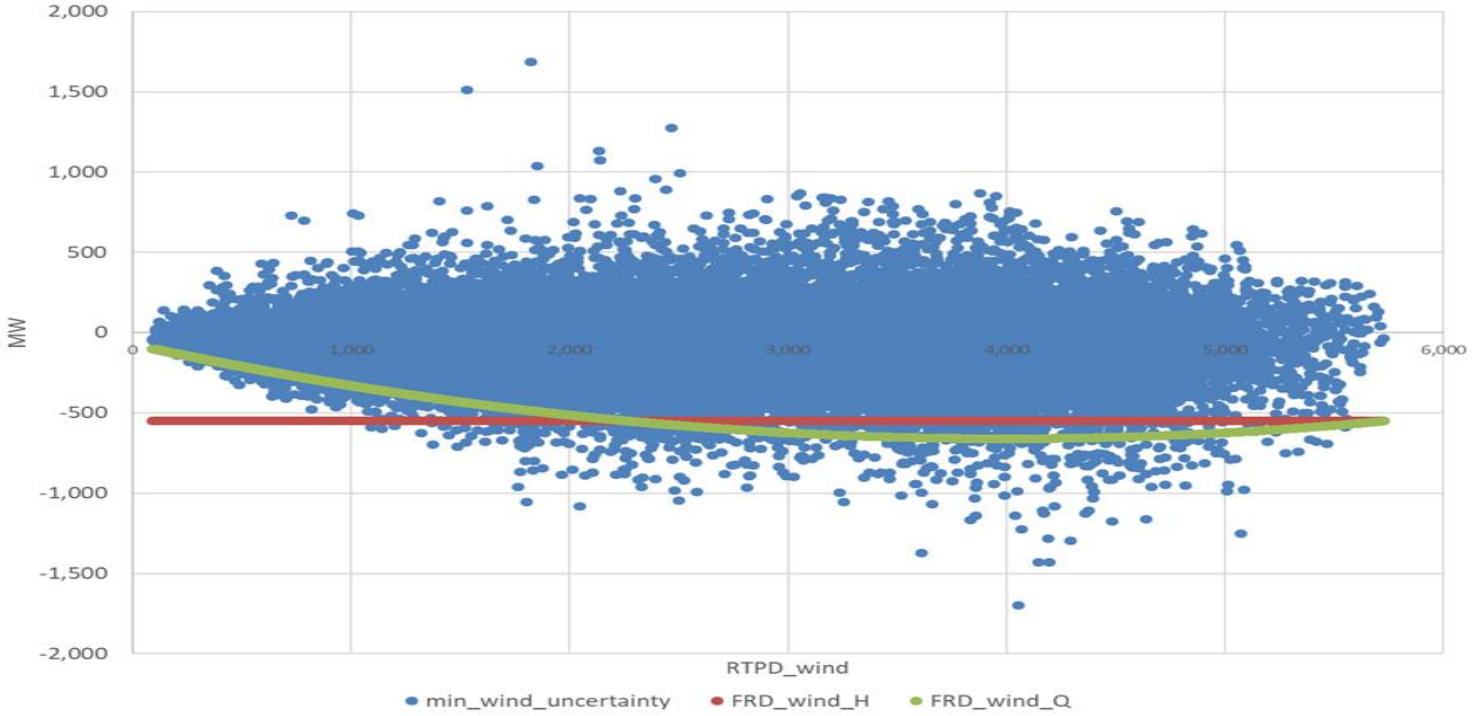


Uncertainty in Solar



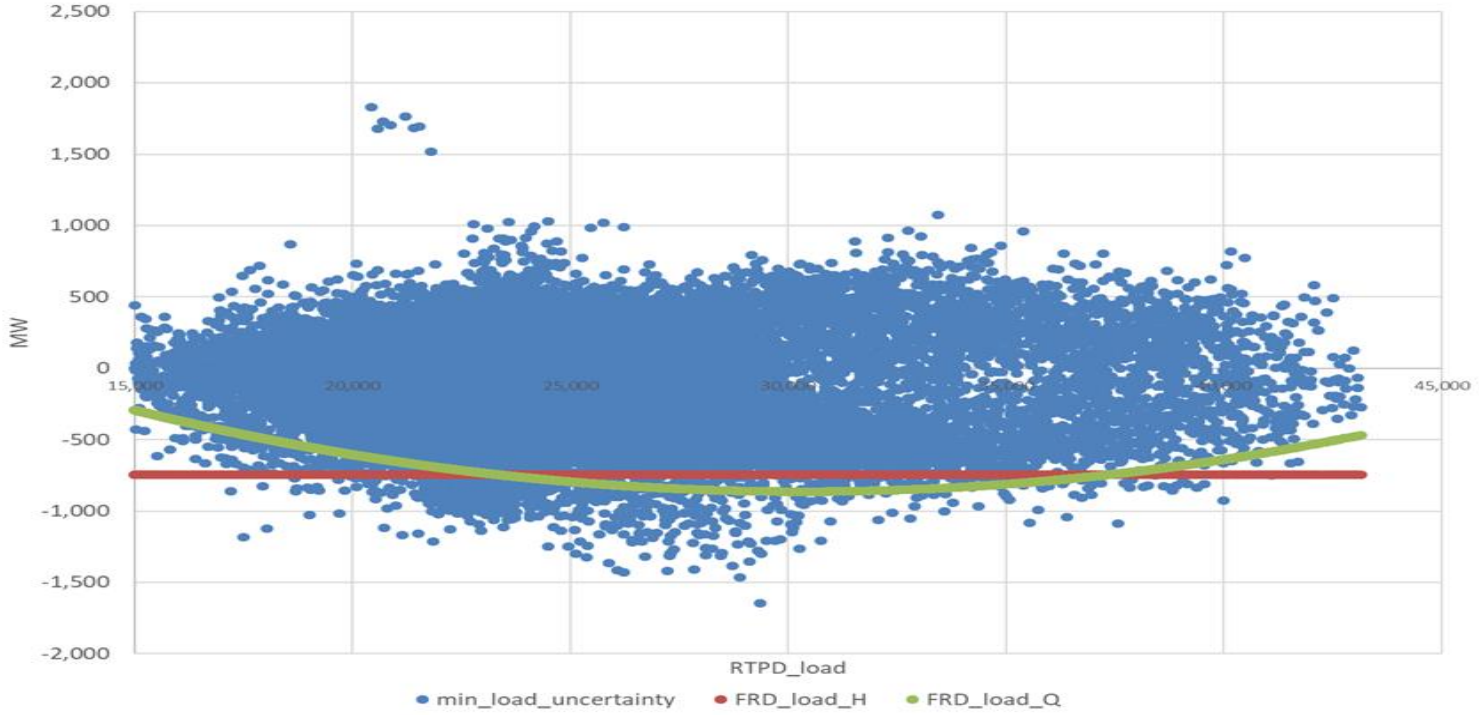
- Quadratic Pattern:
  - uncertainty higher at the mid-range,
  - gradually reduces to zero at the extremes
- Green Line: $S_q = a_s + b_s * solar_{RTPD} + c_s * solar_{RTPD}^2$
- Red Line: $S_H = a_s$

