electricity_market_monopoly

This model, proposed in [1], considers an electricity market where a single supplier sets the price of electricity which a set of N customers use to power their appliances. The problem is defined across a set of time slots H. The electricity supplier, taking the role of the leader in the upper-level, sets the price for each time slot p_h for all $h \in H$, bounded above by the maximum allowed price $p_h^{\max}$. Each customer $n \in \mathbb{N}$ then sets the power level $x_{n,a}^h$ of each of their appliances $a \in A_n$ at time slot $h \in T_{n,a}$, where $T_{n,a} := [TW_{n,a}^b, TW_{n,a}^e]$ is the time window of appliance a owned by customer n. The supplier is concerned with a trade-off between the revenue and the peak load Γ caused by the power levels generated by the customers in the lower-level. A penalty is imposed proportionally to the peak load, controlled by a penalty parameter κ.

The objective of the customers in the lower-level is measured by two terms, the electricity bill, measured by the price of electricity multiplied by the amount used, and an inconvenience cost. It assumed that a customer n would prefer to run appliance a in the initial time slot of the time window $T_{n,a}$. Postponing this would come with a cost, namely the inconvenience cost, defined as

$$C_{n,a}(h) := \lambda_n E_{n,a} \frac{h - TW_{n,a}^b}{TW_{n,a}^e - TW_{n,a}^b}, \quad \forall\, n \in N, a \in A_n, h \in H,$$

where λ_n is the inconvenience coefficient of customer n.

Let $E_{n,a}$ be the demand of appliance a owned by customer n and let $\beta_{n,a}^{\max}$ be its power limit. The bilevel optimisation program is then given as

$$\begin{aligned}
\underset{p,\Gamma}{\text{maximise}} \quad & \sum_{n\in N}\sum_{a\in A_n}\sum_{h\in H} p^h x_{n,a}^h - \kappa\Gamma \\
\text{subject to} \quad & \Gamma \geq \sum_{n\in N, a\in A_n} x_{n,a}^h \quad \forall h \in H \\
& 0 \leq p^h \leq p_{\max}^h \quad \forall h \in H \\
& x \in \arg\min_y \begin{cases} \sum_{n\in N}\sum_{a\in A_n}\sum_{h\in H}\left(p^h + C_{n,a}(h)\right) x_{n,a}^h \\ \text{s.t.} \quad 0 \leq x_{n,a}^h \leq \beta_{n,a}^{\max}, \quad \forall\, n \in N, a \in A_n, h \in H \\ \sum_{h\in H} x_{n,a}^h \geq E_{n,a}, \quad \forall\, n \in N, a \in A_n \end{cases}
\end{aligned}$$

References

[1] Sezin Afşar, Luce Brotcorne, Patrice Marcotte, and Gilles Savard. Achieving an optimal trade-off between revenue and energy peak within a smart grid environment. *Renewable Energy*, 91:293–301, 2016.