Effects of price-making and portfolio size in stochastic optimization of trading in sequential electricity markets

(2) Energieerzeugung/-infrastruktur und Netze

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Motivation and Scope

With increasing uncertainties in the energy system – driven in particular by the expansion of renewables - reserve and spot electricity markets have been moving towards higher granularity and trading decisions move increasingly to the short-term. Deriving an optimal trading strategy in the sequence of reserve and spot markets appears to be a complex task, especially if uncertainties in both volumes and prices are considered. We present a stochastic optimization approach to derive optimal bidding strategies. Moreover, we investigate the value added by coordinated optimal bidding compared to heuristics and effects of price-taking vs. price-making in markets with relatively low liquidity.

Methodology

We include a reserve market, a day-ahead market and an intraday market and develop a multi-stage stochastic Mixed Integer Linear Program based on [1] (see Figure 1). Integer variables are included mainly for an appropriate technical representation of the dispatchable units in the portfolio as well as for price impact modeling.
We use consistent scenarios of renewable generation volumes and prices for a multitude of representative type days covering all seasons and relevant load and renewable feed-in situations. The simulation of stochastic processes and scenario generation is adapted from [2]. The detailed representation of uncertainty across the markets allows thorough analyses of the profit-risk-structures of optimized trading strategies. We assess profitability as well as the risk exposure, quantified by the conditional-value-at-risk, of trading strategies following different risk preferences.

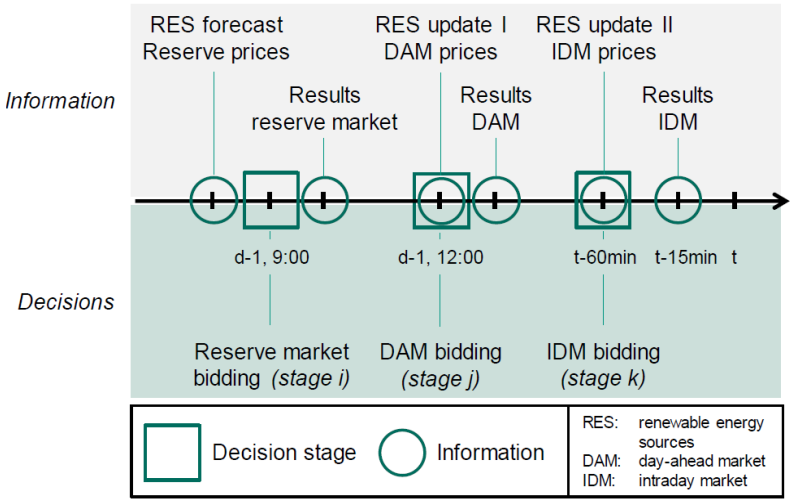

Figure 1: Information and decision structure of coordinated trading on reserve, day-ahead and intraday markets. [1]

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In order to analyze the benefit of coordinated bidding vs. heuristic-based sequential bidding, we compare a myopic bidding heuristic as a benchmark. Further, to investigate the limitation of assuming price-taking, we model a piece-wise linear price-making effect based on historical market liquidity for the intraday market and its impact on the bidding strategies for different portfolio sizes. Last, we analyze sensitivities on the portfolio's (technical) flexibility and the magnitude of price impacts.

Results and Conclusions

We apply the developed setup to a case study of the German market, where the share of renewables is already very high and the sequential market structure is in place - nevertheless, the market setting is representative for many market areas in Europe and across the world.
Results consist on the one hand of trading strategies, i.e. detailed bidding curves for each of the products traded in considered market segments as well as dispatch profiles for the technical units. On the other hand, profit-risk-structures of trading strategies can be presented via empirical cumulative distributions or risk metrics. To get a full understanding of the problem, the aggregated profit-risk-tradeoffs for multiple risk preferences are presented in Pareto-efficient frontiers.
From the results, we conclude that the coordination benefit in our base case is larger compared to values in the literature. However, modeling price-making in the intraday market has a strong impact on the results, even for relatively small portfolio sizes, which shows the importance of price impact modeling. From sensitivity analyses, we conclude that the relative benefit of coordinating bids decreases significantly when risk aversion, magnitude of the price impact, and flexibility of the technical units are increased.

References

[1] Kraft, E.; Russo, M.; Keles, D.; Bertsch, V. (2022): Stochastic Optimization of Trading Strategies in Sequential Electricity Markets. In: European Journal of Operational Research 238 (3), S. 797. DOI: 10.1016/j.ejor.2022.10.040.
[2] Russo, M.; Kraft, E.; Bertsch, V.; Keles, D. (2022): Short-term risk management of electricity retailers under rising shares of decentralized solar generation. In: Energy Economics 109 (4), S. 105956. DOI: 10.1016/j.eneco.2022.105956.