ON THE SMART COORDINATION OF FLEXIBILITY SCHEDULING IN MULTI-CARRIER INTEGRATED ENERGY SYSTEMS

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Overview

Coordinated flexibility scheduling in multi-carrier integrated energy systems (MIES) can lead to an efficient integration of variable renewable energy (VRE) resources, and a more cost-efficient energy transition. However, energy system integration increases the complexity of the energy system. This is because it becomes significantly challenging to coordinate the interactions among a large number of demand-side flexibility assets. Unlike traditional flexibility providers, these demand-side flexibility assets are fully controlled by prosumers who can engage in active demand response. Uncoordinated response from a large pool of demand-side flexibility assets holds the potential to violate the physical limits of the power system. Therefore, while energy system integration offers new sources of flexibility, it also brings along a methodological challenge – the challenge of coordinating the interactions among an arbitrarily large number of different types of flexibility assets to optimally schedule flexibility in MIES.

Traditionally, co-optimization has been the predominant approach used to model such coordinations. However, this approach has several limitations: it scales poorly; it requires agents to share confidential information about their flexibility with a central entity; and has a limited representation of consumer behavior since agents are modeled as passive market participants. Such limitation makes the use of co-optimization inadequate to investigate investigate new market design and policy regulations such as network trariffs that influence the behavior of flexibility providers.

Methods

This paper proposes a model coupling approach based on a market-auction algorithm to model the coordination of flexibility scheduling in MIES. The software-coupled framework of our approach makes it possible to model different subsystems or prosumers in their domain-specific tools with dedicated solvers, and exploit parallelism to increase computational efficiency. Its information exchange requirements eliminate the need for iterations, which, together with parallelism, make our approach highly scalable. Finally, its interface design provides a way to include confidential information about flexibility into system-wide energy models without violating privacy concerns..

We put our approach to test by benchmarking it against traditional co-optimization and a price-response model coupling approach found in the literature through several experimental runs with varying levels of problem size (market agents), problem complexity (non-convexity), and computing infrastructure. This benchmark provides insights into the trade-off that energy system modelers need to make between optimality, scalability, and the monetary cost of computing infrastructure.

Finally, our model coupling framework is made openly available on GitLab, providing a new modeling software for the energy system modeling community to explore an alternative approach to model the coordination of flexibility scheduling in MIES. The code for running our experiments is also made open-source to ensure that the results presented in this paper are reproducible by any third party.

Results

Our model coupling approach outperforms both co-optimization and the iterative-price reponse approach in terms of scalability. This is because in our approach, the full time horizon is partitioned into daily windows, and simulated in a rolling manner since information is exchanged at the resolution and horizon of the day-ahead electricity market. In terms of optimality, our model coupling approach is shown to achieve comparable results with a moderate “optimality gap” in terms of reduction in system costs, peak load, and VRE curtailment. The software is also used to study new market design questions such as electricity distribution network tariffs and shown to be suitable for such analysis.

Conclusions

A practical application of our software is that it provides a modeling environment where prosumers, flexibility aggregators, and network operators can simulate the interactions between their systems, thereby avoiding myopic operational or investment decisions. For example, for heat network operators, coupling their models provides unprecedented insights into the cost of electrifying heat demand on their business case, and the impact of that on the electricity system. Policymakers and regulators can use it to assess the potential of different flexibility options, and to investigate new market design and policy instruments that can lead to an efficient utilization of this potential.