How Smart Grid Technologies & Energy Storage Can Help Offshore Wind in PJM Markets

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Intro

This project aims to investigate advanced strategies for NJ offshore wind to make it marketable in the PJM markets, to embrace its maximum capacity, and to support its sustainable development. Using artificial intelligence (AI) and machine learning (ML) tools, an optimal bidding strategy will be investigated for wind power producers (WPPs) to use in PJM's wholesale market participation.

Methods

The current practices of WPPs in the wholesale electricity markets (including PJM) were firstly baselined. Specifically, the day-ahead and real-time wholesale electricity markets were chosen as the starting point to investigate WPPs' market potential via strategic bidding. The optimal ML algorithms were determined for forecasting wholesale electric energy Locational Marginal Pricing (LMPs) in both the day-ahead and real-time markets, and a reinforcement learning (RL) algorithm was adopted for WPPs to bid into the PJM markets. Using forecasted offshore wind speeds, the optimal bidding capacity from calculated wind power outputs are matched with the forecasted wholesale market prices to learn and construct the optimal (quantity, price) bids via the RL tool. The model will be continually evaluated for further optimization. The Ocean Wind I project was used as a specific example for data analysis.

Results

Offshore wind farms can be more profitable in the electricity wholesale markets than they would be through long-term Power Purchase Agreements (PPAs). LMP price patterns can be matched to temperature and load patterns to forecast future LMP prices. Tuning model hyperparameters and gathering more historical data will continue to strengthen the AI-assisted wind bidding tool.

Discussion

The AI wind bidding tool still needs further development to determine the optimal bidding strategy. Energy storage and smart grid technologies will be investigated for future use in PJM markets and ancillary services to further increase the profitability of WPPs in electricity markets.

Author Affiliations

This research is affiliated with the Electrical & Computer Engineering department of Rowan University in Glassboro, NJ.

Acknowledgements

This research was advised by Professor Dr. Jie Li. The PJM website and training services were used extensively for electricity wholesale market research. Weather data was collected using the platform Visual Crossing. Visual Studio Code and Google Colaboratory were used for all coding and simulations using Python and Jupyter Notebook files.

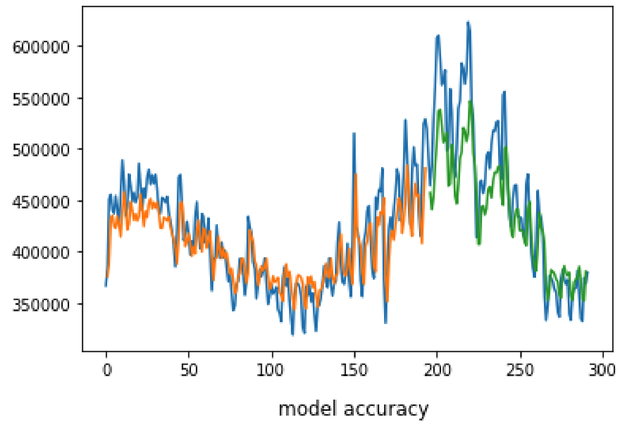
Key Findings: LMP Prices vs PPA Prices

Average LMP prices for 2022 were higher than average PPA prices per MWh, showing that bidding in the electricity wholesale market can be more profitable.

	Power Purchase Agreement (PPA)	**Locational Marginal Price (LMP)**
Year	2022	2022
Area	PJM	Egg Harbor, NJ
Generation Type	Wind Farms	All
Average Annual Price	$55.10 / MWh	$66.31 / MWh

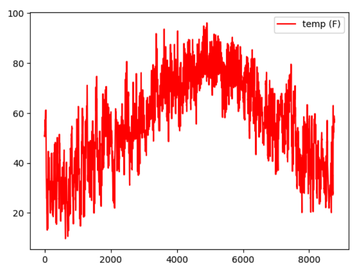
Key Findings: Load Forecasting

Using temperature and load data, forecasting load shows low error (Mean Absolute Percentage Error of 5.2%).

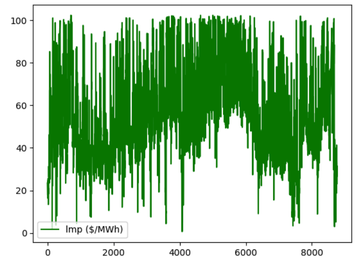


Key Findings: Temperature, Load, & LMP Correlation

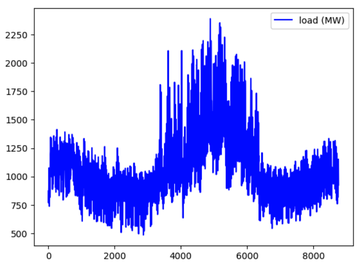
Temperature, Load, and LMP have considerable hourly correlation factors while following similar trends throughout the year. Therefore, historical data along with forecasted temperature values can help forecast LMP values.



Egg Harbor, NJ
Temperature (F)



Egg Harbor, NJ
LMP ($/MWh)



AECO
Load (MW)