Ernesto Garnier and Reinhard Madlener

Balancing Forecast Errors in Continuous-Trade Intraday Markets

Ernesto Garnier, RWTH Aachen[1]
Neusser Strasse 11, 50670 Cologne, Germany, +49 (0) 170 334 5207, ernesto.garnier@rwth-aachen.de
Reinhard Madlener, Institute for Future Energy Consumer Needs and Behavior (FCN)
Faculty of Business and Economics / E.ON Energy Research Center, RWTH Aachen University
+49 (0) 241-80 49820, rmadlener@eonerc.rwth-aachen.de

Overview

The exposure of photovoltaic (PV) and wind power production to competition and wholesale market mechanics is rising in many countries. This development is primarily driven by the cutback of subsidies due to increasing cost competitiveness of PV and wind power production technology. As a result, the value that PV and wind power generate is (more) directly influenced by forecast errors and consequential balancing efforts.

Generally, two options are available to compensate forecast errors before imbalance fees are due: compensation within the operator's own portfolio or compensation in the intraday market. Taking the perspective of smaller operators with no access to balancing resources in their own portfolios, this research develops a bidding strategy for PV and wind forecast errors in the intraday market. Both the timing and volume of trade decisions will be optimized.

The challenge of formulating an efficient bidding strategy is driven by the uncertainty of the forecast error on the one hand, and by intraday market dynamics on the other hand. The forecast error itself is merely a projection, whose accuracy increases when coming closer to the actual time of production. Meanwhile, the intraday market is fairly illiquid, due to its continuous-trade nature and the limited resources available for instant trades. Availability diminishes closer to the delivery date, since an increasing amount of resources is already blocked, while others become unavailable due to longer ramp-up times. As a result, the market tightens when approaching trade closure, implying higher price surcharges and price uncertainty, and even a risk of not finding a counterparty for balancing trades at all. In the context of these dynamics and uncertainties, decisions over timing and volumes of trades substantially affect the extent to which balancing activities reduce the overall market value of PV and wind power. A sound bidding strategy needs to account for the stochastic behavior of both intraday price and forecast error. Further, it needs to include a methodology which allows trading-off the benefits and risks of trading early versus trading shortly before delivery.

Methods

At the core of the model, we formulate a valuation logic for immediate trades. The logic allows trading-off the costs and risks avoided by trading immediately against the costs and risks related to excessive or insufficient immediate trading due to premature forecasts. It accounts for changes in price, spreads (and other transaction costs) as well as counterparty risks. In order to include both price and forecast error uncertainty, the valuation logic is placed into a stochastic setting by means of options valuation methodology. A multi-dimensional binomial tree is created, modeling price uncertainty as a Geometric Brownian Motion and forecast error uncertainty as an Arithmetic Brownian Motion (ABM) with the assumption of correlation between both processes.

At any node of the tree, the optimal trade volume and resulting value are determined through dynamic programming: the aforementioned immediate-trade valuation logic is applied to the probability-weighted range of possible intraday-price-forecast-error combinations that may evolve throughout the remaining trading period to identify the trade volume that maximizes value under uncertainty. This value is then compared to the discounted value of waiting for one more period before trading. The higher of both values is chosen and translated into a bidding decision.

[1] The author is affiliated with The Boston Consulting Group, Germany. The views expressed in this article are purely those of the authors and may not be regarded as the opinion of The Boston Consulting Group.

Results

Inspired by the German market's characteristics, we test the sensitivity of the model's output – namely trade timing and trade volume – to changing uncertainty and transaction cost parameters in 50 different setups. It shows that the model actively outbalances price against volumetric risks. Trades are executed early and with large batch sizes in the case of high price volatility. In contrast, increasing forecast error uncertainty leads to trade delays. High transaction costs trigger batch size reductions and ultimately further trade delays. Generally, the model responds more sensitively to increases in price volatility than to augmented forecast error volatility. This can be explained by the fact that price uncertainty is modeled as a GBM, implying significant price risks and likely value decreases when delaying trades for too long.

Running 10,000 performance simulations across ten scenarios, we find that the model translates its flexible trade execution into a competitive advantage vis-à-vis static bidding strategy alternatives. It yields more than 6% efficiency gains in comparison to the aggregate average performance of all strategies considered across scenarios. Further, it yields the greatest efficiency in every single scenario. Noticeably, the performance advantage grows when introducing more volatile price conditions than in the base case. For instance, in a scenario with both high price growth and high volatility, the bidding model saves 2.5% compared to the second–most efficient alternative and 10.3% compared to the aggregate average. The efficiency gain achieved in the base case amounts to 6.5% in relation to the average; the most competitive alternative strategy trails by 0.6%.

Conclusions

Despite performance advantages in individual scenarios, the real benefit of the proposed bidding model lies in its flexibility. The intraday market is fairly illiquid, subject to frequent changes (e.g. growing market shares of PV and wind power) and far from extensively researched. Bidding models thus need to be able to quickly adapt and embrace volatility along multiple dimensions. Fixed strategies, or strategies purely focused on the forecast error volumes, cannot provide sufficient flexibility. The importance of efficient intraday trading is particularly great for small players with no internal balancing resources.

An important challenge that remains for further research is to account for endogeneity and game-theoretic dynamics in intraday bidding. In our work, we have taken on the perspective of an individual operator with no market power. In fact, if a significant share of operators or large-scale operators (e.g., the TSOs in Germany) were to adopt the same bidding model, prices would very likely respond and thus game-theoretic effects would have to be included into the model to assure optimal results.

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