Uncertainty in Wind



- Quadratic Pattern:
  - uncertainty higher at higher penetration,
  - gradually reduces to zero during lower penetration.
- Green line: $W_q = a_w + b_w * wind_{RTPD} + c_w * wind_{RTPD}^2$
- Red line: $W_H = a_w$

Uncertainty in Load



- Quadratic Pattern:
  - uncertainty higher at the mid-range,
  - gradually getting smaller at the ends
- Green line: $L_q = a_l + b_l * load_{RTPD} + c_l * \ load^2_{RTPD}$
- Red line: $L_H = a_L$

Mosaic Model for Net Load Uncertainty

- The quadratic relationships (green lines) L_q, W_q, and S_q attempt to adapt the weather information (RTPD forecasts) while the linear relationships (red lines) L_H, W_H, and S_H cannot.
- Construct the mosaic variable as

$$mosaic = NL_h + (L_q - L_h) - (W_q - W_h) - (S_q - S_h)$$

- Perform a quantile regression

$$NL_M = a_m + b_m * mosaic + c_m * mosaic^2$$

Definition of the Mosaic Model

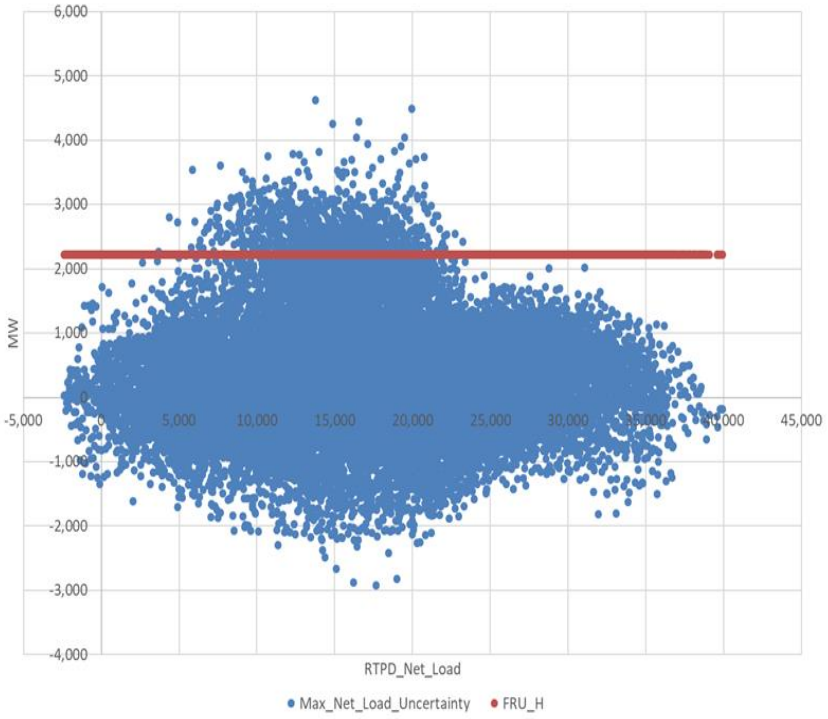
- Mosaic variable

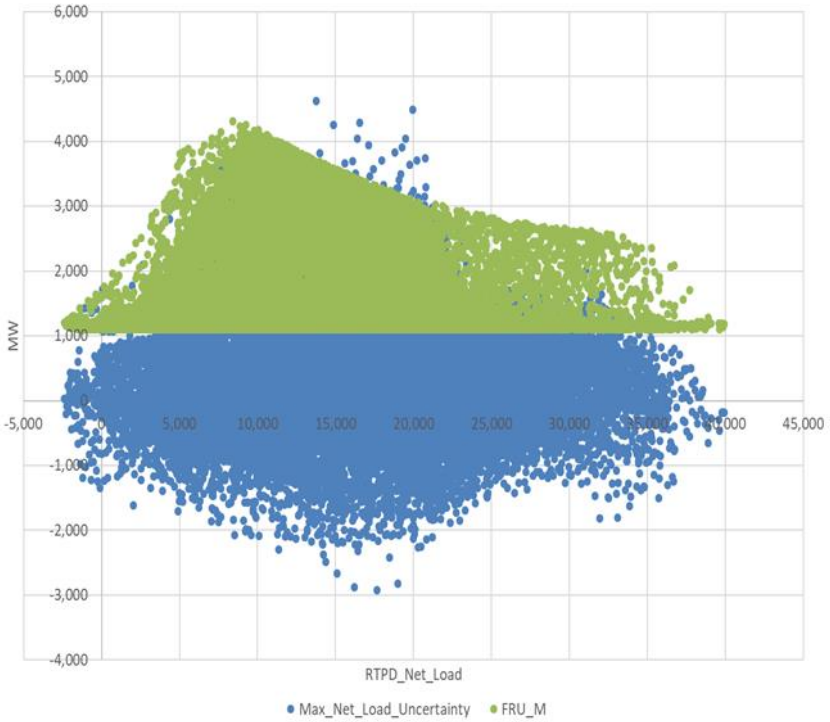
$$NL_h + (L_q - L_h) - (W_q - W_h) - (S_q - S_h)$$

$$= (L_q - W_q - S_q) + NL_h - (L_h - W_h - S_h)$$

- $L_q - W_q - S_q$ has the net load structure
- $NL_h - (L_h - W_h - S_h)$ reflects the effect of non-additive interactions among load, wind, and solar.
- If $L_q = L_h, W_q = W_h,$ and $S_q = S_h,$ then $NL_M = NL_h$.

