Flexibility Potential of Power-to-X Options: A German Case Study

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Overview

In order to comply with the climate protection goals, the energy system requires a reduction of greenhouse gas emissions in all areas. This makes it necessary to greatly reduce the consumption of fossil resources in addition to improving energy efficiency. Therefore, electricity production is increasingly using renewable energies from fluctuating sources. For other areas, further electrification seems to be a promising option. So-called Power-to-X (PtX) options can be used to substitute fossil fuels with renewable electricity and provide some additional flexibility that helps to integrate renewable energy sources. However, these potential new consumers can lead to a significant increase in electricity demand and cause problems in the operation of the grid.

Currently, it is difficult for many PtX options staying competitive on the market under current economic and regulatory conditions. Promising PtX options in the short term are heat pumps and electric vehicles, which are continually increasing their market share and offering additional flexibility. However, the user behavior and operation mode limit this flexibility. Thus, it is not yet completely clear how the best realization of this flexibility is and which user groups are particularly important. Therefore, this contribution analyzes which characteristics of the PtX options have a major influence on the use of flexibility and how regulatory intervention in the price of electricity can suitably control the operation of PtX options.

Methods

The basis of the analysis is the simulation module of the Enertile Platform [1]. This is an agent-based electricity market model that depicts the main players in the areas of markets, electricity demand, utilities, renewable electricity generation and selected PtX options as computational agents. This study focuses on individual agents for electric vehicles and heat pumps in the household sector, whose type can be defined by various characteristics having either an uncontrolled or a price-controlled mode of operation. Thus, different agent types can represent different user groups.

In the reference case of the price-controlled operating mode, the electricity price is determined on the basis of the residual load in the electricity market model with all of its price components. However, in order to analyze the impact of regulatory measures, the price signal to the agents will be adjusted depending on the individual measures. In order to select a suitable regulatory intervention, the price components of the electricity price and its dependent factors are examined. Selected price components are taken into account by price markups and markdowns on the price signal in order to make good use of the flexibility potential of the PtX options.

The data basis for this analysis is a case study based on the German Network Development Plan for electricity in the year 2030 [2]. As a user group for the electric vehicles, agents are used that differ in terms of charging infrastructure and battery size. The user groups for the heat pumps are differentiated on the basis of the heat pump type and the heating requirements of the buildings. The behavior of the agents is then examined in various scenarios where the agent mode of operation and the price signal change.

Results

The comparison of the uncontrolled and the price-controlled operation mode with the reference price signal shows that electric vehicles and heat pumps can provide short-term flexibility and their behavior can be used in principle to exploit a better integration of renewable energies. The overview of the electricity price components also show that preference should be given to controlling flexibility by adjusting grid utilisation fees and the Renewable Energy Act levies. The impact of the price incentives on different user groups is at a similar level. Electric vehicles can offer a higher flexibility potential compared to heat pumps, especially regarding the temporary availability over the year and the time duration.

Electric vehicles can provide year-round flexibility, especially in the evening and night hours. Crucial for this, however, is the temporally available infrastructure. If users have access to a charging infrastructure, both at work and at home, peaks in the supply of photovoltaic systems during the day and wind peaks in the early morning hours can be easily reduced. The flexibility of the vehicles can be utilized largely even with low charging power. However, high charging power can lead to problems or large system influences in the course of unfavourable price signals. Larger battery capacities can bring minor benefits.

Heat pumps offer flexibility due to heat demand mostly in spring and autumn. Depending on the hot water storage and the age of the building, 6-8 hours of flexibility can often be offered in the transitional periods. Not air-driven heat pumps are slightly at the advantage.

Conclusions

In principle, the price-controlled operating mode of PtX options offers a high potential for providing flexibility. However, successful incentives require that price components must constantly be adjusted dynamically. This is currently not the case with the grid utilization fees and the Renewable Energy Act levies in Germany. In addition, local differentiation may be required. Therefore, to make use of the flexibility potential, appropriate adjustments have to be made for the future.

In the case of electric vehicles, time availability is crucial for flexibility. A corresponding charging infrastructure must be available and the users must then use it. A distinction between different vehicle types does not seem to be very relevant. Slow charging power would be beneficial for the electricity market, but are not necessarily in line with the wishes of the users. Accordingly, the power grids must be adapted to it. For heat pumps, the size of the hot water storage tank in relation to the heat requirement is the decisive factor. Here it might be useful to incentive to easily install larger storage systems to provide more flexibility at a low cost.

References

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