Profit-Maximization of Flexible Heat-Pump Control and Operation in the Intraday-Market: Case Study in Austria

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(1) Overview

The goal of this paper is to analyze the potential of load shifting using heat pumps in combination with smart meters in the supply are of an Austrian utility. At the moment all the heat pumps (around 68 MW in total at maximum load) in the electricity supply company's operating area are controlled as one group using power line control and are switched off for one hour a day from 11 to 12 am.

This study consists of the three steps: (i) 'load modeling', (ii) 'load shift simulation' and (iii) 'profit maximization'. The load model is based on heat pump load measurement data of the heating period 2011/12 mainly using weather and climate data. With additional temperature and heating degree day data a load estimation of the heating periods 2009/10 and 2010/11 can be done. By using these three modeled load curves different scenarios for load shifting are analyzed. To calculate the profit of a certain load shift scenario price data of the EPEX Spot intraday market are used (hour market for Germany and Austria).

(2) Methods

In a first step the load of the heat pumps is modeled by using linear and logarithmic model approaches. The parameters influencing the load are the ambient temperature, heating degree days (current and long term average values) and parameters that allow differing between weekdays, weekend and typical patterns in the load flow that repeat every day.

After modeling the load the existing supply interruption has to be eliminated. To realize this the load flow of the interruption interval and the following load peak is interpolated using the load values of the hours before and after. The additional energy needed from 11 am to 12 is calculated and then subtracted from the following hours in small steps to meet the energy balance.

Next, an algorithm is created that allows simulating various supply interruption scenarios with different interruption time and length. The challenge here is to find a possible gradient of the load for bringing the heating systems back to operation temperature (reloading hot water storage systems, …). Three different reload models are compared. One method represents reloading in the shortest time possible with maximum power, the others represent two exponential load gradients with different time constants. Here it is important again to meet the energy balance for each interruption.

The last step is to combine the load shifting model and price data of the EPEX spot intraday market. The energy not needed during the supply interruption is simulated being sold, for reloading energy has to be bought again. The reloading starts directly after the supply interruption. To maximize the profit it is necessary to find the biggest negative gradients in the price curve.

(3) Results

The main result is that the best daytime for a supply interruption of heat pumps is the evening. At this daytime the prices at the intraday markets are falling, so here the negative price gradient has it's maximum.

A longer supply interruption time results in a higher profit, also in relation to the interruption time. This is possible because with longer interruption intervals the difference between the prices at the switch-off time and at the switch-on time can be bigger that the maximum price difference between two sequent hours.

All together the maximum profit of about 12€ per heat pump and heating period can be achieved by interrupting the supply of the heat pumps once a day for two hours at the optimal daytime (fig. 1).

The current tariff for heat pump systems allows the electricity supply company to switch off the heat pumps for one specific hour per day. By using this fact the best solution would be to move the supply interruption to into the evening from 19 to 20 pm. This results in a profit of about 3€ compared to an existing profit of 0,3€ per heat pump and heating period.

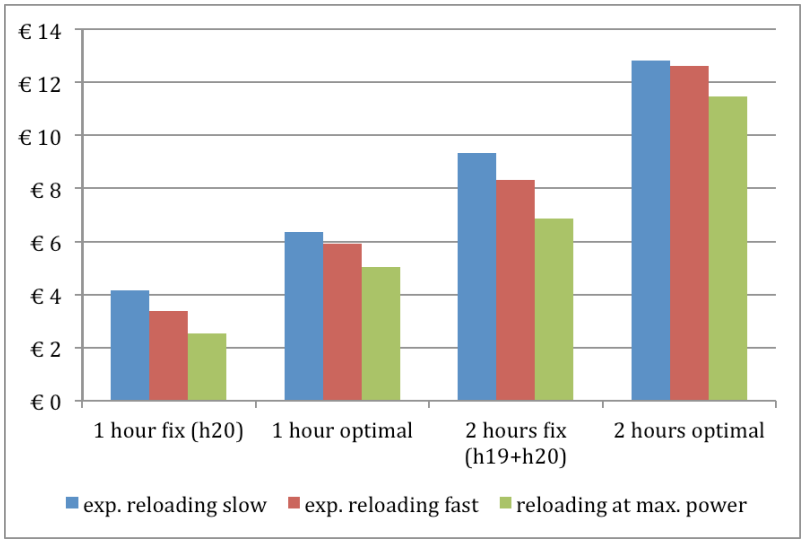

Fig. 1: Comparison of the profits using different load shift scenarios

Compared to the results of [3] of about 14€ per heat pump and year it is necessary to mention that this analysis does not include any costs for trading and system handling and uses a different algorithm for the modeling and load shifting process.

(4) Conclusions

By using smart meters in combination with a load-switching unit each heat pump in the whole supply region can be controlled separately. Households using heat pump systems with similar characteristics can be combined to groups using a load shift scenario that allows meeting the customer's wants and maximizing the supply company's profit. With an increasing number of heat pumps in Austria this method becomes more and more interesting for electricity supply companies with a big number of heat pumps in their operating area [2].

Comparing the profits of the scenarios shows that only changing the time of the heat pump's supply interruption increases the profit significantly. Load shifting with variable interruptions leads to the highest profit, but to realize this information about the households and their heat pump systems is necessary to find out the longest interruption time possible. Future work shall also address the potential for load response in the balancing electricity market (secondary/tertiary market).

References

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