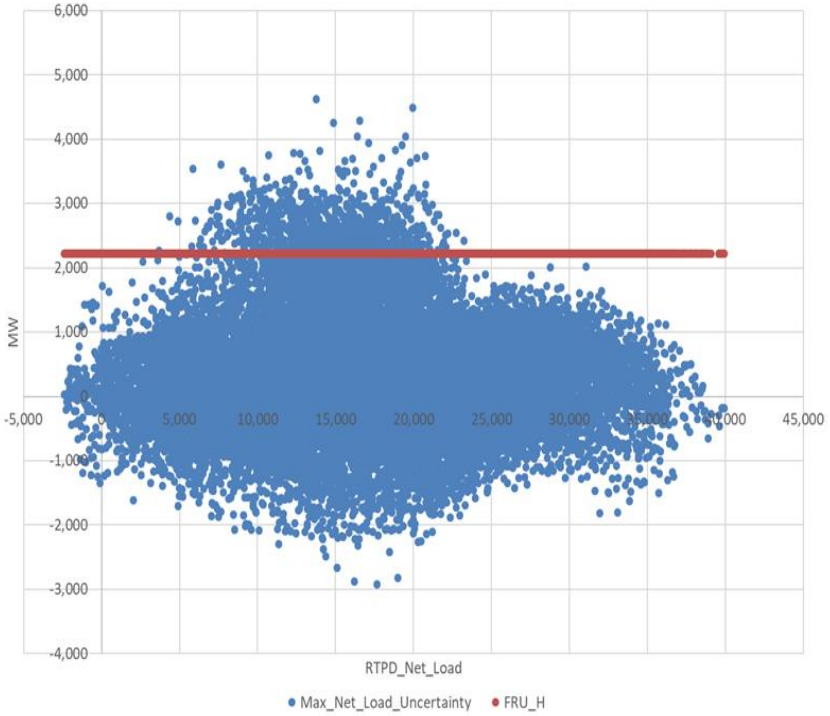
Uncertainty in Net Load vs. RTPD Net Load

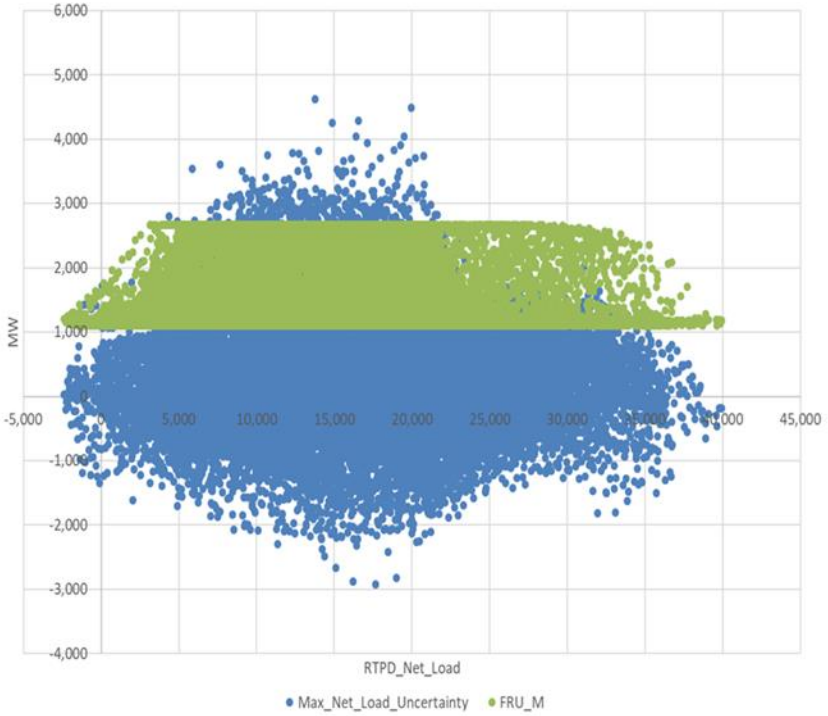




- Quadratic Pattern:
  - uncertainty higher at the mid-range,
  - gradually reduces to zero at the ends
- Blue Dots: observed uncertainty
- Green Dots: $NL_M = a_m + b_m * mosaic + c_m * mosaic^2$
- Red line: $NL_H = a_h$

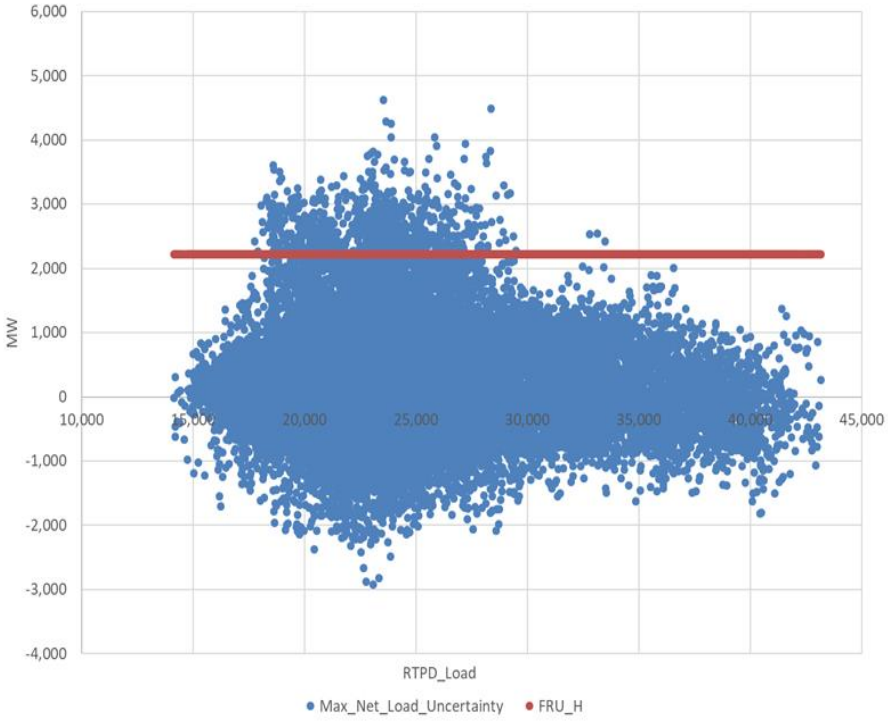
Uncertainty in Net Load vs. RTPD Net Load

