A Reverse Stackelberg Game Model for Grid Usage Pricing with Local Energy Markets

Juan Sepúlveda, Luce Brotcorne, Hélène Le Cadre

INRIA Nord Europe, France

{juan.sepulveda,luce.brotcorne,helene.le-cadre}@inria.fr

Mots-clés : *reverse stackelberg games, game theory, bilevel optimization, quadratic inner problem, grid usage pricing, local energy markets.*

In the context of the massive penetration of renewables and the shift of the energy system operation towards more consumer–centric approaches, local energy markets are seen as a promising solution for prosumers' empowerment. Various local market designs have been proposed that often ignore the laws of physics ruling the underlying distribution network's power flows. This may compromise the power system's security or lead to operational inefficiencies. Therefore, including the distribution network in clearing the local market arises as a challenge.

We propose using grid usage prices (GUPs) as an incentive mechanism to drive the system towards an economically and operationally efficient market equilibrium, subject to security constraints. Our approach requires expressing the incentive policies as affine functions of the prosumers' active and reactive power outputs. This setting falls into the category of reverse Stackelberg games, where we look for the optimal policy in the space of affine functions [2]. This approach takes advantage of controllability guarantees for the problem's unconstrained setting, which hopefully will enable the DSO to influence the output of the market towards an optimally determined target point. Market–related properties of the policy, such as economic efficiency, individual rationality, incentive compatibility, and fairness, will be rigorously studied.

Two alternative solution approaches are proposed: The first is based on reformulating the resulting bilevel problem into a single–level problem employing the KKT conditions of the underlying lower–level problem. Then, the resulting quadratically constrained quadratic problem is solved applying a trust–region method. The second solution approach is based on first obtaining a team–problem solution and solving a feasibility problem to induce it [1]. Finally, extensive computational experiments will be carried out on different IEEE test feeders to assess the performance of the proposed approach statistically.

References

[1] T. Basar and H. Selbuz. Closed-loop stackelberg strategies with applications in the optimal control of multilevel systems. *IEEE Transactions on Automatic Control*, 24(2):166–179, April 1979.

[2] Noortje Groot, Bart De Schutter, and Hans Hellendoorn. Optimal Affine Leader Functions in Reverse Stackelberg Games: Existence Conditions and Characterization. *Journal of Optimization Theory and Applications*, 168(1):348–374, 2016.