Valuing Uncertainties in Wind Generation

An Agent-Based Optimization Approach

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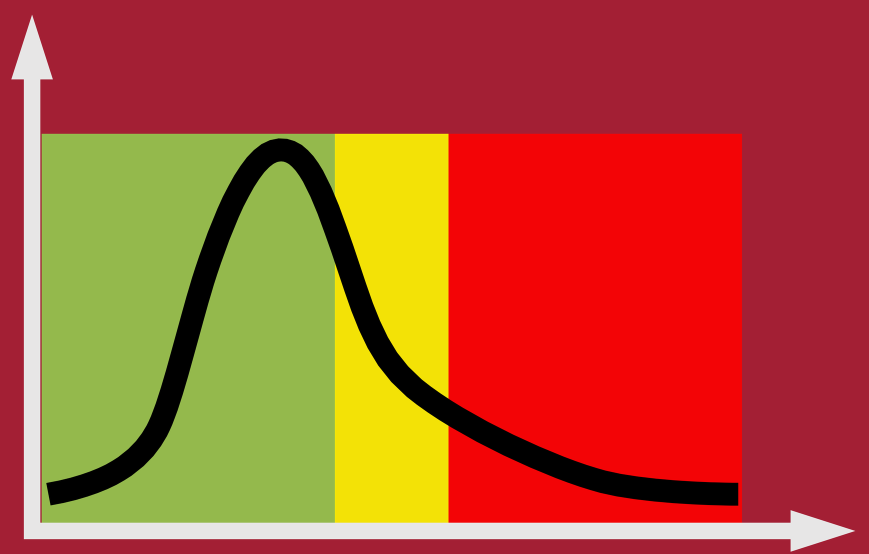
Forecasts for wind & solar come with ***uncertainty***.



Each MW has a different ***likelihood of actually being available***, so each MW has a different value.

We value each MW of wind based on the anticipated system price conditions and wind uncertainty…

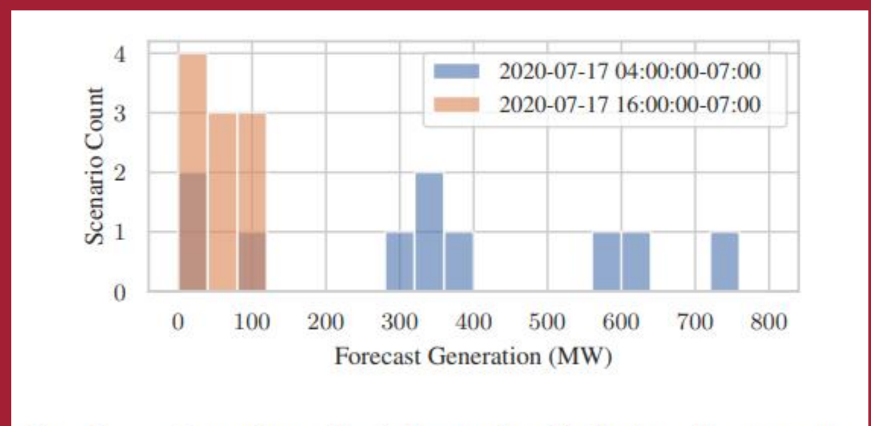


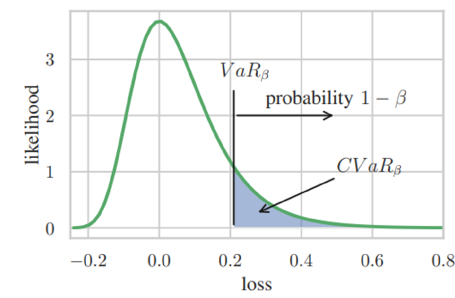
Fig. 3. Comparison of wind scenario distributions for generator 317_WIND_1 at hours 0400 and 1600

And simulate the effects when wind generators apply this offer strategy in a test 73 bus system (RTS-GMLC) .

