SE-34.2 Model-based optimization of heat pump operation – Simple vs. detailed approach (S)

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The importance of solar and wind power for the electricity generation is constantly increasing and will continue to grow in the future. As the generation profile of these two renewable energy sources strongly depends on the current weather conditions, periods of over- or undersupply of electrical energy can occur. But to guarantee a stable operation of the power grid, electricity generation and consumption have to be balanced at any time. Beside electrical energy storage (e.g. batteries) or power plants (e.g. gas-fired power plants) also flexible energy consumers can help to achieve this balance. Electrical driven heat pumps in combination with thermal energy storage devices, can act as such flexible energy consumers. The storage enables a decoupling of the generation and the demand of thermal energy of the building and this allows an operation, which is adapted to the current availability of electrical power in the grid.

A possible solution to optimize the operation schedule of a heat pump system is a model-based optimization approach, which utilizes forecasts as well as models of the technical devices. Necessary forecasts are for example the heating demand of the building, a generation profile of a photovoltaic system, if available, and a flexible energy price curve, which is directly related to the current availability of electricity in the grid. An important question for the development of a model-based optimization is the required level of accuracy. This also defines the modelling depth and affects the potential optimization algorithm.

This work describes the development and the comparison of two control strategies, which utilize models with different modelling depths. Therefore simplified and detailed models of the heat pump and the thermal storage unit are developed in MATLAB.

The simplified heat pump model uses a constant Coefficient of Performance (COP) to predict the expected electrical power of the device. Also the expected thermal power is provided as an output. Hence the parameterization process is quite easy for the simplified model.

The detailed model is based on a polynomial equation, which is derived from manufacturer data. The implemented polynomial equation allows a temperature-dependent calculation of the COP, which is a better representation of real-life operation. Apart from this the mass flow rates as well as the temperature levels of the heating water and the brine are considered. Compared to the simplified model, the detailed model shows a higher accuracy, but also a higher effort for the parameterization is required.

The detailed model of the thermal buffer storage represents a stratified storage model with three layers, which considers the mass flow rate and temperature level of the entering and leaving heating water. Additionally the temperature-dependent density of water is considered, which directly has an effect on the stratification of the storage medium, whereas the simplified model uses a single capacity node. Here the provided heating power from the simplified heat pump model is just summed up.

As mentioned above the modelling depth also affects the choice of the optimization algorithm. For the simplified models the method of mixed-integer linear programming (MILP) in MATLAB is used. This algorithm needs less computing time as well as reproducible results. On the other hand, the detailed models are implemented in an optimization environment, which utilizes the genetic algorithm (GA) from MATLAB. This optimization algorithm is able to handle models with a higher complexity, which results in higher computing time. Another disadvantage of the genetic algorithm is the non-reproducibility of the results.

To compare the two systems, the same inputs for thermal load and electricity price are provided. First analyses show, that in theory both systems cause the desired effect. The operation of the heat pump is shifted to times of low electricity prices, even if the thermal demand is low. The excess heating energy is stored in the thermal storage device for later use.

Additionally the operation strategies will be tested on a thermal emulation test bench, to show the differences between the two approaches as well as to validate the required modelling depth of the technical devices.