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INFLUENCE OF HEATING AND VENTILATION MODES ON THE ENERGY CONSUMPTION OF UNIVERSITY EDUCATIONAL BUILDINGS UNDER QUARANTINE CONDITIONS IN UKRAINE

Abstract: *The global pandemic COVID-19 caused Ukrainian institutions continued their work in a blended learning mode or completely switched to remote mode. The paper analyzes the university educational building energy consumption for the heating season under quarantine and normal conditions. Building dynamic energy model in the DesignBuilder software was created. According to the results of modeling partial use of the building during quarantine allows to reduce the consumption of heat energy by 61.32%. Simultaneously the specific heat energy consumption of separated heated rooms increases by 68.86% under the influence of heat exchange with unused premises.*

Keywords: *quarantine, educational institutions, energy consumption, energy modeling, DesignBuilder software*

Introduction

Since the end of 2019, humanity has faced an unprecedented phenomenon for the modern world – the global pandemic COVID-19, which has dramatically changed the lives of each of us. World Health Organization declared the COVID-19 outbreak a global pandemic. It was indicated that social distancing, sufficient ventilation of enclosed spaces and personal hygiene are the main measures that can prevent the spread of COVID-19 (Sun and Zhai, 2020). The same changes have taken place in the field of education. Therefore, to avoid crowds, most countries have introduced partial or complete closure of educational institutions, commercial and industrial companies (Ivanko et al., 2021). In Ukraine, in the field of education, some institutions continued their work in a blended learning mode, while some completely switched to remote mode to prevent the spread of coronavirus disease.

At the same time, the issue of expediency in maintaining the normative operational characteristics of educational buildings for their entire heating volume with partial use has become especially relevant. Therefore, simulation dynamic modeling of the educational building for the heating season for various modes of operation of the heating and ventilation system during the quarantine period with partial use of the building is the most convenient tool in order to obtain a set of energy characteristics. Carrying out a number of simulations allows us to estimate the amount of heat transfer between the premises for different modes of their operation and to justify the location of the premises that will be used during the period of quarantine restrictions. When analyzing energy consumption it is necessary to take into account a number of parameters that characterize the building, and, first of all, these are its operational and behavioral factors that determine the set of conditions under which the building is operated (work schedule, indoor air temperature, quantity and the period of stay of people, the mode of operation of lighting, equipment, etc.). Educational institutions normal operation is characterized by a large number of people staying during working hours (Saraiva et al., 2018; Katić et al., 2021), which in turn largely affects the integral characteristics of heat gains into the premises and energy consumption depending on the level of awareness potential consumers (whether the light is turned off, the faucet is closed towards the end, windows are opened/closed, etc.) (Zhiyuan et al., 2021; Laaroussi et al., 2019). However, the COVID-19 pandemic has had a significant impact on the energy demand of public institutions, in particular higher education institutions. This has led to radical changes in energy consumption (Bahmanyar et al., 2020). Therefore, it is obvious that it is relevant to conduct an in-depth analysis of energy consumption for isolated rooms of a building of educational institutions for quarantine conditions.

Purpose and research objectives

The purpose of the work is to analyze the heating consumption of educational building for the heating season under quarantine and normal conditions. According to the set goals, the following tasks should be solved:

1. Creation of dynamic models of the educational building apartment in the DesignBuilder program, considering the internal zoning of premises.
2. Simulate the energy consumption of the building for normal operation.
3. Simulate the energy consumption of the building for quarantine conditions operation.
4. Analyze the results of modeling and evaluate the possible level of energy consumption of the building during the period of quarantine restrictions.

Material and research results

Initial data and model description. For creating a building model in the DesignBuilder software, the educational building of the Igor Sikorsky Kyiv Polytechnic Institute was used. It was built in 1969. The building is located in Kiev. Geometrically, the building is a regular extended rectangular shape. The main part of the facades is oriented to the north and south sides of the world. The building has 5 floors, as well as a heated basement and an unheated attic**.**

The heating volume of the building is 42371 m^3, the area is 12185 m^2. The share of the area of translucent structures is 36.73%, 12.02%, 35.44% and 12.02% in the northern, eastern, southern and western orientations, respectively. Glass U-Factor for windows – 2.38 W/m^2·K. The bearing layer of the outer walls of the building is made of expanded clay concrete. For external walls U-Factor with Film – 1.02 W/m^2·K. Covering of the building – flat roof, rolled: U-Factor with Film – 0.80 W/m^2·K. Foundation – concrete blocks (floor U-Factor with Film – 0.75 W/m^2·K. The building is supplied with heat through the networks of a centralized heating system. In addition, it is provided that the heating devices installed in the premises are M140 cast-iron radiators, the model of which with thermostatic heads allow adjustment by building zones.

The ventilation is provided at the level of 0.7 ac/h; another 0.3 ac/h is provided by the infiltration component (due to the looseness of the enclosing structures). Thus, the total air exchange is 1 ac/h, which corresponds to the standard for educational buildings.

