New forecast control of heat for heating

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Abstract.
In many existing buildings, the reduction in energy consumption has already been made by carrying out the thermal modernization of the building envelope. Therefore, other renovation measures, aimed at further increasing the level of energy efficiency in such a buildings, will focus in particular on improvement of control and automation of the processes of supply, as well as storage and use of energy.
This paper presents the field results of applying forecast control of heating system, which can be easily employed in existing buildings (time of installation in existing buildings: below 2 hours) and may work with existing, widely used weather controller. The new methods (applied in forecast controller) used for the creation of real energy model of the building (energy characteristics of buildings and their heating systems) and for forecast of heat power for heating are presented. The field research was conducted for a multi-family building located in Poland for part of a single heating season. The analyzed multifamily building in the first part of research was regulated only by a traditional weather-based controller, whereas forecast control system was used in the second part of research. The application of the proposed forecast control allowed decreasing the supply temperature of heating medium, lower the heat power supplied and in such a way generate energy savings of above 10%.

Keywords. forecast control of heating system, load forecasting, energy in buildings, energy efficiency
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1. Introduction

Existing buildings use around 42% of total final energy in the European Union [1] and about 80% of this energy is used for space heating [2]. Therefore, in order to increase the energy efficiency of existing buildings, several opportunities including the envelope and services such as heating, ventilating and air-conditioning (HVAC) are available. The measures which are easy applicable are preferred. One of such solutions may be optimization of HVAC control. In this light and with the development of technology, the demand for intelligent building control increases. Intelligent control of heating, ventilation and air conditioning (HVAC) generates potentially large energy savings at relatively low installation costs. For efficient building management, the influence of several atmospheric factors should be taken into account. These are in particular the outdoor air temperature, solar radiation, relative humidity and wind speed [3]. One of the methods of controlling HVAC systems is the Model Predictive Control (MPC) [4-6]. For example, it allows reducing the energy consumption for cooling in the office by 58.5% and decreasing the electricity consumption in the conference room by 36.7%, in relation to the previously used control method. Additionally, owing to the use of MPC in both rooms, an improvement in thermal comfort is observed [7]. An important aspect used to determine the heat demand in MPC is the weather forecast. Several methods are used to define it. One of them involves artificial neural networks that mimic biological neural networks. This allows for adapting the principle of the network operation towards changing initial conditions.

However, such a control of heating system is not easy applicable, especially in existing buildings. Therefore, this work shows the results of preliminary field test of forecast control of heating system. However, detailed presentation of the method for forecast control of space heating in existing buildings will be included in an journal article [8]. This manuscript is organized as follows: section 2 presents the object and methods of analysis. Section 3 presents the main research findings regarding the heat power delivered to analysed building without and with forecast control of space heating system.

2. Materials and methods

The subject of the research was a multi-family building located in Poland before and after the application of the forecast control of space heating systems. The studied building is located in the 3rd climatic zone for the winter period in Poland, where the designed outdoor temperature is -20°C, and the average annual outdoor temperature is 7.6°C. The building is a 5-storey building. The heating system in buildings is a traditional system with vertical risers and radiators connected from one side. The heating installation is made of steel pipes, convection radiators with thermostatic radiator valves. The heating installation is supplied with the heating medium (80/60°C by outdoor air temperature equal to -20°C). Individual thermal station for heating and hot water purposes is located in the lowest part of the building. The control of heat supply is realized by weather base control which uses heat curve dedicated for this building. The building was equipped with a calibrated heat meter, which is installed in the main circuit of the heating system. The heat power supplied to the heating system and the temperature of heating medium on supply and return were monitored on an hourly basis and sent to information system (*IS*), which was to perform future calculations using algorithms.

The research included in this manuscript was conducted for four weeks in heating season 2020/2021 during which for two weeks the heating system was regulated only by traditional weather base control, and by two following weeks by forecast control system which cooperates with the existing weather base control.

The new forecast control system uses existing weather base control and allowed for the appropriate modification (only increase) of the current outdoor temperature, taking into account the building energy model (in form of T_{eq}), the forecast of user profiles and the forecast of weather conditions ($T_{outdoor}$, V, *Insol*).

This forecast control system has the ability to take into account in advance (what may be set individually in the control system) the impact of the forecasted changes in weather parameters (especially the forecasted increase in outdoor temperature and the occurrence of solar radiation) and use the thermal inertia of the building. Therefore, owing to such functions, this system allows increasing the value of the outdoor temperature sent to the existing controller of heating system, which lowers the supply temperature and allows for energy savings, which will be presented in Chapter 3.