Background

- Variable Renewable Energy (VRE) has zero fuel costs but more uncertain delivery characteristics
- While forecasts for these resources are improving, there will always be uncertainty in the forecasts; we could be 99% confident in the first 50MW forecast block but only 30% confident of the next 10MW.
- *What if the energy offers reflected the firmness of each MW instead of solely variable costs such as fuel?*

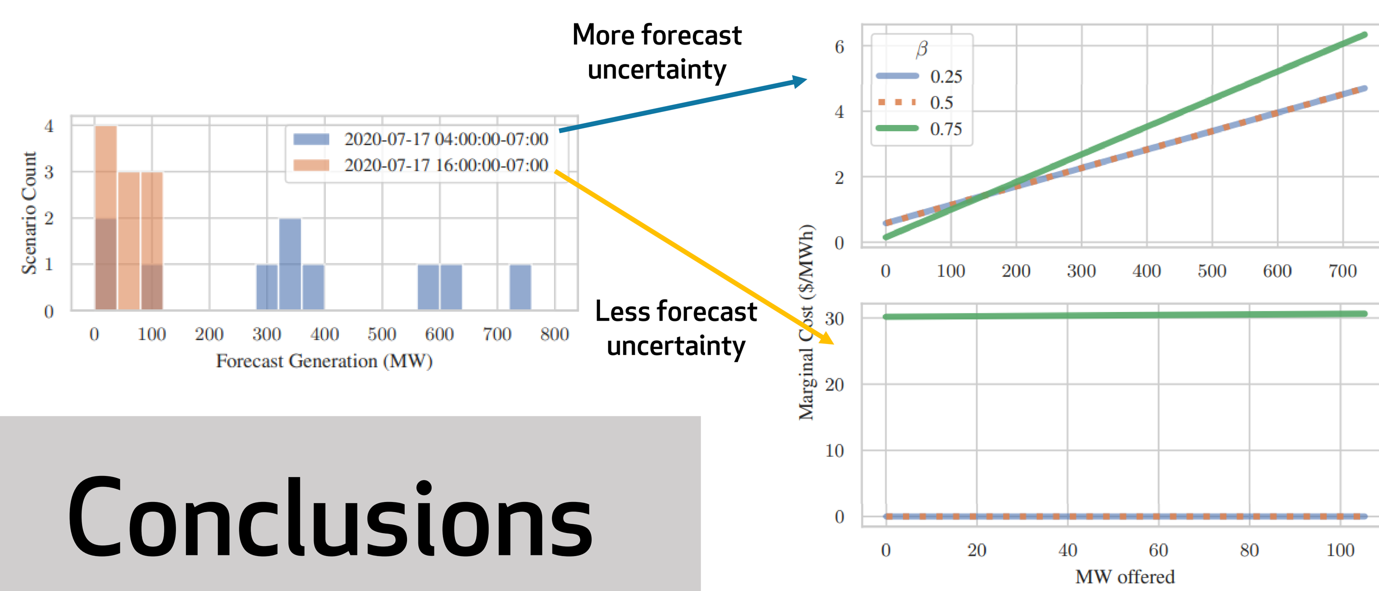
Methods



$$\max_{a,b} \; CVaR_{\beta,\lambda_{i,t},\alpha_{i,t}}\left(\lambda_{i,t}\cdot\frac{\lambda_{i,t}-b}{2a}-\alpha_{i,t}\cdot\Delta\tilde{p}\right)$$
$$s.t. \; a \geq 0$$

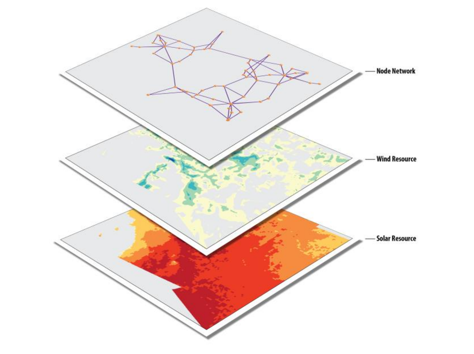
Risk Preference · DA Clearing Price · RT Clearing Price

