Non-Convexities and Congestion in Two-sided Markets for Electricity

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Overview

Non-convexities are a common characteristic in markets with divisibility issues and economies of scale, for example. In the case of electricity systems, there are operational conditions as- sociated to the unit commitment problem, and more recently the ramping costs incurred by conventional generators with the integration of renewable energy sources, creating challenges in the determination of prices that support an equilibrium (e.g., non-confiscatory). In this work, we explore this issue in electricity markets, considering market non-convexities, the effect of convex quadratic costs and the effects of congestion in equilibrium clearing prices as a result of network transmission constraints in the electricity market model.

Methods

Our model formulates the economic dispatch problem with unit commitment for an indepen- dent system operator in a deregulated electricity market. We use this Mixed Integer Program (MIP) formulation to recast it as a mixed integer second order cone program (MISOCP). This equivalent formulation has a liner objective function and linear constraints including the net- work flow equations, in addition to integer variables and the cone constraint. An advantage of this reformulation is that the final problem is convex, and therefore we can obtain efficient solutions that can support a Walrasian equilibrium.

Results

We present a sequence of models, starting with a modified version of a classical problem (Scarf, 1994) that has startup and shutdown of generators and a network based on a modified IEEE 9- bus system. We compute and analyze the clearing prices associated to this modified problem, based on the methodology presented in O'Neill et al. (2005), with different types of plants in the electricity market. We show the effects of ramping on the market clearing prices, and the congestions that can arise in some nodes of the system. We measure the social welfare for all cases, and present the consequences on the dispatch and operation of the electricity system.

Conclusions

Our results show that using convex optimization techniques, we can find a set of market clear- ing prices in a congested network that improves the allocational efficiency of resources when we care about deliverability costs and integer variables. As in our previous work without con- gestion, we show the implications for electricity markets with more penetration of renewable energy sources once some lines become congested. Moreover, the variability and uncertainty in the availability of these renewable sources require conventional generators to ramp up and dow more frequently, leading to further congestion in certain areas. Therefore, better prices that internalize these externalities can improve the efficiency of the market.

References

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