Multilevel Modeling of Electricity Markets

Redispatch-Based Electricity Trading

Many European countries have implemented a system of spot market trading of electricity that is redispatch-based [1]. Electricity is traded at power exchanges like the EEX in Leipzig, Germany. During these auctions, no or only a certain part of the technical and physical constraints of electricity transport through the transmission network are respected. For instance, in Germany, only a market clearing is imposed that yields the balance of traded production and consumption. As a result of this drastic simplification, spot market results do not have to be feasible with respect to transport through the transmission network. If this turns out to be the case, traded quantities have to be redispatched such that the resulting quantities can actually be transported. Different systems of redispatch rules are implemented in Europe, e.g., cost-based redispatch in Austria, Switzerland, and Germany or market-based redispatch in Belgium, Finland, France, or Sweden [2]). However, and independent of the actual redispatch system, this market design of spot market trading and redispatch yields a two-stage model that involves different agents and stakeholders like:

- producers owning conventional power plants or facilities for producing power from renewables like sun or wind;
- consumers like municipal utilities or large industrial enterprises; and
- transmission system operators (TSO) that control and maintain the transmission network and organize the redispatch.

It is shown in the literature that this system of electricity market design may yield significant decreases in total social welfare; see [2, 3] and the references therein. Thus, the natural question arises if and how different markets can be designed that yield higher welfare outcomes. This question is currently an active field of research and involves the investigation of alternative systems like the introduction of zonal pricing [3, 4] or nodal pricing [3, 5].

Mathematical Models

From a mathematical point of view, the study of different market designs may introduce the regulator or state as an additional agent that decides on certain questions like, e.g., the specification of the actual price zones in zonal pricing or the specification or regionally differentiated network fees. Since the regulator or state anticipates the influence of his decisions on the actions of all other agents, such a rigorous mathematical modeling has important implications on the overall model, since the decisions of the regulating agent couples all other levels of the system, yielding a (typically mixed-integer) multilevel optimization; cf., e.g., [6].

These models are extremely hard to solve [7, 8, 9]. Hence, there is a politically and social need to develop new mathematical theory and algorithms for solving realistic instances of these models.

References

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