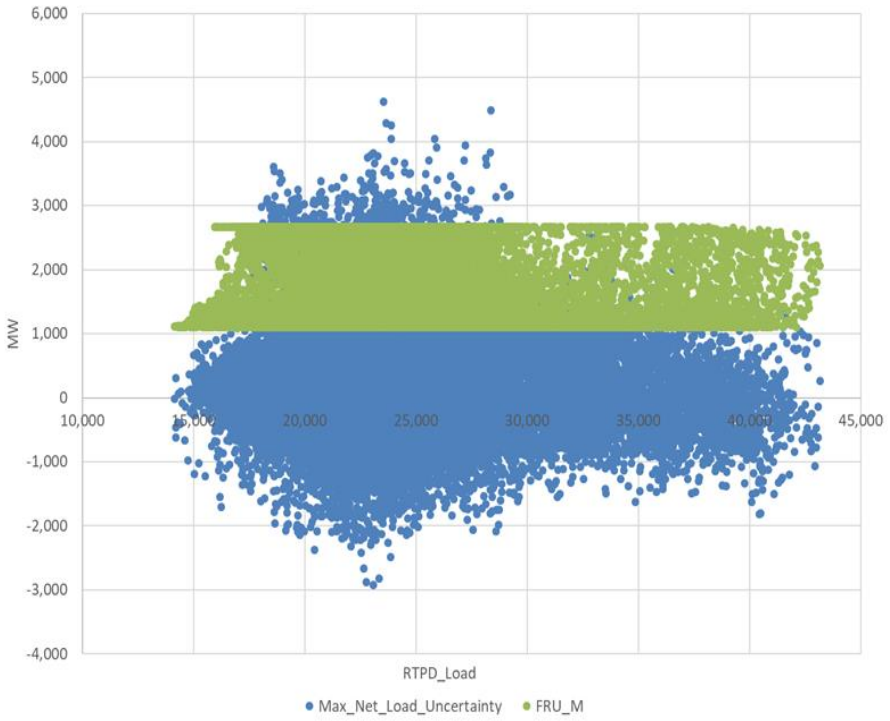




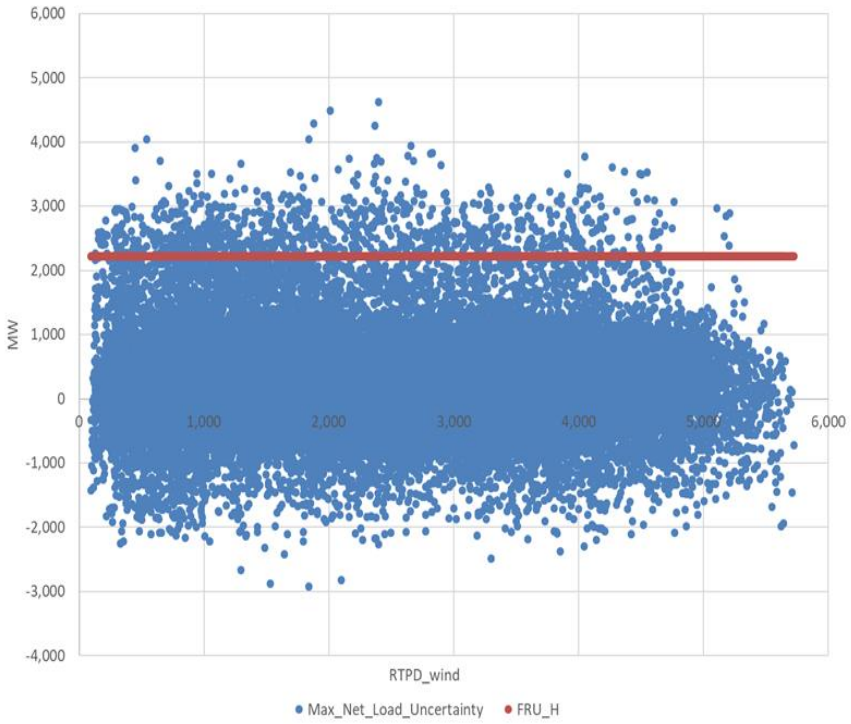
- Green Dots capped by 99% of NL_H
- The 99% is to ensure stability of regression output

