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Forecasting and optimization of the heat demand at city level

Abstract: Computational methods have been developed for the predictive optimization of the heat demand to increase energy efficiency in heating by taking into account the point of view of both the energy producers and consumers. Research methods included the modelling of the individual buildings indoor temperature and heat demand, which can then be expanded to a larger scale to optimize the heat demand at the city level. The developed models are accurate and easily adaptable enabling the city level predictive optimization of the heat demand. This makes it possible to better adapt to and prepare for future changes in the outdoor temperature while at the same time ensuring the normal living conditions and optimized energy efficiency, also enabling the demand side management in the heating network. However, the full realization of the concept requires proper real-time and two-way information flow through the whole energy chain.

Keywords: district heating, modelling, prediction, demand side management, optimization

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Introduction

Energy Efficiency Directive (EED) sets binding measures for EU countries to improve energy efficiency. At the same time, buildings represent 20–40% of the total energy consumption. Furthermore, for 15 of the 28 EU countries the annual heat demand in buildings presents the largest energy demand. For the aforementioned reasons, the implementation of new energy efficiency measures for the heating and building sectors is of utmost importance.

As the requirements for energy efficiency are becoming stricter, buildings cannot be considered as isolated elements in energy systems when developing new control and optimization schemes for district heating systems. A concept for optimizing the heat demand in district heating systems has been proposed by the authors (Figure 1) [1]. The concept approaches the subject by predicting the heat demand and then optimizing the heat production utilizing demand side management (DSM). However, city level consumption forecasts can be extremely time-consuming if the simulations are done on a single building level. Consequently, forecast models are widely used for individual buildings, but their application at the large scale is lacking. Ease of modelling would make the forecasting of heat demand and the implementation of predictive control strategies at the building and city level more cost-effective. In this regard, the applied models have to be easily reproducible for multiple buildings. This sets requirements for the simplicity and ease of parametrization of the models. The straightforward implementation in real applications should also be kept in mind. In modern automation, the cost of implementation work plays a key role while the cost of the hardware is decreasing.

Forecasting models

Straightforward modelling methods would enable DMS to be implemented at city level. When optimizing the heat demand utilizing DSM, maintaining the indoor temperature at an acceptable level in buildings is important as the control actions should ensure the quality of the living conditions.

For wide use of any indoor temperature or heat demand model, it should be applicable to different types of buildings with minimum extra implementation work. A new dynamic modelling approach was developed to predict and optimize the indoor temperature in large buildings [2]. The average relative modelling error of the developed model was below 5%. Two different straightforward modelling approaches were developed to forecast the hourly heat demand at city level considering more than 4000 individual buildings [3]. The relative error was 4% for the city level heat demand forecast. Low amount of estimated parameters reduced the calculation time and easily attainable measurement data facilitates the

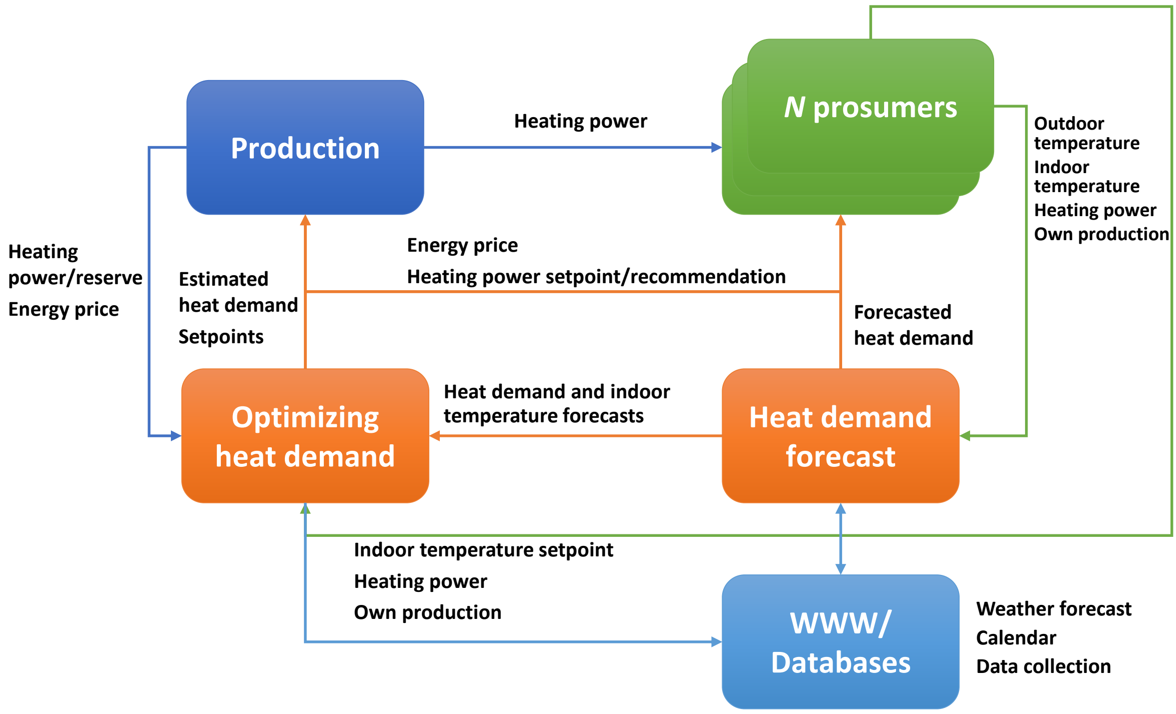

Figure 1. Concept for the predictive optimization of the heat demand.

implementation of the models for thousands of buildings.

Optimization

Heat demand forecast based on the forecasted heat demand of individual buildings together with the information on the indoor temperature of the buildings would enable different DSM action. These include peak load cutting, the minimization of the heat demand and timing of the energy production.

Peak loads refer to times of high energy consumption. The heat demand forecast would be used to identify these peak loads before they happen and the thermal mass of the buildings could be used to cut them. Simulations of different peak load cutting scenarios have been performed in two apartment buildings by utilizing the developed indoor temperature model [4]. The results showed that the studied buildings had very different heat storage capacities and that the system level effect of peak load cutting cannot be concluded based on the results of a single building.

Optimization strategy that would have direct benefit for the building owners would be the minimization of the heat demand. Preliminary results from a field test, where the optimization of the heat demand was performed in a school building, showed that significant savings in heat consumption and reduction in peak loads are possible [1].

The timing of energy production refers to the timing of electricity production in combined heat and power (CHP) plants. At favorable times, electricity production could be increased and the extra heat could be stored in the buildings.

All the aforementioned predictive optimization strategies would utilize buildings as short term heat storages. As the heat storage capacity of buildings is already existing, only proper ways to utilize it are needed. The easily adaptable models would enable the application of the predictive optimization methods to the whole building stock providing predictive information on the heat demand and indoor temperature in buildings. However, the full realization of the concept would require proper real-time and two-way information flow through the whole energy chain.

References

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