The 3D model of the building of educational building, created in the DesignBuilder software (DesignBuilder), is shown in Figure 1.

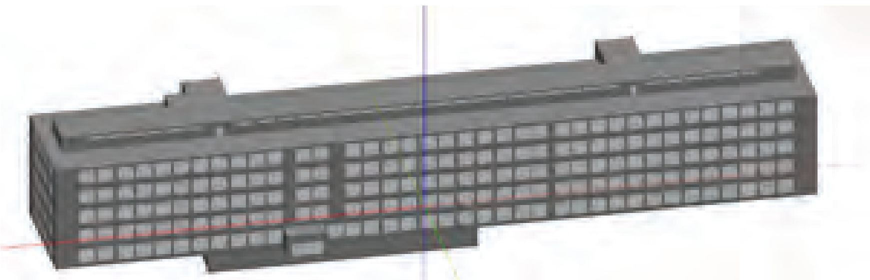

FIGURE 1. *3D-model of Igor Sikorsky KPI educational buildings (DesignBuilder)*

The energy consumption of the building was analyzed, for the normal mode of operation of the building and premises used during quarantine, under constant temperature 20°C and steady air exchange; Unused premises temperature was 14°C. During quarantine, less than 10% of the heated rooms of the educational building are used.

For normal operation of the building, rooms with the same functional purpose were combined into thermal zones (auditoriums, corridors, basement, attic, vestibules). During normal operation, the heat and mass flows between the classrooms are quite active, and the parameters (temperature, air exchange, number of people per unit area) are the same, so it is not advisable to separate each auditorium into a separate zone. For the same quarantine regime, since the difference between heat and mass flows, as well as the set parameters, between the zones is significant, additional thermal zones were identified, which geometrically coincide with the boundaries of the classrooms, and the necessary parameters were set separately for each zone in accordance with the scenario that is modeled (Fig. 2).

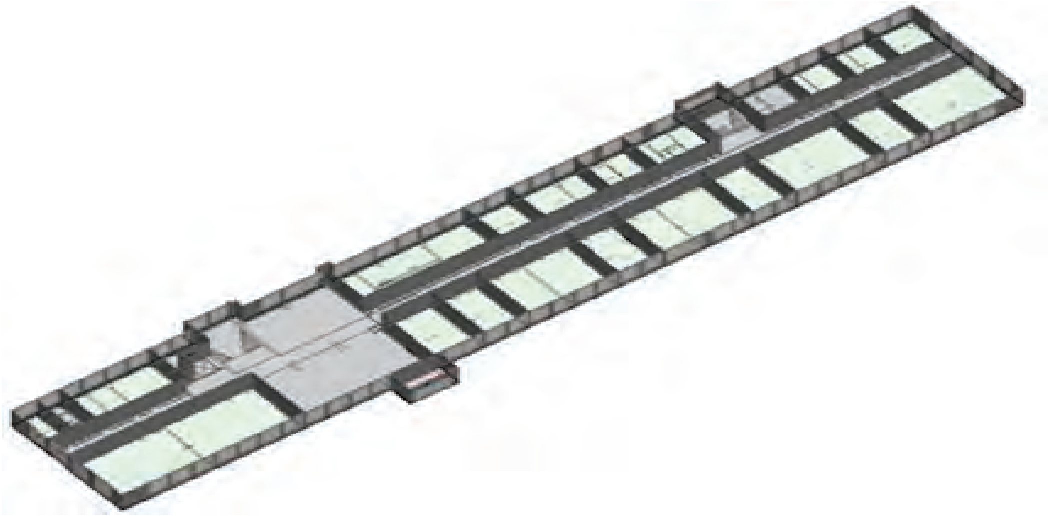

FIGURE 2. *Zoning of the 1st floor for the quarantine regime*

The hourly climate data used for the simulation is an IWEC hourly file for a typical year for Kiev conditions (International Weather for Energy Calculations). Figure 3 shows the hourly change in outdoor temperature and the level of solar heat gains that the room receives through window structures, per unit of heated area of this room.

