BIDDING FORMATS FOR SHORT-TERM ELECTRICITY MARKETS

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Overview

Short-term electricity markets, especially day-ahead and intraday markets have the goal to efficiently match generation and demand of electricity. A key challenge for market participants is to account for inter-temporal linkages between time due to the technical characteristics of generation units connected to the electricity grid. An example of these inter temporal technical limitations are start-up costs that occur once a power plant is started up, ramping rates that limit the rate of change of production, the maximum time a load can be shed without impacting its service quality (for example cooling houses) or the remaining electricity stored in a battery. All these limitations imply that actors cannot sell electricity in different time periods as fully independent products, and thus introduce some level of complementarity of sales in consecutive hours (or in the case of limited storage capacity substitutes). Traditionally, these inter-temporal linkages have received less attention, because (i) overall load profile followed repeated patterns and thus could already be considered in bids or even in product design (ii) large and often integrated generators could optimize within their portfolio. With rising shares of intermittent renewable energy sources and their stochastic variations in production and adjustment to forecast schedules closer to real time as well as increasing role of smaller scale generation and flexibility providers, larger shares of generation or load need to be rescheduled in shorter time frames, with considerable uncertainty remaining.

Various market designs exist in practice to dispatch generators, usually distinguishing on the one hand between markets with simple (single time period) and block (multi-time period) bidding, and on the other hand multi-part bidding, where generators submit bids describing their variable and start-up costs (and/or other technical and financial parameters). The advantages and disadvantages of these designs have been discussed in literature (Sioshansi, 2011), however have mostly focused on market power aspects of the problem. In contrast, this paper concentrates on the effect price uncertainty has on the bidding strategies of generators. This is a relevant problem, since in intra-day price uncertainty has very significant levels (Neuhoff, 2016).

In simple bidding generators need to account for startup costs in individually accepted bids, to exclude inefficient dispatch solutions, while not excluding too many profitable dispatches where the price is low in one period, but high in the other. Due to this inherent trade-off in bidding, ex-post several inefficiencies in dispatch are possible for simple bidding: the unit is accepted for one or two periods, although the price is not high enough to recover costs, and only one period is accepted, when it would have been efficient to dispatch the unit in two periods. For block bidding the unit can only be accepted jointly, while under low prices below variable cost in on period and high prices in the other, it would be more efficient to let the unit run for a single time period. To capture these inefficiencies, we build a simple two-period model of a single actor's optimal bids under three different bidding formats: simple, block and multi-part bidding.

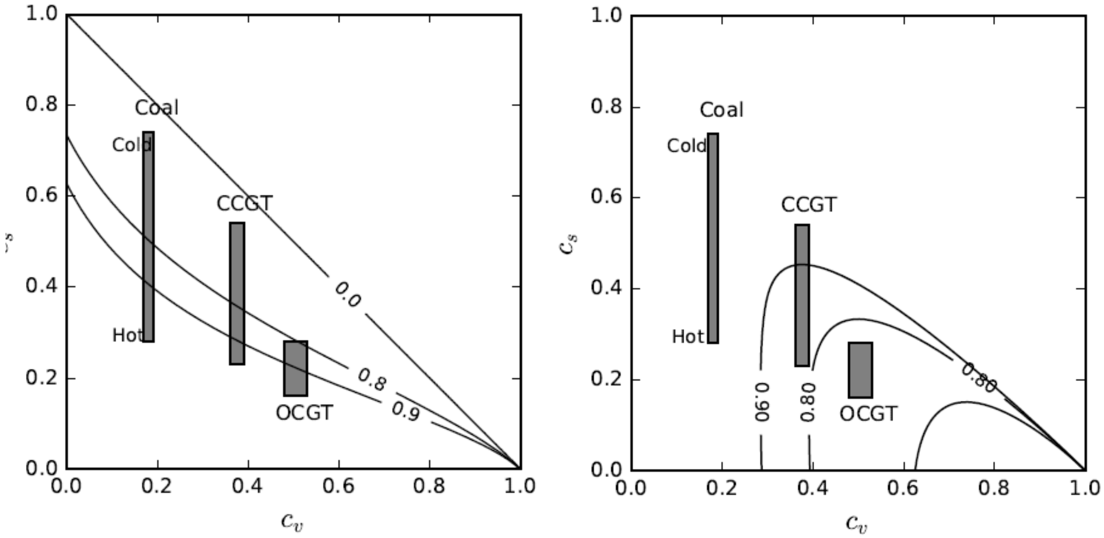
Methods

Analytical model of a single actor owning a power plant with fixed and variable costs, who is a price taker and exposed to two independent uniform price distributions. We derive optimal bidding strategies for the bidding formats simple bidding, block bidding and multi-part bidding, as well as the expected profits following these strategies.

Results

We show analytically that for all combinations of variable costs c_v and start-up costs c_s, multi-part expected profits are larger than either single bid or block bid profits. Whether block or simple bidding is more profitable depends on the combination of c_v and c_s as compared to the price distribution.

In the following we show numerical evaluations for the profit differences and ratios of expected profits for all relevant combinations of c_v and c_s for two periods of 1 hour each with uniform price expectations between 0 and 100 Eur/MWh (scaled to U(0,1) on the graph). For illustration we compare these profit differences to typical ranges of c_v and c_s of common power plant types: coal, combined cycle gas turbines (CCGT) and open cycle gas turbines (OCGT), with variations on start-up costs based on whether it is a cold or hot start. While this comparison is based on expected profits and not on an market equilibrium, it gives a first indication of the efficiency losses under the different bidding formats, since we model the market actor as a price taker, and thus lesser profits show an inefficient dispatch under given prices.



a) Ratio: $\mathbb{E}[\pi^*_{Simple}]/\mathbb{E}[\pi^*_{Multipart}]$ b) Ratio: $\mathbb{E}[\pi^*_{Block}]/\mathbb{E}[\pi^*_{Multipart}]$

Figure a) compares multi-part bidding and simple bidding profits, whereas Figure b) compares multi-part with block bidding profits. The figures show the relative difference each in comparison to the multi-part benchmark via isolines. For example all variable and fixed cost combinations on the 0.8 line in Figure a) mean that under simple bidding such power plants only make 80% of the expected profit as compared to the multi-part bidding format . It is evident that if the only available format available is simple bidding, producers with high start-up costs, such as coal power plants and CCGTs, have significantly lower expected profits as compared to the multi-part benchmark (at least for the example dispatch duration of 2 hours), as they run the risk of being accepted in only one period, although they face high start-up cost.

If block bidding is available (Figure b), power plants with very high start-up costs have nearly as high expected profits using block bids, as in the multi-part bidding format, whereas power plants with lower start-up costs and high variable costs, have significantly lower profits as compared to the multi-part case (and the simple bidding case), as they loose the opportunity to be accepted in only a single period.

Conclusions

In this paper, we identify that under presence of start-up costs price uncertainty in electricity markets can lead to an inefficient dispatch under simple and block bidding, while it doesn't occur in multi-part bidding. We derive optimal bidding strategies for simple bidding, block bidding and multi-part bidding in a simple, two-period model of a price taker in a simultaneously cleared uniform price auction and show that multi-part bidding has higher profits, and thus a more efficient dispatch than either simple or block bidding. Whether simple or block bidding is more efficient depends on whether start-up costs are high as compared to variable costs (in which case block bids are more profitable). Using numerical examples of different power plant types we show that this effect could occur at significant levels given common electricity market prices and power plant characteristics.

References

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