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Electricity market potentials of Thermal Energy Storage Power Plants –an agent-based modelling approach

Inhalt

Motivation

Future energy systems with high shares of variable renewable energy require new sources of emission free flexibility that can provide both short-term balancing and long-duration backup capacity. Thermal Energy Storage Power Plants (TESPs) [1] are promising candidates, as they combine electricity storage, heat supply for district heating or industrial processes, and backup generation in a single power plant. In this sense, TESPs can be understood as a decarbonized extension of combined heat and power plants (CHPs). Energy system optimization modeling [2] has shown that TESPs can support renewable integration, but makes the assumption of the ‚central planner', and therefore does not yet capture the strategic, market-driven behavior of TESP operators. Furthermore, TESPs, and likewise CHPs, simultaneously participate in multiple sectors, namely electricity, heat, and backup services. Their operation depends on expectations, price signals, and player interactions. Although ABM is well-suited to simulate these interactions, neither TESPs nor even conventional CHPs have been represented in agent-based market models in a way that reflects their multi-market nature, as most ABMs focus solely on electricity.

Methodological approach

To analyze the market behavior of TESPs from an operator perspective, we extend the agent-based electricity market model AMIRIS [3] by introducing a hybrid TESP agent. The TESP is represented as a flexibility trader that controls a set of thermal power plants and a dedicated thermal storage. Three technologies provide heat to the TESP, a heat pump, a biomass boiler, and a gas or biogas turbine with combined heat and power capability. These technologies are modeled as individual power plant agents, each submitting either just heat or combined power and heat marginal cost offers to the storage trader. We implement a new contract type that allows the TESP agent to receive these marginal offers and, in turn, send dispatch instructions back to the plants. The thermal storage is characterized by a fixed heat outflow profile representing the heat demand. Based on incoming heat and power marginals, the TESP agent optimizes the inflow into the storage and decides, for each time step, whether the required heat outflow is served with or without electricity generation. This design enables the analysis of multi-output dispatch decisions and their interaction with electricity price formation in a realistic market environment.

![TESP Schema][4]

Expected Contribution

The proposed model extension provides the first agent-based representation of TESP and enables previously unavailable analyses of their strategic behavior. By modeling TESPs as flexibility traders with multi-output capabilities, our approach allows investigating how these technologies react to price signals, heat obligations, and market uncertainty by calculating multiple scenarios. The model reveals how TESPs select between charging, discharging, heat-only supply, and backup-based generation, and how these decisions influence electricity price formation and system flexibility. Furthermore, the framework makes it possible to assess the economic viability of TESPs under different market designs and fuel or CO_2 price scenarios. Overall, this contribution offers a novel methodological basis for studying hybrid storage-generation technologies and their impact on electricity markets.

Literature
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