Stochastic Wind Power Bidding in the Southwest Power Pool Market

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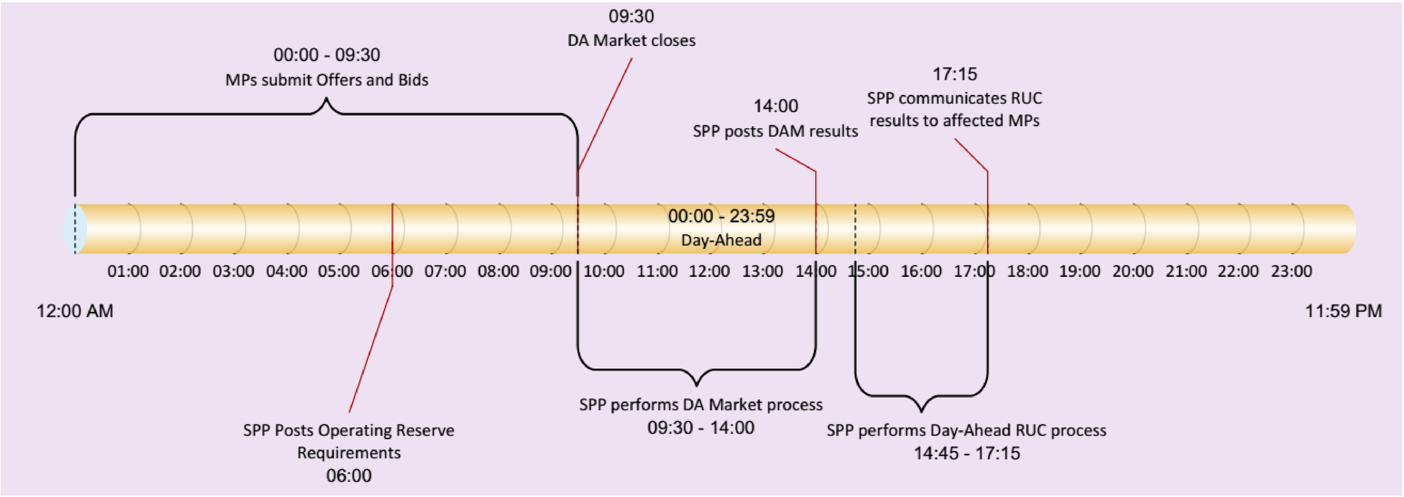
Introduction

- Goal: Develop a stochastic optimization-based dynamic operation model to generate the optimal bidding strategies for wind power producers to participate in the Southwest Power Pool's (SPP's) electricity market.
- The wind power producer is considered as a price taker in the market.
- The model generates day-ahead optimal bidding curves for the wind power units while considering their operations in the real-time market.
- Uncertain parameters, including day-ahead wind power production, day-ahead prices, and real-time prices, are modeled using prediction-based scenario generation and reduction methods.
- Risk management is considered in the model to manage the risks associated with uncertainties.

Market Framework and Current Operation Strategy



- Market participants submit their day-ahead offers and bids from 00:00 to 09:30 AM every day.
- The market operator clears day-ahead prices from 09：30 AM to 14：00 PM.
- The offering price of wind power producer in the day-ahead market is a negative value per MW. This ensures that all the bid wind power capacity will be accepted in the day-ahead market.

- Current bidding strategy

$$\pi_W = \sum_{t=1}^{N_T} \times [\lambda_t^D W_t^D d_t + \lambda_t^r \Delta_{tw}^+ - \lambda_t^r \Delta_{tw}^-]$$

- The capacity bid in the day-ahead market is the same as the wind power generation forecasted by the SPP operator.
- If the actual wind power generation on the next day is different from the capacity bid in the day-ahead market, the deviation should be traded in (sold in or purchase from) the real-time market.

