A Bilevel Model for Large-scale Time-and-Level-of-Use Pricing

Mathieu Besançon[1,2], Miguel F. Anjos[1], Luce Brotcorne[2]

[1] GERAD & Department of Mathematics and Industrial Eng., Polytechnique Montréal, Canada
[2] INOCS Team, INRIA Lille-Nord Europe, France

mathieu.besancon@polymtl.ca, anjos@stanfordalumni.org, luce.brotcorne@inria.fr

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1 Context & Time-and-Level-of-Use pricing

The increase in stochastic power generation from wind and solar systems has highered the variability of supply in modern grids, along with a diminished guaranteed generation. Demand Response tackles this challenge by creating incentive for demand-side decision-makers to modify their consumption profile. We leverage the Time-and-Level-of-Use (TLOU) pricing policy to gain guarantee on energy demand of a large number of consumers, which corresponds to the fact that deviations from announced consumptions yield an increase in prices for the consumers.

The TLOU pricing was introduced in [2], built as an extension of Time-of-Use, used to create incentives to shift or reduce consumption. The goal of TLOU are to extend TOU by allowing users to signal back their consumption intention. The tariff consists in a booking fee K, a lower energy price function $\pi^L(c)$ and a higher energy price function $\pi^H(c)$. In the variant developed in [1], the whole energy consumed during the time frame is billed at either the lower or higher tariff. For a given time frame, the client books a capacity ahead of time. If the energy they consume during the time frame remains below the announced capacity, they are billed at the lower price, if it is above, they pay the higher price.

2 Price-setting as a bilevel optimization problem

We consider the problem of optimally setting the components of the pricing policy from a supplier perspective. The decision is cast as a bilevel problem modeling a Stackelberg or leader-follower game. The random consumption of each client is represented as a mixed continuous-discrete probability distribution. The supplier, acting as the leader of the game chooses the price components before announcing them to the consumers, who then react by choosing a capacity minimizing their expected cost. Starting from a general formulation of the leader's decision, we reduce the problem to an equivalent single-level MINLP by exploiting the structure of the follower cost function, deriving a finite set of second-level optimality candidates. The non-linear problem is then linearized using regularity conditions and reformulation of co-linear terms. The problem structure is leveraged to derive a solution method based on row generation.

Références

[1] Mathieu Besançon, Miguel F. Anjos, Luce Brotcorne, and Juan A. Gomez-Herrera. A Bilevel Framework for Optimal Price-Setting of Time-and-Level-of-Use Tariffs. Sep 2018. http://arxiv.org/abs/1809.00512.

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