DEMAND PARTICIPATION IN ANCILLARY SERVICE MARKETS

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Overview

Transaction costs associated with the control of end-user equipment have lowered to the point where demand response is now considered a viable and potentially attractive option to provide ancillary services to electric power systems. This is particularly interesting in control areas where large shares of intermittent renewable energy sources contribute to increase the demand for reserve and balancing services, driving up the societal costs of maintaining a steady balance between electricity supply and demand. Still, as of today, demand participation (DP) in the provision of ancillary services is scarce and system operators rely almost entirely on large, conventional thermal or hydro units.

A demand resource which provides ancillary services faces different challenges from a price sensitive consumer who adjusts consumption to the evolution of wholesale spot market prices – the latter issue has been exhaustively examined in the economic literature (e.g., Joskow and Tirole, 2006). Ancillary services generally involve small amounts of energy (the service is used for short periods of time), but their value is in the capacity held in reserve and in the technical capability to respond on time and accurately to a dispatching order sent by the system operator (Ma et al., 2013). While several engineering papers have explored the technical aspects of ancillary service provision by end-users (e.g., Biegel et al., 2014), the question of how demand resources can be efficiently integrated in ancillary service auctions remains an open issue.

This paper contributes to filling this gap by theoretically investigating the option of allowing electricity consumers to present bids on a daily ancillary service market along two dimensions of market efficiency: first, in terms of the efficiency of the ancillary service market outcome, i.e., the effect of DP on the state-contingent prices that ensure system balance; second, in terms of the incentives of supply and demand resources to strategically inflate their "true" costs and willingness to pay, respectively, on the day ahead market.

Method

We consider the simplest possible setting:

- with a perfectly competitive day-ahead market, i.e., a uniform price which clears forecasted electricity demand and supply the day before delivery (*d-1*);
- an ancillary service market in two phases:
  - a scheduling phase, i.e., a contract offered by the system operator to the reserve margins in the afternoon of the day before delivery (*d-1*), which consists of a fixed remuneration for injecting/withdrawing any amount necessary to balance the system in every possible state of the world at the day of delivery (*d)*;
  - a balancing phase, i.e., the realization of the state and system operator's call upon the reserve margins, which ensures balance between actual supply and demand on the day of delivery (*d*).

Participants in the day-ahead market are electricity consumers and power producers. The latter operate with a portfolio of thermal generators and renewable energy sources. While the output of thermal generator is deterministic, the output of the renewable sources follows a random distribution with a finite and positive minimum and maximum.

During the scheduling phase of the ancillary service market, the system operator purchases reserve margins, i.e. the availability of controllable power plants and demand resources to deviate from, respectively, the injections and withdrawal programs defined on the day ahead market. Specifically, the system operator organizes a sealed-bid procurement auction, whereby he potentially discriminates between electricity consumers and power producers, so as to minimize the social costs of extra supply or the foregone energy consumption on the day of delivery (*d*).

During the balancing phase of the ancillary service market, the system operator does nothing but activating the reserve, either upward or downward, for the necessary quantity, crediting (debiting) the reserves as agreed upon at *d-1*, and passing on the generated loss (income) to electricity consumers. The demand at *d* amounts to the imbalance between demand and actual supply from the renewable energy sources, which might be positive or negative.

Results

The welfare effects of DP: our baseline result is that, under a competitive day-ahead market and a pricing schedule as defined above, DP increases total welfare, both from an *ex-ante* and an *ex-post* perspective, and decreases the expected tax burden from maintaining a balanced system. The main driver behind this result is that DP effectively introduces another potential margin of supply adjustment in the balancing phase, thereby, reducing the wedge between the day-ahead price and the balance-inducing price in any state of the world at the day of delivery.

Speculation under DP: We then consider the possibility that market participants might supply or demand a quantity that is incompatible with their "true" willingness to consume or their "true" production cost, respectively, in the day-ahead market at *d-1*. This allows us to extend on earlier studies on the incentives of speculating on the price schedule offered by the system operator (Chao & DePillis, 2013; Crampes & Léautier, 2015). We show that DP reduces the incentive of every individual producer to understate the true cost of thermal production and the expected output of the producer's renewable energy sources.

Conclusions

In this work we theoretically investigate demand participation in daily auctions for ancillary services, where system operators secure, and eventually activate, reserve margins to balance supply and demand in real time.

Under the hypothesis of perfect competition, we show that demand participation increases total welfare, both from an *ex-ante* and an *ex-post* perspective. Moreover, once we allow for speculation, we find that demand participation increase producers' incentives to state their true cost of thermal production and expected renewable output.

From a policy perspective our findings broadly support changes in current market designs to allow demand participation. Clearly, the examination of additional realistic features of existing power systems is necessary before moving to practical applications. Among others, interesting extensions include an analysis of the role of the load aggregator (the so-called Balancing Service Provider) as well as a study of suppliers' incentives to reshape their portfolio of renewable energy sources and flexible, conventional capacities.

References

Biegel, B., Westenholz, M., Hansen, L. H., Stoustrup, J., Andersen, P., & Harbo, S. (2014). Integration of flexible consumers in the ancillary service markets. *Energy*, 67, 479-489.

Chao, H. P., & DePillis, M. (2013). Incentive effects of paying demand response in wholesale electricity markets. *Journal of Regulatory Economics*, 43(3), 265-283.

Crampes, C., & Léautier, T. O. (2015). Demand response in adjustment markets for electricity. *Journal of Regulatory Economics*, 48(2), 169-193.

Joskow, P., & Tirole, J. (2006). Retail electricity competition. *The Rand Journal of Economics*, 37(4), 799-815.

Ma, O., Alkadi, N., Cappers, P., Denholm, P., Dudley, J., Goli, S., Hummon, M., Kiliccote, S., Macdonald, J., Matson, N. & Olsen, D. (2013). Demand response for ancillary services. *Smart Grid, IEEE Transactions on*, 4(4), 1988-1995.