Introduction:

Over the last couple of decades, the electricity markets have been undergoing a rapid transformation from tightly regulated monopolies to deregulated competitive market structures. Hence, there has been a surge of research activities on studying various market mechanisms. In these mechanisms, generators submit their bids, and then the independent system operator determines the power allocation and the payment for each generator. Here, the central element is the design of the payment rule, since the generators have incentives to strategize around it. In particular, the operator designs the payment rule to ensure that the generators reveal their true costs in order to achieve a stable grid with maximum social welfare.

Under the commonly-used pay-as-bid and nodal pricing rules, generators can bid strategically to influence their profits since these mechanisms do not incentivize truthful bidding. As an alternative, under the Vickrey-Clarke-Groves (VCG) payment rule, truthful bidding is the dominant-strategy Nash equilibrium. Despite this desirable property, coalitions of generators can strategically bid to increase their collective VCG utility. These manipulations occur when the VCG outcome is not in the core. The core is a concept from coalitional game theory where the participants have no incentives to leave the grand coalition, that is, the coalition of all participants. Instead, if the payments are selected from the core, coalition-proofness is ensured. Naturally, such core-selecting payment rules relax the truthfulness of the VCG mechanism.

Many of these previously mentioned payment rules are not truthful. Thus, to understand their properties, we must study them at equilibrium instead of at truth. Early analysis for core-selecting, pay-as-bid and nodal pricing rules were derived in full-information Nash equilibrium. However, bidders work hard to keep their private information secret. Hence, it is not realistic to assume that bidders have access to full information to compute their equilibrium strategy. Instead, more appropriate assumptions are that each bidder knows his own valuation, but has an imperfect information about the other bidders' valuations. In the literature, there are well-studied learning algorithms that yield this solution concept which is more general than the one of full-information Nash. Specifically, the goal of this project is to study iterated best-response algorithms for Bayes-Nash equilibrium. These learning algorithms can potentially provide us with a valuable tool to analyze these non-truthful payment rules on their way to convergence to an equilibrium. Convergence analysis of the algorithms and equilibrium comparisons of different payment rules will be the two main aspects of this work.

Project Description and Main Steps:

The project starts off with the DC-OPF electricity markets described in [1]. Grid and generator data are provided by the IEEE test systems. Using these test systems, the initial goal is to get familiar with the existing payment rules and how they are computed [2]. We then conduct a study on the Bayes-Nash approach using analytical methods, which are limited to 3-bidder convex market problems [3]. To address larger cases, we build on existing iterated best-response algorithms, discussed in [4] and [5], and develop a variant for the Bayes-Nash equilibrium of the IEEE test systems, and study its convergence. Using this approach, we can compare the equilibrium of different payment rules under several criteria. For instance, these criteria could be efficiency and total payment. There is a potential to propose an alternative payment rule from this study. If time permits, the analysis can be extended to the Swiss Reserve Markets. Depending on the scope, we may also address alternative solution concepts such as the ones attained by no envy learning. At the end of the project, the work will be presented at the Automatic Control Laboratory in a 25min seminar.

Required Background: Courses in optimization and game theory, and a good working knowledge of MATLAB or Python are required.

Acquired Skills: Student gets a solid grasp of mechanism design in combinatorial auctions, and a wide range of solution concepts in game theory.

Procedure:

Please apply by writing to Orcun Karaca at okaraca@ethz.ch and including your CV and transcript of grades at Bachelor and Master's level.

Main References:

An extensive list will be provided to the student.


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