Proposed Operation Strategy

- Proposed bidding strategy

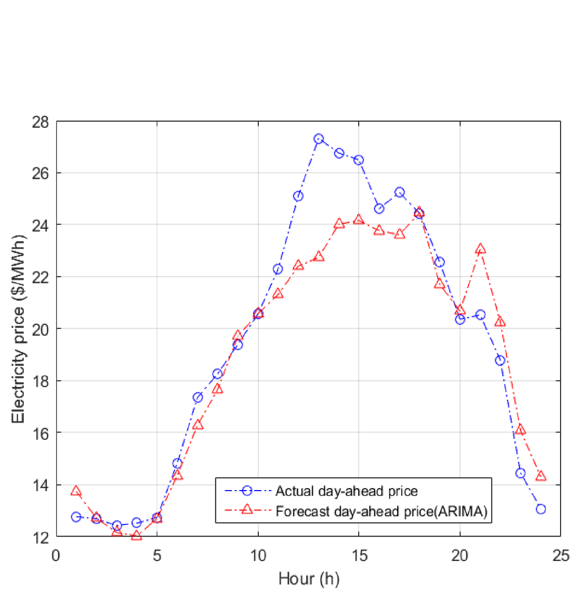
$$\underset{W_{tw}^D, \zeta, \eta_w}{\text{Max}} \ \pi_W = \sum_{w=1}^{N_\Omega} pr_w \sum_{t=1}^{N_T} \times [\lambda_{tw}^D W_{tw}^D d_t + \lambda_{tw}^r \Delta_{tw}^+ - \lambda_{tw}^r \Delta_{tw}^-]$$
$$+\beta_W[\zeta - \frac{1}{1-\alpha} \sum_{w=1}^{N_w} pr_w \eta_w]$$

Subject to:

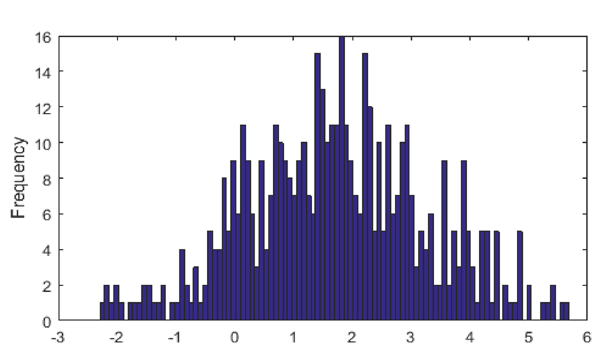
$$0 \le W_{tw}^D \le W^{max}, \quad \forall t, \omega$$
$$\Delta_{tw}^+ - \Delta_{tw}^- = \Delta_{tw}, \quad \forall t, \omega$$
$$\Delta_{tw} = d_t (W_{tw}^{ac} - W_{tw}^D), \quad \forall t, \omega$$
$$0 \le \Delta_{tw}^+ \le W_{tw}^{ac} d_t, \quad \forall t, \omega$$
$$0 \le \Delta_{tw}^- \le W_{tw}^D d_t, \quad \forall t, \omega$$
$$W_{tw}^D = W_{tw'}^D, \quad \forall t, \omega, \omega' : \lambda_{tw}^D = \lambda_{tw'}^D$$
$$(\lambda_{tw}^D - \lambda_{tw'}^D)(W_{tw}^D - W_{tw'}^D) \ge 0, \quad \forall t, \omega, \omega'$$
$$\eta_w \ge 0, \quad \forall w$$
$$\zeta - \sum_{w=1}^{N_\Omega} pr_w \sum_{t=1}^{N_T} [\lambda_{tw}^D W_{tw}^D d_t + \lambda_{tw}^r \Delta_{tw}^+ - \lambda_{tw}^r \Delta_{tw}^-] \le \eta_w, \quad \forall w$$