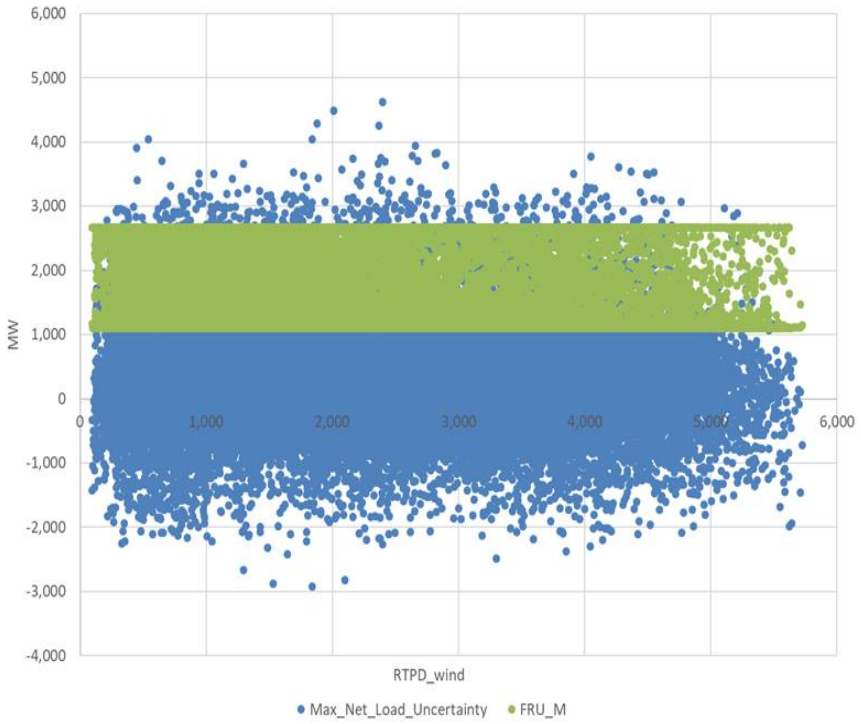
Uncertainty in Net Load vs. Load



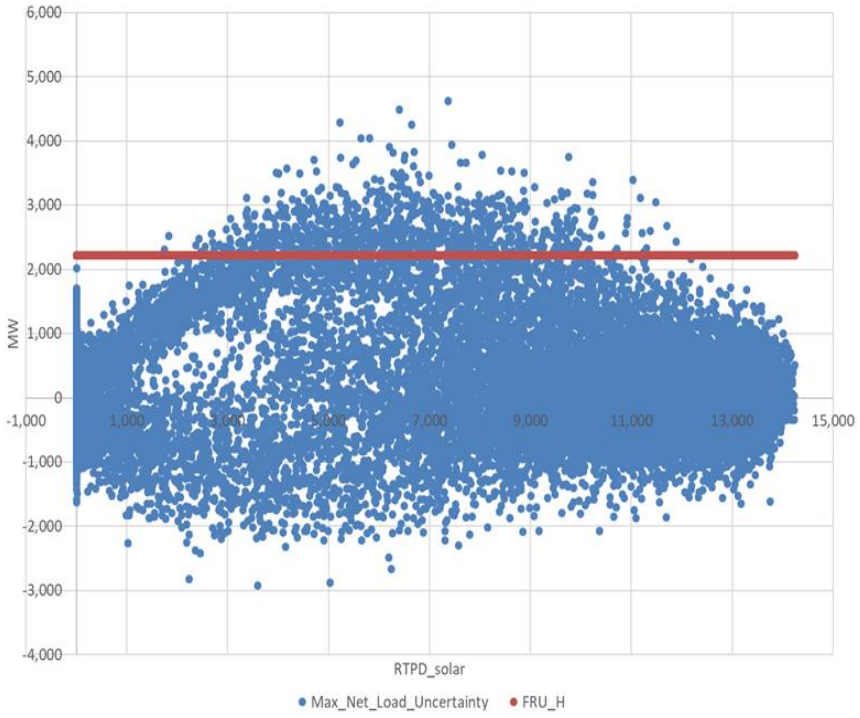


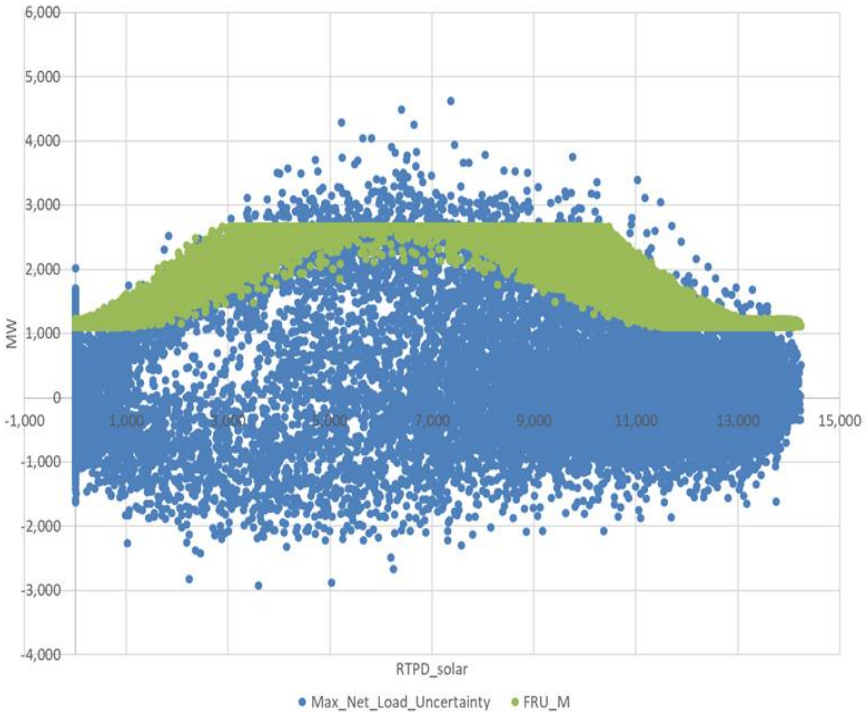
Uncertainty in Net Load vs. Wind





Uncertainty in Net Load vs. Solar



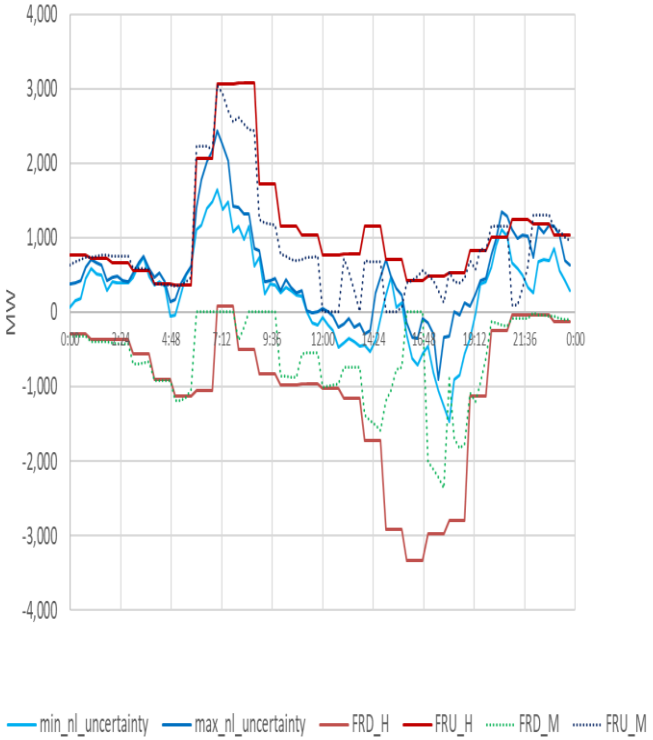


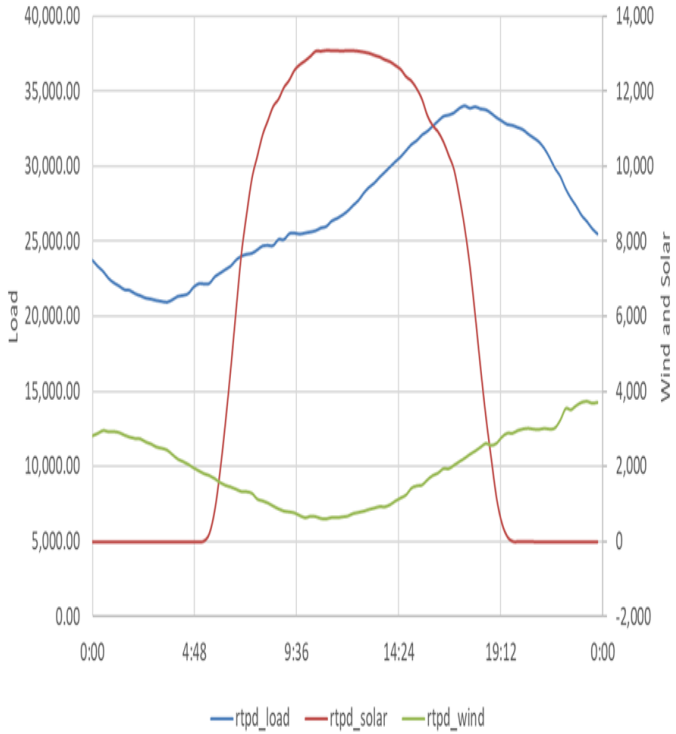
Simulation Study

BAA name	first wind date	first solar date	wind pmax	solar pmax	load max	wind pcent	solar pcent	load pcent
APS	10/1/2016	10/1/2016	399.20	560.00	7627.43	4.65%	6.52%	88.83%
BANC		4/3/2019		189.28	4387.95	0.00%	4.14%	95.86%
BCHA	4/4/2018		755.17		11887.00	5.97%	0.00%	94.03%
CISO	5/1/2014	5/1/2014	4386.19	5153.10	47484.16	7.69%	9.04%	83.27%
IPCO	4/4/2018	4/4/2018	718.57	289.50	4100.46	14.07%	5.67%	80.27%
LADWP	4/1/2021	4/1/2021	426.63	1154.00	4893.04	6.59%	17.83%	75.58%
NEVP	12/1/2015	12/1/2015	149.10	341.50	9444.36	1.50%	3.44%	95.06%
NWMT	6/16/2021	6/16/2021	462.54	18.70	1912.25	19.32%	0.78%	79.89%
PACE	10/15/2014	12/17/2015	1520.75	130.00	9413.13	13.75%	1.17%	85.08%
PACW	10/15/2014	6/1/2016	617.85	5.00	4227.01	12.74%	0.10%	87.16%
PGE	10/1/2017		716.70		4531.45	13.66%	0.00%	86.34%
PNM	4/1/2021	4/1/2021	957.00	392.20	2533.19	24.65%	10.10%	65.25%
PSEI	10/1/2016		375.10		5032.94	6.94%	0.00%	93.06%
SRP	4/1/2020	4/1/2020	128.00	136.00	7746.96	1.60%	1.70%	96.70%

Simulation Period: January 1, 2021 to December 31, 2021
Historical Data: January 1, 2020 to December 31, 2021
Sampling Scheme (2): 180d, matching weekday/weekend

Daily Graph(CISO) showing the adaptive nature of M vs H with differing weather patterns





How do we assess the performance of the proposed approach? M *vs.* H

- Four criteria in measurements
  - Coverage: This is used to check the validity of a model, and is the coverage of observed uncertainty against the estimate requirement. The uncertainty requirement is targeted for 95%, which is achieved with 97.5% for upward and 2.5% for downward requirement.
  - Requirement: This is the average of the estimated requirement over a period of time.
