Agent-Based Simulation and Optimization with Learning and Applications on Electricity Markets

by

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ABSTRACT

This dissertation introduces and adopts an agent-based simulation and optimization (ABSO) approach to model and analyze electricity markets under various market structures and scenarios. ABSO is a novel optimization approach that exploits the power of decentralized agents' learning and adaption mechanisms. The optimal search procedures in ABSO are based on exploring and simulating the interactions of autonomous goal-directed agents. This distinguishes ABSO from conventional simulation-based optimization techniques, in which simulation is mainly used for evaluations of system performance.

We first implement two important components in an ABSO model: a mathematical model that represents the optimization problem for each agent and a learning algorithm that guides each agent to compete and achieve its goals. Based on the mathematical model, we analyze market equilibria for duopoly markets. We then develop an ABSO model for general electricity markets, and test and evaluate the advantages and disadvantages of three typical agent learning algorithms.

Specifically, we conduct three studies. The first one investigates bidding behaviors (e.g., competitive or cooperative) of generation companies under various market structures and examine their effects on market clearing prices. The second one studies how a market share goal influences bidding behaviors and obtains conditions for cooperative or competitive behaviors. The third study examines how portfolios affect bidding behaviors of generation companies in a constrained transmission network and develops conditions for coordination bidding strategies.

Experimental results suggest that ABSO is an effective approach to modeling and analyzing auction markets. With proper formulations of individuals and system objectives, ABSO allows us to investigate not only transient properties and steady states of the system at the market level, but also interactions and evolution of agents' behaviors at the individual level. This facilitates the understanding, evaluation, and optimization of existing or potential market mechanisms, which are crucial to deregulated electricity markets. Besides auction markets, ABSO could also be an effective candidate approach for modeling, analyzing, and optimizing other complex systems that involve a large number of interacting autonomous agents.