Controlled Ventilation of Interior Spaces Using a Central Recuperation Unit

Jakub Jiřinec
Department of Electrical Power Engineering
University of West Bohemia
Pilsen, Czech republic
jjirinec@fel.zcu.cz

Lenka Raková
Department of Electrical Power Engineering
University of West Bohemia
Pilsen, Czech republic
lencar@fel.zcu.cz

David Rot
Department of Electrical Power Engineering
University of West Bohemia
Pilsen, Czech republic
rot@fel.zcu.cz

***Abstract*—A common way of ventilating indoor spaces for more significant buildings is to use a central recuperation unit. In contrast to the decentralized recuperation unit, the system must be equipped with a control system that will control the individual parts of the ventilation system. This article describes a designed and implemented control system for commercial, school, or office buildings. The created control system minimizes the operating costs of buildings while adhering to the prescribed limits by effectively controlling the amount of air entering the individual rooms.**

***Keywords*—central recuperation unit, control system, heating, CO_2 concentration, energy management**

I. Introduction

The efficiency of recuperation units is affected by the outdoor air temperature. By operating the equipment at high efficiencies, financial costs can be saved. Standard heating systems only respond to the current outdoor temperature and do not exploit this potential. The solution is predictive control, which would consider the future development of the outdoor temperature and thus optimize the operation of the entire device. Based on the measured data of outdoor temperatures (January 2016 to March 2018), we found that it is possible to compile type courses of outdoor temperatures valid for individual days and months of the year and thus enable an approximate offline prediction. With the help of this prediction, recuperation units can be effectively controlled. Fig. 1 shows an example of outdoor temperatures with marked areas suitable for cooling and heating the building. This control principle was also applied in our designed control system of recuperation units. [1, 2, 3, 4]

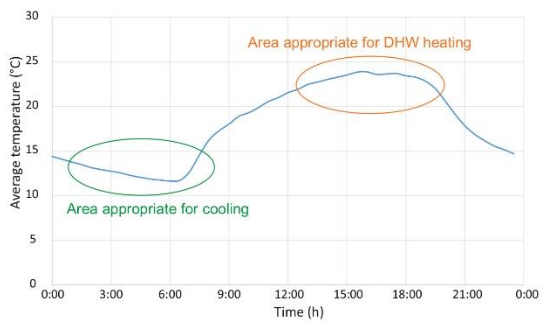

Fig. 1. Average temperatures during the day (August)

II. Control System Design of Active Recuperation Units

The proposed system was installed in kindergartens and primary schools for the hearing impaired in Pilsen. The main part of the system is the active recuperation unit NILAN VPM1000. The control system can be controlled via a web user interface, which is used to control the operation, set working time intervals, and set the required temperatures and CO_2 limits in classrooms. According to the current operating state and system settings, the opening of the ventilation flaps and the radiator actuator is controlled. The WAGO PLC with the appropriate expansion cards was chosen as the core of the control system. Using the Modbus RTU communication protocol, the PLC communicates with individual components (sensors, electricity meter, recuperation unit). A significant advantage of the used hardware is the easy expandability and integration into superior building control systems (via the KNX, LON, etc.). [4, 5]

III. Test Operation Results

The control system was launched in May 2020 and was gradually improved. Interior cooling testing took place in August at outdoor temperatures above 25 ° C. The measurement found that if the outdoor temperature is above 30 ° C and the interiors are not cooled, then the room temperature is up to 35 ° C. With continuous cooling of the whole building, the temperature in the interiors decreases, see the results in Fig. 2.

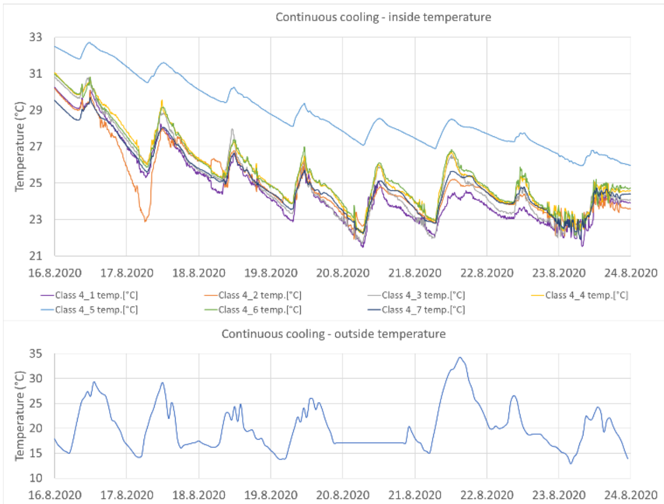

Fig. 2. The course of temperatures with continuous cooling in August 2020

This graph shows that the recuperation unit is not able to cool the entire building space effectively. The temperature in the rooms is decreasing, but very slowly. This is mainly due to the high value of thermal energy, which is accumulated in the concrete structure of the building. However, the maximum temperature was reduced from 32.6 ° C to 26.6 ° C during the day. During the last tested day, the internal temperature dropped below the set limit of 23 ° C, and the system began to regulate the opening of the air flaps.

