ANALYSIS OF THE ROLE OF ENERGY STORAGE IN POWER MARKETS WITH STRATEGIC PLAYERS

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Overview

Renewable energy sources have lately gained increasing attention in the energy sector due to their vast potential in reducing the dependence on fossil fuels. There has been an increased call for the technology development of renewable energy sources because of the issues concerning climate change as well as consumer efforts. Energy sources such as wind and solar are considered as climate friendly, but the drawbacks of these sources are the variables and the uncertain level of electricity generation. The variability of these sources leads to the deployment of energy storage as an essential source for flexibility in future energy systems.

To determine the potential role of energy storage in future energy systems, it is important to examine the economic impacts in the development of such systems. Several studies have been conducted to examine an effective way energy storage can be utilized in a power system. These earlier research have mainly focused on the assumption of perfect competition, which suggests that all market players operate as price takers. Assuming perfect competition implies that the market participants expect that they have no influence on the market price. However, a market does not always behave perfectly competitive. As a result of this, the assumption may limit the reliability of the outcome of a power market. Hence, the role of strategic players on energy storage should be further examined.

To the author's knowledge, the attempt to model a strategic behaving energy storage unit has not previously been studied before. Previous relevant work rather focus on analyzing how energy storages can reduce market power in a monopoly frame work. (Yujian Ye, et al., 2016)

Methods

In figure 1, the representative agents of the market are illustrated with their objective functions. The arrows pointing outwards from the agents` are their decision variables, whereas the arrows pointing inwords are the variables that affect the agents` decision. The problems are either formulated as a Mixed Complementarity Problem (MCP) or a Matematichal Problem with Equilibrium Constraints (MPEC).

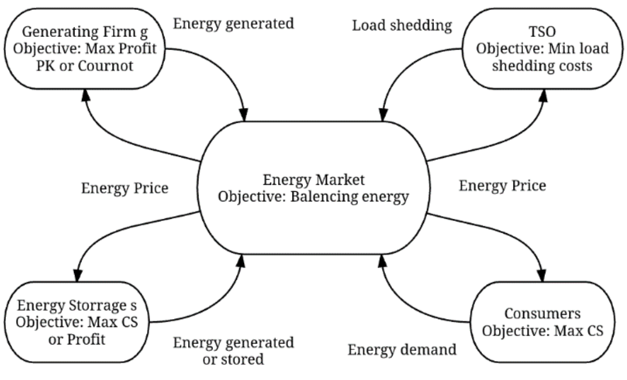

Figure 1 Model illustration, with agents' objective and decision variables

In order to obtain a realistic representation of the market and the variability of renewable energy, restrictions on storage and production capacity are simulated.

Results

The study reveals that the intra-day price variations get smoother as more storage capacity is added to the system. Even during production with no constraints, there is a mild effect on price due to the strategic behaving storage.

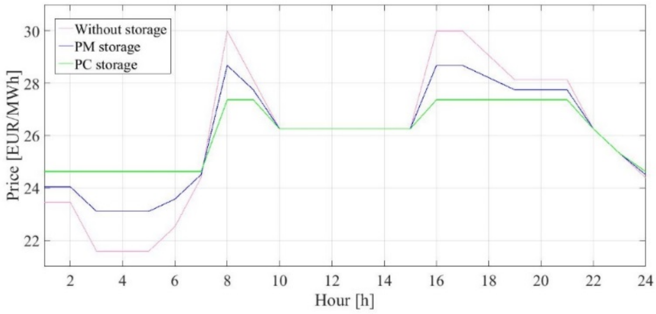

Figure 2 Market price, under different storage operation strategies, profit maximizing (PM) and perfect competitive (PC)

If the operator behaves strategically, the operator will exercise market power in order to increase its profits. Nevertheless, the magnitude of market power is shown to be limited by the level of production capacity. At 93 % of the optimal production capacity, the energy storage facility can have a significant impact on market prices. During morning and evening peak demand the market price increases from 40 EUR/MWh to 69 EUR/MWh, which is caused by the strategic behavior in terms of withholding production capacity. The results point out the effects of strategic behavior of an energy storage in an imperfect power market.

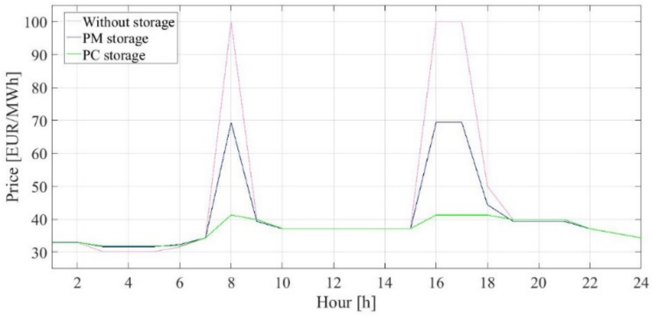

Figure 3 Market prices under different storage operation strategies and production capacity of 200 MW

Conclusions

In all scenarios, the strategic playing energy storage will exploit the benefit of market power. The magnitude of the effect on price and consumer surplus are highly affected by the assumptions of the market (a perfect market). If the flexibility is controlled by a few agents, the major market failure will accrue (occur). Thus, in order to quantify the magnitude, further expansions and scenarios of the model should be explored.

The uncertainty related to the Renewable Energy Sources (RES) may have a major influence in how the energy storage will operate under different strategies and ownership. The role of RES, in terms of solar and wind, will play an increasing role in the future power system. Hence, exploring this area of expertise is highly relevant.

This work has primary focused on the analysis of the supply-side of the power market. However, the demand response becomes highly relevant when SmartMeters are installed. The continuity and availability of information enables the consumers to respond quicker on price incentives, which will lead to increased flexibility of consumption. Thus, introducing representing agents for consumers group will be a realistic and relevant extension of the model.

The extensions of the models are indeed an important way in the search of a realistic representation. However, further work should be considered by validating the input parameters in order to obtain an applicable model of the complex problem.

References

Yujian Ye, Papadaskalopoulos , . D. & Strbac , G., 2016. *An MPEC approach for Analysing the Impact of Energy Storage in Imperfect Electricity Markets* , s.l.: Department of Electrical and Electronic Engineering Imperial College London London, UK .