INF569 — peak load shaving project

1 Projection description

We consider the case of a electricity retailers selling electricity to consumers. This can be seen as a game $G = (N, S, g)$ with N players numbered from 1 to N with strategies sets $S_1, \ldots, S_N$ and payoff functions $g_1, \ldots, g_n$.

We consider a global welfare function W that we want to maximize assuming that each player plays rationally. This leads to the mathematical optimization program

$$\begin{aligned} \texttt{maximize} \quad & W(s_1, \ldots, s_N) \\ \texttt{subject to} \quad & \\ & s_i \in S_i \quad \forall i \\ & (s_1, \ldots, s_N) \in NE(G) \end{aligned}$$

were $NE(G)$ denotes the Nash equilibriums of the game G.

The notion of Nash equilibrium can also be replaced by public or private correlated Nash equilibrium if we want to model for example a state regulator that incite players to play some strategies considered as better.

1.1 Literature

In the article [1], the authors consider the game with only one electricity retailer and only on consumer, what leads them to the mathematical bilevel program

$$\begin{aligned} \texttt{maximize} \quad & W(s_1, s_2) \\ \texttt{subject to} \quad & \\ & s_1 \in S_1 \\ & s_2 \in \arg\max_{s \in S_2} g_2(s_1, s_2) \subset S_2 \end{aligned}$$

where player 1 is the retailer, player 2 the consumer and W is the payoff of the retailer.

The retailer purchases electricity from the market and resell it to the consumer according to diverse tariffs strategies that the consumer can choose among. The tariffs strategies set S_1 is designed to be the set of tariffs strategies that are indifferent for the consumer. In the article they explore four patterns of tariffs strategies.

The consumers, at the lowest level of the mathematical program, is described with profusion of details. In fact, he can purchase electricity from the retailer, produce some electricity with solar panels, consume it or resell it to the grid, stock electricity in a limited capacity battery, produce or stock heat, ... Thus, the case of the consumer is quite well modelled and treated in this study.

1.2 What we propose to do with regards to the literature

The general problem described in the first section is far more general than the one studied in [1] but is really hard on the mathematical plan. Furthermore, the notion of welfare W is quite difficult to define on the ethical plan.

We propose to study in this short project to type of improvement with regard to the article [1]. On the modelling point of view, we can improve the retailer model : indeed, in [1] he only has four strategies and the global welfare is considered to be its profit. Even if it is argued that because the consumer is indifferent between the tariffs, the global welfare is the retailer profits, this is quite questionable with regard to the environmental issues nowadays.

On the second hand, we propose a mathematical improving by considering more sophisticated formulations like the general one provided in the first section. As this is difficult problem, we will allow us to consider simpler consumer model.

We will probably spend equivalent time on both problems but we propose to study one of them in further details.

Proposition 1 : modelling improvement To extend [1] to the case when the retailer does not just purchase electricity on the market but is in fact in charge of its production. To this aim, we will model the retailer in more details.

For example, he will be able to produce electricity from three sources

- conventional electricity (hydroelectricity, nuclear plants) with a constant production, low production costs but high fixed ones
- fossil electricity (coal, fuel) with a on demand and flexible production, high production costs and low fixed ones. The high production costs include environmental externalities.

- renewable electricity with random (variable, we will not consider the stochastic case) production, low production cost and high fixed ones (in term of maximal power generated)

The producer is also facing some costs for the grid maintenance and deployment. He can choose how he will design the tariffs and the energetic mix to produce electricity, with the aim to maximize its profit.

Proposition 2 : algorithm improvement We will try to improve the mathematical work done in [1] by considering at least several consumers (or types of consumers).

We propose to consider four types of consumers

- homes
- services / office
- industry
- transports

and to include in their payoff function not only their electricity bill but also their deviation for what they consider to be their more comfortable consumption in the case where they are not incite to move it to avoid peak loads.

That will lead to a mathematical program like

$$\begin{array}{rl} \texttt{maximize} & W(s_1, s_2, s_3, s_4, s_5) \\ \texttt{subject to} & \\ & s_1 \in S_1 \\ & (s_2, s_3, s_4, s_5) \in NE(G[s_1]) \end{array}$$

where 1 remains the retailer, W its profit and $G[s_1]$ denotes the game played by players 2 to 5 when the strategy of player 1 is fixed an given by s_1.

As this bilevel problem is quite complicated and maybe difficulty tractable because of de Nash equilibrium concept, we will possibly allow us to reduce the model complexity of consumers and retailers or to consider it on really small instances (like only a day). If we manage to get sufficient good results early on this problem, we will eventually consider the harder general problem with several retailers.

References

[1] Veronika Grimm, Galina Orlinskaya, Lars Schewe, Martin Schmidt, and Gregor Zöttl. Optimal design of retailer-prosumer electricity tariffs using bilevel optimization. *Omega*, 102:102327, 2021.

[2] Moslem Uddin, Mohd Fakhizan Romlie, Mohd Faris Abdullah, Syahirah Abd Halim, Ab Halim Abu Bakar, and Tan Chia Kwang. A review on peak load shaving strategies. *Renewable and Sustainable Energy Reviews*, 82:3323–3332, 2018.