Scenario Generation

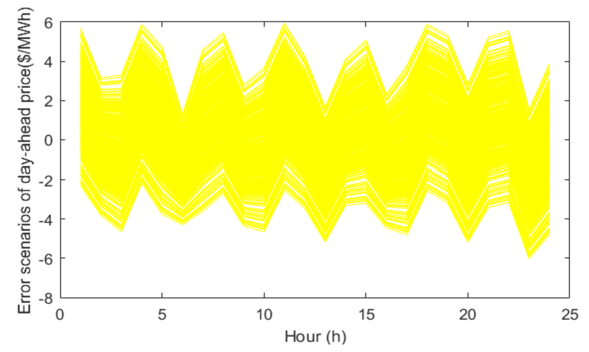
- Scenario generation based on autoregressive integrated moving average (ARIMA) prediction for uncertain parameters and Gaussian distribution for prediction errors



- ARIMA prediction results of the 24-hour day-ahead electricity prices on June 1, 2015.

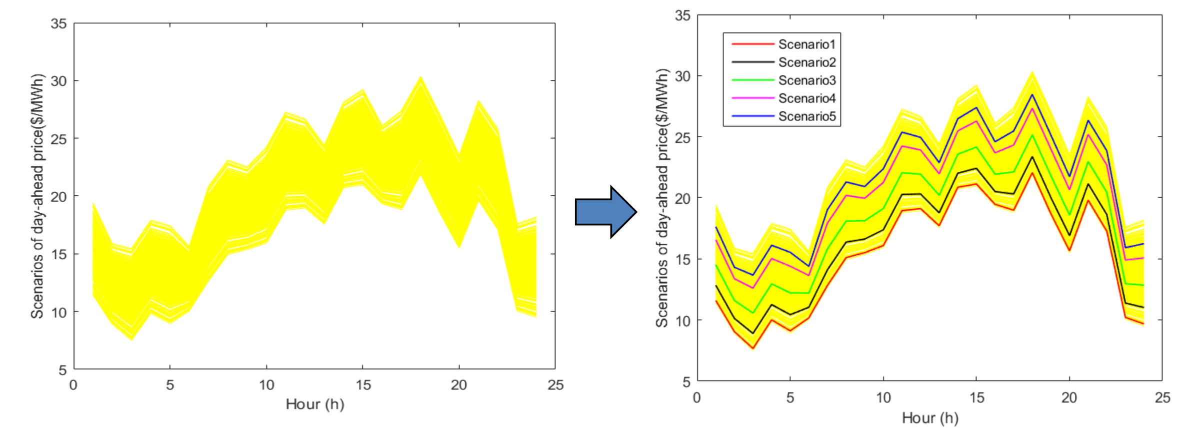


- 500 scenarios of forecast errors of day-ahead price for the first hour of June 1, 2015.



- Scenarios generated for 24-hour forecast errors.