  - Closeness: This is defined as the average distance between the observed uncertainty and the estimated requirement.
  - Exceeding: This is the average MW difference when the observed uncertainty is exceeding the estimated requirement.

Performance comparison: M vs. H

- Coverage with proposed approach is comparable to but marginally lower than current approach

BAA	FRU_H	FRU_M	FRD_H	FRD_M
APS	95.78%	95.27%	96.27%	95.27%
BANC	97.23%	96.70%	95.47%	96.32%
BCHA	96.84%	95.39%	96.86%	96.00%
CISO	96.41%	95.44%	96.47%	95.59%
IPCO	96.72%	95.70%	97.16%	96.23%
LADWP	98.07%	98.03%	97.69%	96.95%
NEVP	94.74%	94.22%	96.47%	95.60%
NWMT	96.56%	94.39%	97.86%	96.46%
PACE	96.31%	95.14%	96.07%	94.93%
PACW	97.09%	96.28%	96.58%	95.85%
PGE	97.14%	96.33%	97.17%	96.41%
PNM	98.92%	98.72%	99.69%	99.01%
PSEI	96.74%	95.76%	96.95%	96.11%
SRP	95.34%	94.95%	95.80%	94.70%

Performance comparison: M vs. H

- Requirement with proposed approach is lower than with current approach

BAA	FRU_H	FRU_M	FRD_H	FRD_M
APS	150.68	135.89	-127.24	-117.99
BANC	60.52	41.45	-49.14	-43.81
BCHA	157.49	151.57	-169.00	-161.67
CISO	1142.37	1042.13	-943.51	-850.52
IPCO	105.89	101.74	-132.72	-124.42
LADWP	152.43	147.32	-148.52	-135.85
NEVP	165.02	141.58	-139.53	-129.69
NWMT	81.15	77.15	-98.52	-91.95
PACE	250.80	241.12	-286.39	-273.01
PACW	112.55	106.14	-98.53	-92.13
PGE	130.70	121.66	-118.67	-112.25
PNM	136.49	137.04	-166.43	-161.23
PSEI	94.00	90.04	-101.46	-98.19
SRP	113.68	102.66	-109.17	-97.01

Performance comparison: M vs. H

- Closeness is smaller (better) with proposed approach

BAA	FRU_H	FRU_M	FRD_H	FRD_M
APS	133.49	119.11	120.32	111.92
BANC	53.59	34.69	44.91	39.56
BCHA	138.48	134.05	148.10	141.64
CISO	891.44	798.23	931.16	843.43
IPCO	105.86	102.24	118.68	110.85
LADWP	138.40	133.07	136.17	123.58
NEVP	146.10	122.81	126.87	117.91
NWMT	80.56	77.46	89.32	83.16
PACE	239.31	231.18	256.79	245.03
PACW	99.34	93.23	93.11	86.90
PGE	113.65	105.10	118.71	112.60
PNM	128.85	129.68	155.25	150.30
PSEI	86.46	82.97	93.10	90.20
SRP	99.86	89.10	99.15	87.65

