POOLING FLEXIBILITY OF HEAT PUMPS IN SINGLE-FAMILY HOMES FOR THE AUSTRIAN BALANCING MARKET

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Overview

The topic of flexibility is omnipresent in the whole electricity sector. Whereas traditionally, gas power plants and pumped hydro storages fulfilled the need for flexibility in the system, demand response has become more important in the last years as well. Besides large flexible industrial customers, this demand elasticity can also be provided by pooling many small customers. This facilitates households to become an active part of the electricity markets and use their available flexibility to support the system. This crossing of traditional voltage level boundaries and the prosumer market integration is one of the research topics in the ERA-Net SmartGrid+ [1] funded project DeCAS[2].
One of the most promising technologies for flexibility provision in the household sector are heat pumps. They can be controlled automatically and show a fast dynamic behaviour as well as big storage capacities in the form of hot water tanks and the buildings themselves. Furthermore, the number of heat pumps has been increasing steadily in the last years: According to the heat-pump roadmap [3] the amount of sold heat pumps in Austria has increased by an average of 10.2% in the years from 2011 to 2015. In some European countries like Switzerland, heat pump pools that participate in the balancing markets already exist; however, in many others, like also in Austria, no such pool has yet been pre-qualified. In the project *iWPP-Flex,* the usage of the flexibility of a heat pump pool for manual frequency restoration reserve (mFRR) was evaluated positively for the Austrian market [4].
The aim of this paper is to determine the different influencing factors on the available flexibility of a heat pump pool and thus on its revenues on the market. The analysed variations were the type of building (passive house/ renovated building, etc.), the heating system (radiator / floor heating), the availability of an additional buffer storage, the type of heat pump (air-water / brine-water) as well as the influence of the temperature comfort limits.

Methods

The potential earnings of a pool of heat pumps offered on the mFRR balancing market is analysed in this paper, using a techno-economic bottom-up model. The basis are detailed physical models of different single-family buildings and their heating systems, describing their thermal properties [4]. From those, linearized state space models for the building behaviour, as well as for the domestic hot water and additional buffer storage tank are derived. The behaviour of the heat pump is represented using a monthly seasonal performance factor, dependant on the type of heat pump as well as the connected heating system. These descriptions of the physical system behaviour serve as boundary conditions for the economic optimization model. The objective function is to maximize the profit on the balancing market, while keeping the temperatures of all customers in the specified comfort limits.
In order to create a realistic pool behaviour, 40 different customer configurations are considered. They differ in the type of building and heat pump, in their location, in the hot water usage profiles and the availability of a buffer storage. The case study is calculated for the Austrian mFRR balancing market, using historical weather and price data, as well as call probabilities for the year 2016.

Results

The analyses show that the most important storage in the heating system is the building itself. An additional system heating buffer storage increases the yearly profits by only 2-3%, in comparison to only using the building itself as a storage. The influence of the domestic hot water storage is of similar magnitude: As can be seen in the figure below, during summer, when the heat pump is only used for domestic hot water, hardly any power can be offered to the balancing market. The available flexibility more or less correlates with the heating demand of the building. Furthermore, the figure shows the results for the variation of the building type: Four different case studies are compared here, one with a pool of passive houses, one with low-energy buildings, one with old buildings and the last one with renovated buildings. The figure shows the amount of energy offered for mFRR in each week over one year. The most power can be offered with the two older buildings. Their heat pumps have the largest electric power, due to the larger heating requirement resulting from the poorer insulation. With good insulation, like the passive house and low energy building, the heat pumps have less power, but can offer flexibility for longer periods per day. While in the old building, flexibility is only available for four hours per day, the passive house can offer up to 12 hours of balancing energy per day.

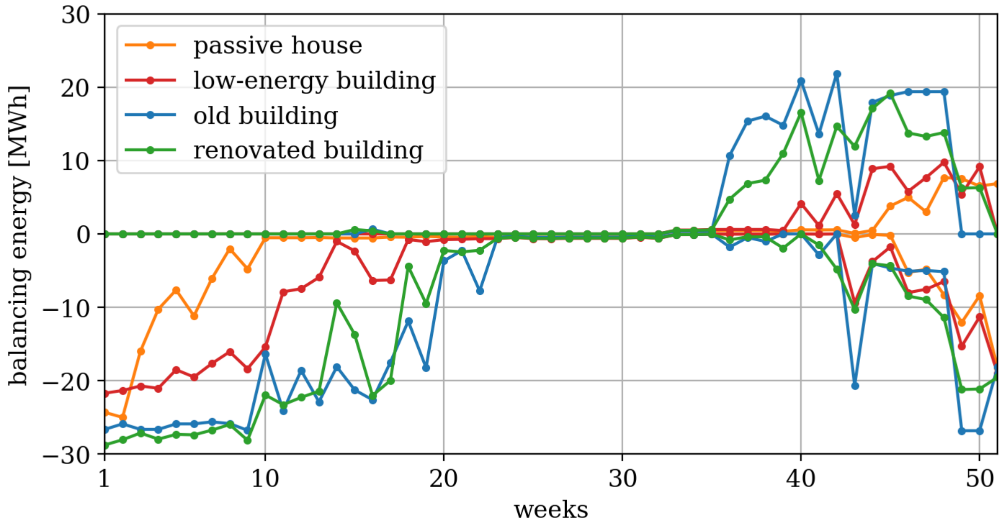

Figure 1: Positive and negative offered manual frequency restoration reserve for each week within a year, for four different building types. The optimization is based on historical prices of the Austrian mFRR balancing market in 2016.

Conclusions

As the amount of renewables and thus the fluctuations in production are increasing, the flexibility in demand becomes more important. Due to their increasing number and available storage capacity, heat pumps in single-family homes are well suited to providing some of this needed flexibility.

In order to create a positive business case of the pooling of residential heat pumps for the electricity markets, having cheap and standardised information and communication infrastructures will be key. The available Smart Grid Ready Label provides a first guideline in this direction. However, to fulfil the strict requirements of the reserve markets, some additions will be necessary.

Some further research will be also necessary in the regulatory aspects of pooling end-customers. Topics like catch-up effects and the definition of a common base line will be crucial for a positive prequalification. From a technological point of view, it is also important to consider the efficiency of the heat pumps, since this might suffer due to the external, market-driven control. Only if the whole system is taken into account, an optimum situation can be achieved.

Although the focus in this work is the balancing market, the determined flexibility of the heat pump pool can also be used for other applications. They could optimize their consumption towards spot market prices, help to reduce imbalance in their balancing group or support the distribution system operator. Those other applications will be further investigated for the German innovation cell in the project DeCAS [2].

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Smart Grids Plus
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