ASSESSING THE POTENTIAL OF DEMAND RESPONSE AS A SOURCE OF FLEXIBILITY IN LOW-CARBON POWER SYSTEMS: INSIGHTS FROM THE FRENCH CASE.

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Demand response (DR), Renewable Energy Sources, Power System, Stochastic Dual Dynamic Programming

Overview

Demand Response (DR) is frequently mentioned as a key source of flexibility in a low-carbon, renewable-energy-dominated power system. DR aggregation and integration on a broad scale has yet to be realized. To understand how that supply of flexibility will be mobilized, one must first understand the economics of DR. Because DR is not the only source of flexibility, a system perspective is required to account for the availability of other sources (e.g., hydropower, or flexible generation units). The economics of DR are investigated in this work using a computational model that consists of estimating the optimal hourly operations of a RES-dominated power system that minimize the expected total system cost over an entire year. This stochastic model allows several sources of DR to be incorporated, indicating load-shifting and load-shedding capabilities from diverse end-uses. The core of our contribution is an analogy with Verrier's (2018) case of hydro-power management, which allows us to use stochastic dual dynamic programming (SDDP), a computationally efficient solution technique (Pereira and Pinto, 1991). The SDDP technique, along with the hydropower viewpoint, allows for the calculation of the opportunity cost to deploy each DR-technology. Furthermore, because it includes the effects on both energy wholesale prices and emissions levels, that technique makes it easy to measure the economic and environmental repercussions of DR. A new understanding of the interactions between demand response technologies and other dispatchable generating strategies can be gained by using that model. It also offers valuable information on the economics of DR aggregators that may develop to supply flexibility services. Indeed, we investigate the requirements for such businesses to enter and profitably operate in distinct DR segments for the first time. In accordance with the most recent policy literature, the model is applied to the French situation, both to the existing system and to several prospective future French systems. Overall, our findings have significant implications for low-carbon power system viability and economics.

Methods

We build a stochastic optimization model with 364 stages (days), with uncertainty on total demand and intermittent renewable production. Within each day, a perfect foresight optimization is performed. But we insist on the fact that the problem is no longer anticipative beyond that horizon. Representative units of each production/storage type are dispatched while the total expected cost of operating the system during a year is minimized. Scenarios for random variables are derived from historical data. Different degrees of integration of demand response are considered. A demand response aggregator controls all demand response deposits, as negative generation means, inside contractual limits. The resulting stochastic optimization model is solved using the SDDP approach.

Results

Demand response provides flexibility to the power system resulting in decreased prices at tensed times, less outages (in cumulated time and in depth), reduced calls to thermal generation means and interconnections. Overall, demand response improves social welfare, but, once a certain amount of flexibility is provided, supplementary demand response yields only marginal gains of social welfare. Load-shifting complements power hydro-electric storage on a shorter term while load-shedding competes directly with the most costly peak thermal units. Opportunity costs follow different profiles between demand response deposits reflecting their respective place in an instantaneous demand response merit order. Finally, all demand response deposits are not similarly profitable for the aggregator due to different constraints of availability, acceptance and installation costs.

Conclusions

Power systems benefits from the integration of demand response, even more as the share of intermittent renewable energy sources increases. A demand response aggregator generates profits in most scenarios and thus becomes economically possible. However, all demand response deposits are not individually profitable. The aggregator seems therefore incentivized to tap into the most profitable ones and leave others behind, at the detriment of the whole system. This incentive is fostered by the natural competition existing between demand response deposits: a decreased number of deposits increases the value of the flexibility contained in the remaining ones. We illustrate here a possible misalignment between the social interest of the power system and the private interest of the demand response aggregator.

References

Aïd, R., D. Possamaï, and N. Touzi. (2022) Optimal Electricity Demand response Contracting with Responsiveness Incentives. Mathematics of Operations Research, Forthcoming.

Pereira M. V. F. and L. M. V. G. Pinto (1991). Multi-stage stochastic optimization applied to energy planning. Mathematical Programming, 52:359–375, 1991. doi: 10.1007/BF01582895.

Papavasiliou, A., and S. S. Oren (2014). Large-scale Integration of Deferrable Demand and Renewable Energy Sources. IEEE Transactions on Power Systems, 29(1):489–499, 2014.

Verrier A. (2018). The Economic Potential of Demand Response in Liberalised Electricity Markets – A Quantitative Assessment for the French Power System. PhD thesis, Université Paris-Dauphine, PSL Research University, 2018.