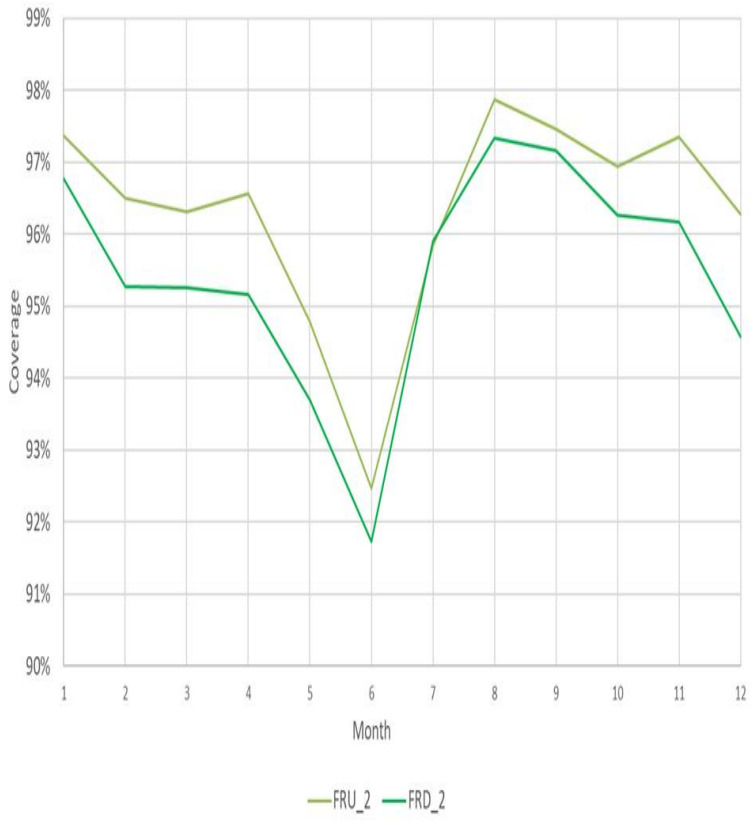
Performance comparison: M vs. H

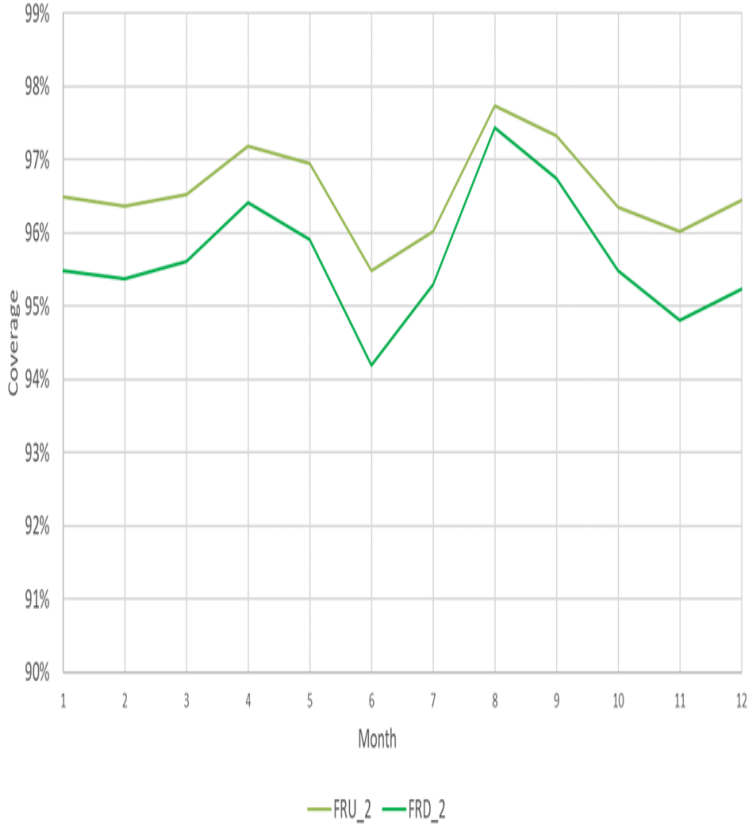
- Exceeding with proposed approach varies by balancing area

BAA	FRU_H	FRU_M	FRD_H	FRD_M
APS	39.97	39.99	38.30	39.22
BANC	14.47	14.73	6.46	7.73
BCHA	37.96	42.12	46.00	47.07
CISO	235.30	262.11	242.17	253.37
IPCO	37.52	34.85	34.26	32.12
LADWP	52.74	45.95	36.60	28.99
NEVP	45.73	42.87	39.94	42.00
NWMT	26.20	24.09	17.58	16.31
PACE	71.96	70.52	86.07	82.69
PACW	32.86	29.64	30.01	26.93
PGE	40.46	38.23	47.20	41.53
PNM	19.69	27.16	22.33	19.44
PSEI	28.59	27.58	29.28	27.76
SRP	26.51	27.11	32.15	31.78