- The generator determines coefficients *a* and *b* that characterize its marginal price offer as a function of MW: [$/MWh] = 2a + b
- This offer is influenced by:
  - Revenue from the day-ahead market
  - Penalty from repurchasing shortfall in the real-time market
  - Generator risk preference
  - The distribution of forecasted wind power



Results

Generation	Total capacity (RTS-GMLC)	Count	Keep?	Final %
Gas (CC)	3550	10	Yes	31
Wind	2508	4	Yes	22
Coal	2317	16	Yes	20
Gas (CT)	1485	27	Yes	13
Hydro	950	19	Yes	8
Nuclear	400	1	Yes	3
Oil (CT)	240	12	Yes	2
Oil (Steam)	84	7	Yes	1
PV (Utility)	1555	25	No	0
Rooftop PV	1161	31	No	0
Concentrated Solar	200	1	No	0
Run-of-River	50	1	No	0
Storage	50	1	No	0



A modified RTS-GMLC system was used for the simulation.

TABLE III
MEAN TOTAL PAYMENTS TO GENERATORS ($, THOUSANDS) BY GENERATION TYPE AND WIND OFFER STRATEGY

Generators	Centralized Dispatch 25th	50th	75th	Risk-Aware Wind Bids β=0.25	0.5	0.75
Coal	197432	195418	195407	189988	217076	207836
Hydro	91328	89724	88916	88494	101349	99549
Gas (CC)	236498	234349	224971	205979	238631	241216
Gas (CT)	72343	70984	73424	77706	79749	76999
Nuclear	45687	45294	44749	41594	47462	46026
Oil (CT)	49	44	70	0	1005	0
Oil (Steam)	183	182	182	183	183	185
Wind	32312	35289	24425	-9647	-610	10240
Total	675832	671284	652144	594297	684845	682051

TABLE IV
STANDARD DEVIATION OF TOTAL PAYMENTS TO GENERATORS ($, THOUSANDS) BY GENERATION TYPE AND WIND OFFER STRATEGY

Generators	Centralized Dispatch 25th	50th	75th	Risk-Aware Wind Bids β=0.25	0.5	0.75
Coal	4146	4180	4320	3886	2825	1086
Hydro	2291	1954	1588	858	816	840
NG (CC)	3036	3077	3429	3431	2887	1528
NG (CT)	2404	2624	3257	3089	2671	1250
Nuclear	14	13	14	14	9	4
Oil (CT)	11	8	12	0	6	0
Oil (Steam)	0	0	0	0	0	0
Wind	7572	8160	9049	9138	6582	2331

- In certain risk-preference scenarios (low risk tolerance), wind generators lose money because their input estimates of market clearing prices are not accurate.
- Wind generators make more profit when the system operator dispatches them based on simple heuristics, but the variance in generator payments significantly increases to fast-response generators.
- The specific impacts of allowing generators to hedge in energy markets will be dependent on the mix of generation resources and system loading.

Conclusions

- Possible to create offers that empirically reflect uncertainty-associated costs
- “Uncertainty-aware” offers empirically lower the variance in wind generator revenues, with the tradeoff of lower expected revenues; hedging works
- Multiday cycle simulations with learning of generator offer vs. market price needed to demonstrate effectiveness of hedging strategy & find Pareto frontier of expected system cost vs. variance in costs

Read our paper from ACC 2023→
https://arxiv.org/abs/2210.02963

The information, data, or work presented herein was supported by the National Science Foundation Graduate Research Fellowship under Grant No. 2141064 as well as in part by the Advanced Research Projects Agency - Energy (ARPA-E), U.S. Department of Energy under Award Number DEAR0001277. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.