3. Results and discussion

The new forecast control module was installed (beginning of 2021) in the investigated building first to create the data-driven real building energy model in the form of equivalent outdoor temperature (T_{eq}). This building energy model of the investigated building was created based on the data from February 2021 till mid-April. In this period the heating system was controlled by existing weather base control. The building energy model includes a correction of T_{eq} due to wind speed (T_V^{rev}) and correction due to solar radiation (T_{insol}^{rev}) – see [9] for more details. The influence of wind speed on the heat power delivered to building (T_V^{rev}) was estimated based on the data from night hours (11 p.m. – 4 p.m.), because then the influence of users and solar radiation is minimized. In turn, the data from Monday to Friday at 10 a.m. – 2 p.m. for wind speeds below 3 m/s were used to determine T_{insol}^{rev}. For these conditions, the influence of wind speed and users (who are usually away from home during these hours) is limited.

The equivalent outdoor temperature (T_{eq}) is presented in Equation 1.

$$T_{eq}=T_{outdoor}-(1.23\cdot V-2.16)+(0.01\cdot Insol+0.47)[°C] \quad (1)$$

Where: $T_{outdoor}$ is outdoor air temperature in °C, V- wind speed in m/s; *Insol*- solar radiation in W/m^2.

When calculating the energy model for the analyzed building, the coefficients of determination were 0.91 and 0.89 for T_V^{rev} and T_{insol}^{rev}, respectively. The details about validation of building energy model in the form of T_{eq} are provided in [9].

The minimum training period of creating a building energy model is 1 month, but 1 heating season is preferable.

Besides the building energy model above presented, also the profile of equivalent indoor temperature as the parameter related to the effect of the building occupant behaviour (see [10] for more details) was taken into account. This profile is updated for the analysed building on the weekly base. The forecast system is integrated with API meteo, owing to which the forecast of outdoor meteorological parameters for specific location is provided. The main output from the calculations made on *IS* are the outdoor temperature settings for 6 hours in advance. Then, the forecast control module emulates in the specific manner the outdoor temperature, which is the input to existing weather base control.

In such a way, the forecast system has the possibilities to react in advance to changing outdoor meteorological parameters. Owing to such a way of control of heating systems, it is possible to lower the supply temperature of heating medium for the investigated building by 7%, which is presented in **Figure 1**.

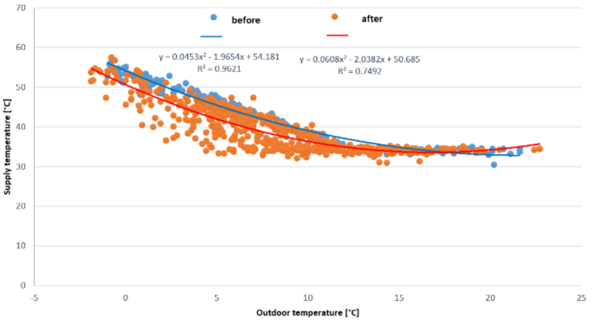

Fig. 1 – Supply temperature before and after the installation of forecast control.

Owing to lower supply temperature (in comparison to the period before the use forecast control of heat supply), the energy savings may be achieved (**Fig. 2**), which account for about 12.7% for the analysed buildings.

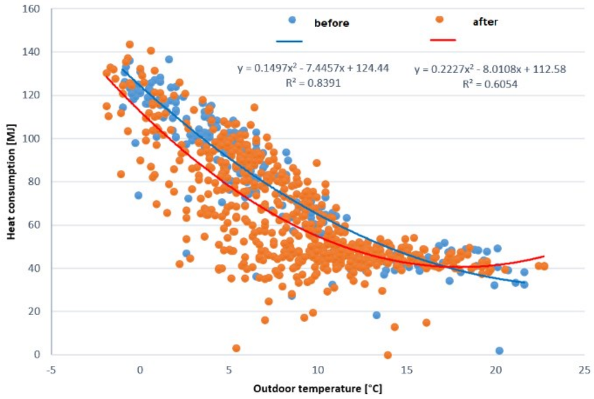

Fig. 2 – Heat consumption before and after the installation of forecast control.

Regarding the possible application of the proposed forecast control of heating system and easy extrapolation for other buildings, it should be emphasized that the proposed system may cooperate with the weather based controller already existing in a given building. Therefore, it takes no more than 2 hours to install the proposed system in an existing building. Additionally, for the purposes of building an energy model, it is not necessary to have a building (or a heating system) documentation, because this is data-driven real building energy model in the form of equivalent outdoor temperature (T_{eq}), which significantly simplifies the installation process. The proposed system also has a user friendly interface that allows adjusting individual settings (for example amount and period for data used) for creation of the building energy model of the building, the control process and allows setting additional indoor temperature reductions at night or during the day – see more details in [8].

4. Conclusions

Nowadays, there is limited numbers solutions others than weather base control of heating system in the existing buildings. In this manuscript, the preliminary results of new forecast control of space heating were shown. It has been observed based on the research conducted in existing building, that the use of forecast control allowed decreasing the supply temperature of heating medium and lower the heat consumption by 12.7% for the analysed building. This methodology may be widely applied in different countries, where central heating of buildings is applied. The detailed presentation of the method for forecast control of heating system will be presented in scientific journal paper.

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Data Statement

The datasets analysed during the current study are not publicly available because privacy reason but will be available on request.