Performance comparison: M vs. H

- Seasonality: The proposed approach (M) exhibits less seasonality fluctuation



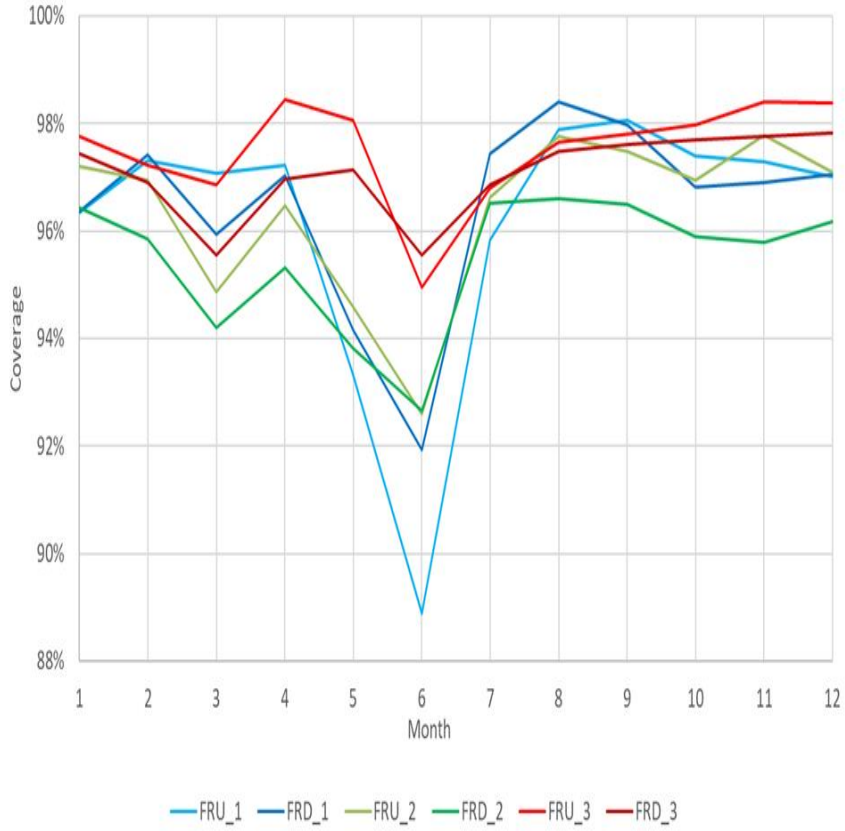


Other Considerations: Sampling of historical data set

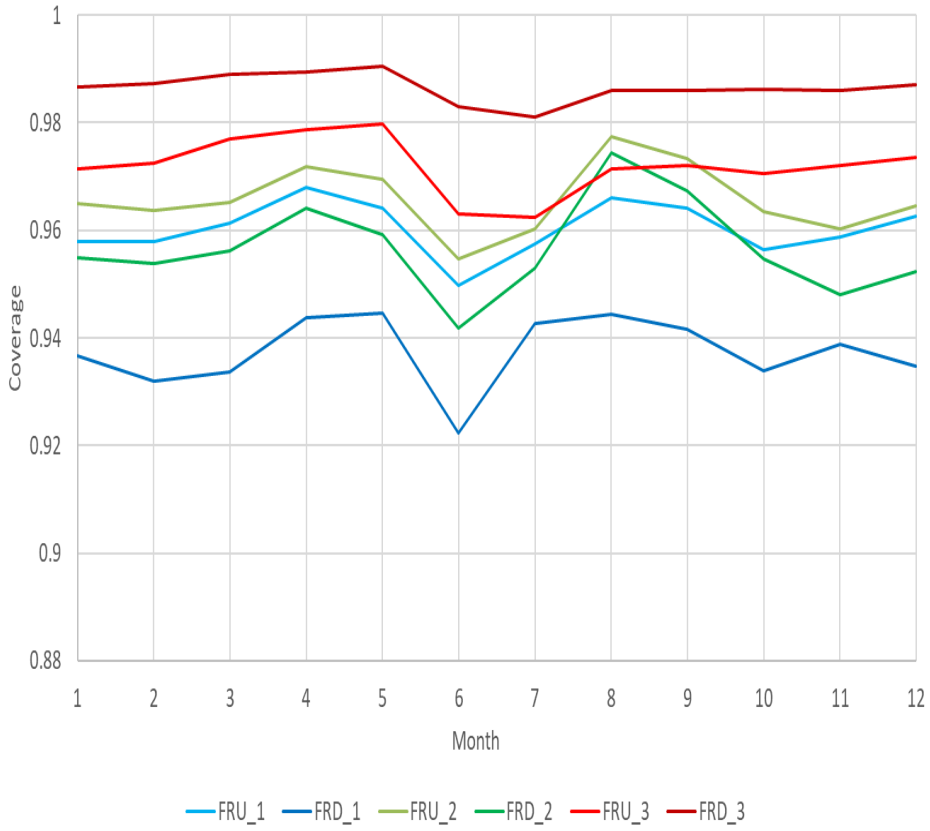
- **Sampling Scheme 1:** Rolling previous 40 days matching weekdays and 20 matching weekends. This is the sampling used in the ISO's current Histogram approach.
- **Sampling Scheme 2:** A fixed 180 rolling days with varying number of weekdays and weekend (holidays included). The increased sample size will bolster the robustness of regression computation.
- **Sampling Scheme 3:** In addition to the sampling scheme 1, use the forward historical data in last year anchored from a date similar to the current day with matching weekday/weekend. The scheme balances out backwards and forward data for any given day.

Sampling scheme 3 performs the best throughout the year for both M & H

Histogram

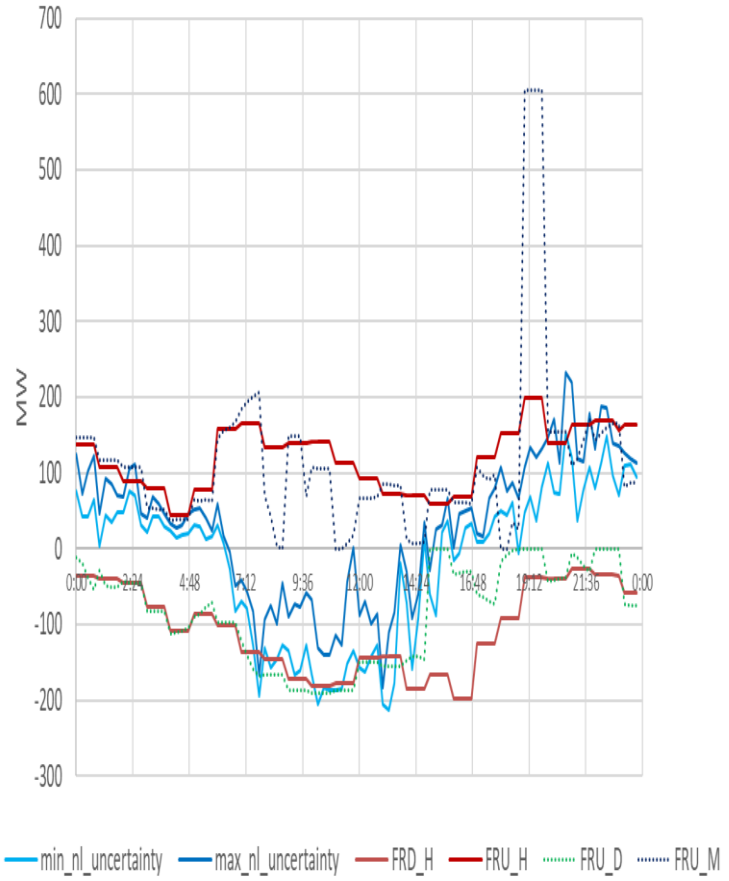


Mosaic



Other Considerations: Additional Thresholds

- Add additional thresholds to further control input outliers, regression abnormality caused by small size
  - One overall positive upper threshold for FRU to cap the estimated requirement
  - One overall positive lower threshold to prevent the requirement to be zero for FRU



Acronyms

APS	Arizona Public Service
BANC	Balancing Authority of Northern California
BCHA	Powerex
BTM	Behind the Meter
FRD	Flexible Ramping Down
FRP	Flexible Ramping Product Requirements
FRU	Flexible Ramping Up
H	Histogram
IPCO	Idaho Power Company
ISO	Independent System Operator
L	Load Uncertainty
LADWP	Los Angeles Department of Water and Power
M	Mosaic Quantile
MW	Megawatt
NEVP	NV Energy
NL	Net Load Uncertainty
NWMT	Northwestern Energy
PACE	PacifiCorp East
PACW	PacifiCorp West
PGE	Portland General Electric
PNM	Public Service Company of New Mexico
PSEI	Puget Sound Energy
Q	Quantile
RTD	Real Time Dispatch
RTPD	Real Time Pre-Dispatch
S	Solar Uncertainty
SRP	Salt River Project
W	Wind Uncertainty
WEIM	Western Energy Imbalance Market