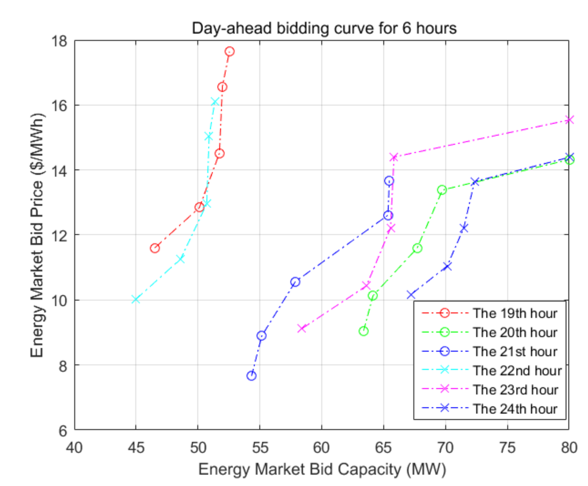
Scenario Reduction



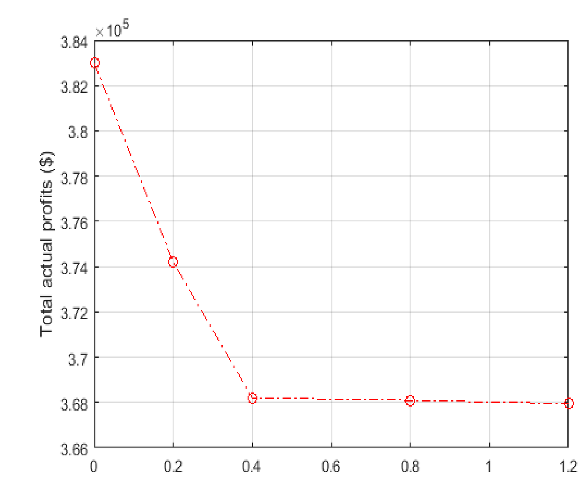
- Scenarios of 24-hour day-ahead prices on June 1, 2015.
- Three random parameters in the model
  Day-ahead price: 5 scenarios
  Real-time price: 5 scenarios
  Wind power production: 5 scenarios
- 5×5×5 ➡ 125 scenarios

Scenario number	1	2	3	···	124	125
Day-ahead price($)	11.604	11.604	11.604	···	17.64	17.64
Real-time price($)	0.957	0.957	0.957	···	25.523	25.523
Wind power production(MW)	46.288	51.133	57.681	···	65.703	69.887
Probability	0.0000219	0.0000267	0.000431	···	0.00621	0.00474

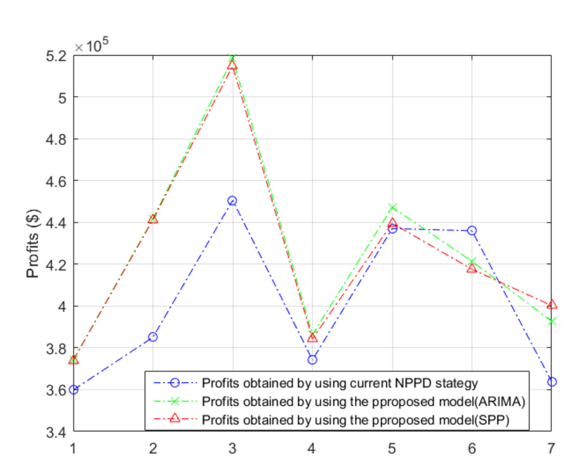
Results and Analysis



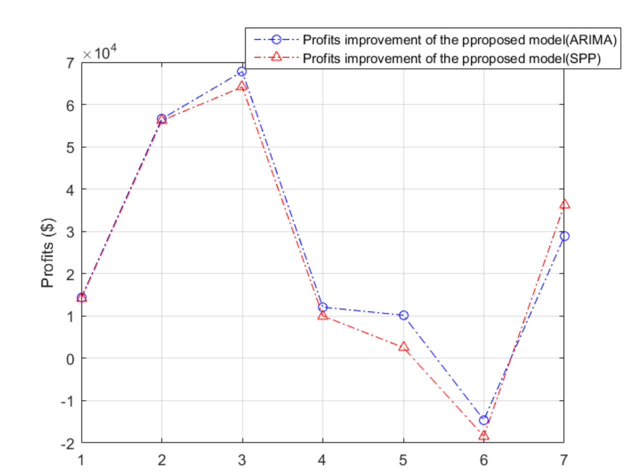
- Bidding curves for 6 hours on June 1, 2015



- Risk-aversion parameter sensitivity analysis



- Actual monthly profits for June-December, 2015.



- Profit improvement of the seven months in 2015 obtained from the proposed model.

Conclusion

- A dynamic operation model for price-taker wind power producers to participate in the SPP electricity market has been developed based on the stochastic optimization principle.
- Day-ahead bidding curves have been generated using the model for wind power producers to gain the maximum profits in the SPP Market.
- Case studies have been performed for a wind power producer using real data obtained from the SPP market. Results show that the proposed model enabled the wind power producer to gain over 6% more profits in the SPP market than the current operation strategy.
- Additional information (e.g., maintenance schedule and outage) and additional resources (e.g., energy storage if available) can help better manage uncertain risks in the real-time market.

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