OPTIMAL BIDDING STRATEGIES FOR ELECTRICITY GENERATION ASSETS IN THE DAY-AHEAD, INTRADAY, AND BALANCING MARKETS

Miguel Ferreira, ISEL / Polytechnic University of Lisbon, A47170@alunos.isel.pt
Jorge Sousa, ISEL / Polytechnic University of Lisbon, jorge.sousa@isel.pt
João Lagarto, ISEL / Polytechnic University of Lisbon, joao.lagarto@isel.pt

Overview

This research explores optimal bidding strategies for electricity generation assets within the multifaceted landscape of modern electricity markets. The study centers on photovoltaic (PV) plants, a rapidly growing sector within the renewable energy space, examining their participation in day-ahead, intraday, secondary reserve, and tertiary reserve markets. A comprehensive optimization model, developed and implemented using the GAMS modeling language, forms the core of the analysis. This model simulates the operational behavior of a 100 MW PV plant, capturing its unique characteristics, particularly its non-dispatchable nature. Crucially, the model analyzes two distinct scenarios: a price-maker scenario, where the plant's actions influence market clearing prices, and a price-taker scenario, where the plant operates within pre-determined market prices.

The model incorporates a wide array of constraints reflecting real-world market dynamics and plant operational limitations. These constraints include physical limits on power output, ramp-rate restrictions, minimum day-ahead market participation requirements, and the complexities of the residual demand curves in each market. The objective function of the model is to maximize the plant's operational profit across all market segments, considering revenue from energy sales and costs associated with plant operation.

The findings reveal a substantial difference in profitability between the price-maker and price-taker scenarios. The price-maker scenario, allowing for strategic market influence, consistently yields significantly higher revenues. This underscores the importance of understanding and leveraging the potential for strategic bidding to optimize returns from renewable energy assets. Analysis of market participation under both scenarios provides valuable insights into optimal energy allocation across different markets at various time intervals. The study also highlights the nuances of pricing dynamics in each market segment and how these impact optimal bidding strategies.

Further research directions could include expanding the model to incorporate energy storage, exploring the effects of varying market rules and regulations, and analyzing the impact of different plant technologies. This research provides a crucial contribution to the ongoing effort to improve the economic viability and grid integration of renewable energy sources.

Methods

The research employed an optimization model (implemented in GAMS) to simulate a 100 MW PV plant's participation in day-ahead, intraday, secondary, and tertiary reserve markets. The model considered both price-maker and price-taker scenarios. The price-maker scenario assumes the plant's actions influence market prices, while the price-taker scenario assumes the plant operates within a pre-defined market price. The objective function maximizes operational profit, calculated as the difference between total market revenue and operational costs across all market segments. The model incorporates constraints reflecting the physical limitations of the plant (minimum and maximum power output, ramp rates), market rules (minimum day-ahead quotas), and the characteristics of the residual demand curve for each market.

Key Model Components:

- **Objective Function**: Maximizes total operational profit over a defined period.

- **Market Participation**: Simultaneous participation in day-ahead, intraday, secondary reserve, and tertiary reserve markets.
- **Price Scenarios**: Both price-maker and price-taker scenarios are evaluated.
- **Constraints**: Physical limitations of the plant (minimum/maximum power output, ramp rates), market rules (minimum day-ahead quota), and residual demand curve restrictions are incorporated.

Results

Price-Maker Scenario: In the price-maker scenario, the plant significantly influenced market prices. Analysis revealed that the upward tertiary reserve market generally offered the highest prices, with intraday markets 5 and 6 also providing advantageous pricing during specific hours. The model's output illustrated that the plant strategically allocated its energy sales across different markets based on real-time pricing and operational constraints. The optimal strategy involved prioritizing markets with the highest prices while respecting physical and market limitations. The overall revenue under the price-maker scenario was significantly higher than under the price-taker scenario.

Price-Taker Scenario: Under the price-taker scenario, the plant's actions did not significantly impact market prices. The optimal bidding strategy focused on maximizing revenue given fixed market prices. The upward tertiary reserve market again presented the highest prices, but the overall revenue was substantially lower than under the price-maker scenario due to the inability to strategically influence market prices.

Comparative Analysis:The price-maker scenario consistently outperformed the price-taker scenario in terms of overall revenue. This highlights the considerable economic benefits that can be achieved by strategically influencing market prices.

Conclusions

This research demonstrates the significant impact of market design and plant-specific characteristics on the profitability of renewable energy sources, specifically focusing on photovoltaic (PV) plants. The comparative analysis of price-maker and price-taker scenarios reveals a substantial advantage for the price-maker approach, where strategic bidding allows the plant to influence market prices and optimize revenue generation. The considerable difference in profitability highlights the importance of considering market power dynamics when developing optimal bidding strategies, particularly for non-dispatchable renewable resources.

The detailed model, incorporating diverse market segments and operational constraints, offers a practical and valuable tool for understanding the complexities of electricity market participation. The ability to simulate both price-maker and price-taker scenarios enhances the model's applicability and provides a robust framework for evaluating the efficacy of different bidding strategies under varying market conditions. The findings suggest that the optimal strategy is not simply about maximizing energy sales in the highest-priced markets, but also involves skillfully balancing participation across various markets to maximize overall profit while navigating inherent constraints.