The operation of the proposed system was also monitored in the winter months. The required temperature during working hours was set to 24 ° C and outside working hours to 21 ° C. In the first tests, it was found that at low temperatures, the recuperation unit is not able to sufficiently heat the cold outdoor air to a temperature higher than 24 ° C. For this reason, the recuperation unit was started only according to the current CO_2 concentration in the rooms. The room was heated by radiator bodies equipped with servo drives. The course of the class temperature on the selected day is shown in Fig. 3

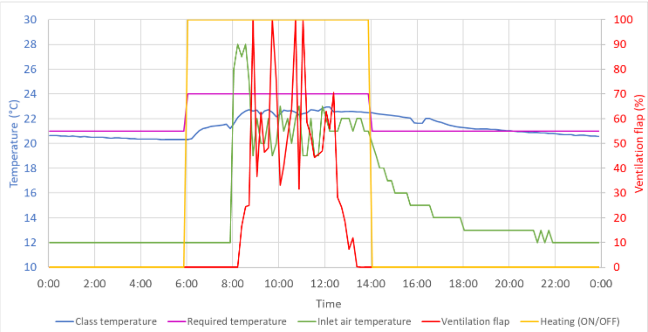

Fig. 3. Temperature course during winter operation in class (8.1.2021)

Fig. 4 shows the course of CO_2 concentration in the selected class. The system starts to regulate the opening of the air flaps from the value of 800 ppm, and at the value of 1,200 ppm, the damper is already fully open.

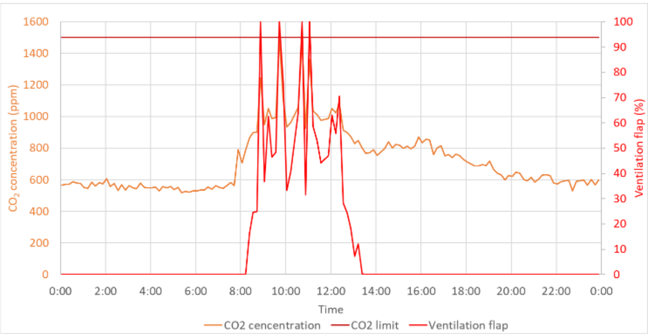

Fig. 4. The course of CO_2 concentration during winter operation in class (8.1.2021)

IV. Impact on Energy Management at School

Continuous cooling is very uneconomical, the energy consumption of the primary school building and the curve of the indoor temperature of the selected room is shown in Fig. 5.

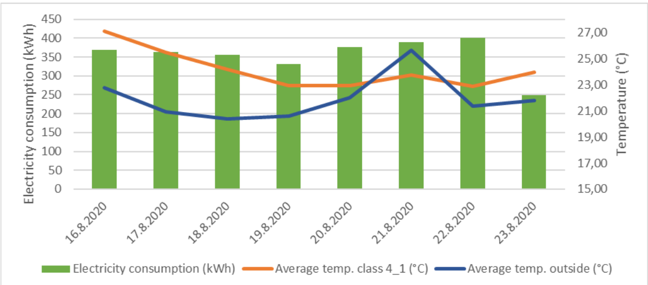

Fig. 5. Energy consumption for continuous cooling

If the recuperation unit is to be used for efficient cooling of the entire building, it would be necessary to increase its cooling capacity. Another important element in reducing cooling consumption would be the effective shading of windows using window blinds, eliminating heat gains from solar radiation. However, the school's energy management evaluation shows that the reconstruction of the building and the proposed controlled air recuperation have significantly improved the energy efficiency of these buildings, see Fig. 6.

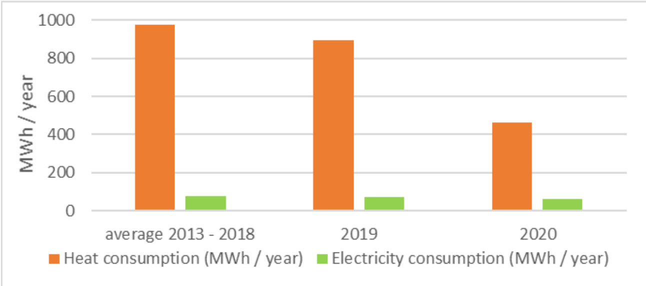

Fig. 6. Results of energy management

V. Conclusion

Long-term monitoring of the proposed system proved its suitability for keeping the CO_2 concentration within the required limit. In terms of efficient cooling, the system encounters the limits of the recuperation unit used, which does not have sufficient power to cool the entire building at high outdoor temperatures. However, this unit was not designed to cool the entire building, so we anticipated this in advance. During long-term cooling by the recuperation unit, the indoor temperature can be reduced to a value of around 24 ° C.

A significant result from the analysis of the operation of this system is that the control of night cooling in the summer months was, in many cases, not at the lowest outdoor temperature. The system has therefore been extended with an outdoor temperature forecast. The night cooling interval is controlled so that it always takes place at the lowest night temperatures. The energy analysis results showed that the energy consumption of the buildings was reduced thanks to the proposed controlled recuperation system and building insulation.

Acknowledgment

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