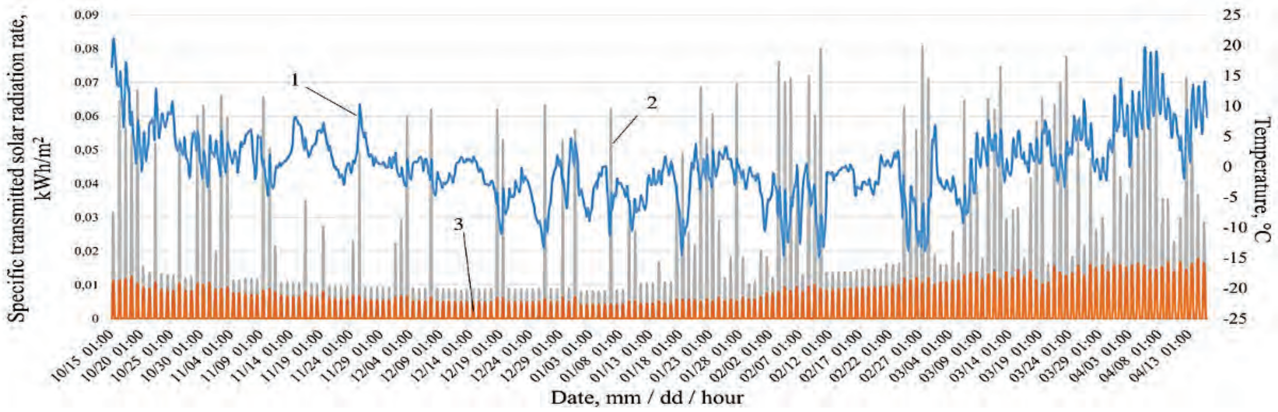

FIGURE 3. *Hourly values of outdoor temperature and solar radiation rate per heated area according to the IWEC weather file (International Weather for Energy Calculations): 1 – outside air temperature, 2 – solar radiation rate on the south side, 3 – solar radiation rate on the north side*

Analysis of the study results. Consumption of heat energy, according to the results obtained in the simulation are given in Table 1.

TABLE 1. *Annual energy consumption for heating in different operating modes*

Mode	Normal	Quarantine	Δ%
Heating area of the building, m^2	12185		–
Area of premises used, m^2	12185	992	**-92**
The need for heating, premises in use during quarantine, MWh/season	–	219.5	–
Energy consumption for the heating season, MWh/season	1596.3	617.5	**-61**
Specific energy consumption, kWh/m^2	131.0	50.7	**-61**
Specific energy consumption of premises in use, kWh/m^2		221.2	**69**
Specific energy consumption of the representative premises in use, north orientation kWh/m^2	131.9	241.7	**83**
Specific energy consumption of the representative premises in use, south orientation kWh/m^2	115.1	215.1	**87**

Partial use of the building during quarantine allows to reduce the consumption of heat energy during the heating season by 61.3%. At the same time, the specific consumption to the total heating area is reduced by the equivalent value. However, if we compare the specific consumption of premises in use, this value increases by 68.9% compared to the normal mode. If we consider a single room, which is zonally separated in both models for analysis, its specific consumption increased by 83.2% and 86.9% for the northern and southern orientation compared to the normal regime, respectively. This phenomenon is due to the fact that these rooms are in contact with cold areas, where a constant temperature is maintained at all times (t_{air_in} = 14°C). Internal heat flows lead to a transferring heat to cold zones.

Figure 4 shows the hourly load on the heating system of the building as a whole for normal operating conditions and quarantine restrictions.

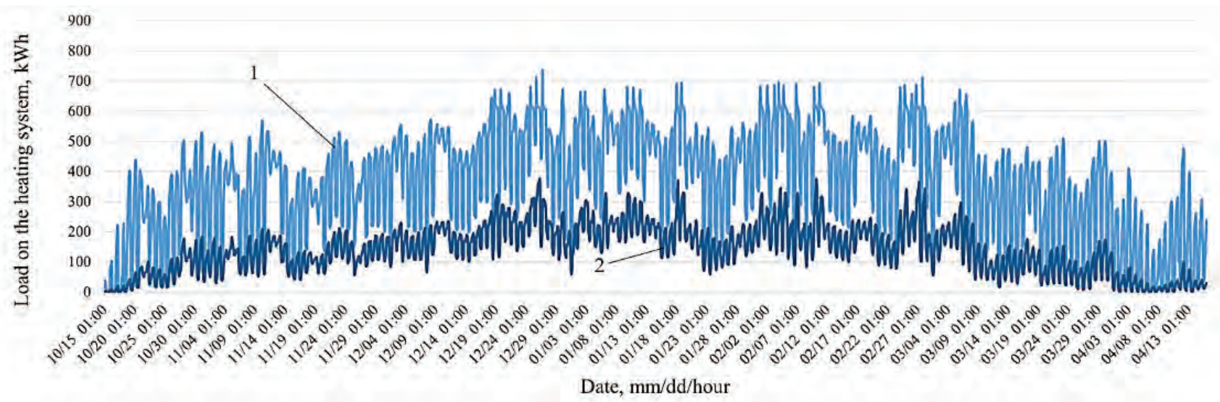

FIGURE 4. *Hourly heat consumption by the building: 1 – normal mode, 2 – quarantine mode*

Conclusion

The operation of educational buildings under quarantine conditions has necessitated in-depth studies of the energy performance. For this purpose, a dynamic multi-zone model of the educational building of Igor Sikorsky Kyiv Polytechnic Institute was created.

According to the results of modeling partial use of the building during quarantine allows to reduce the consumption of heat energy during the heating season by 61.32%. At the same time, the specific consumption to the total heating area is reduced by the equivalent value. However, if we compare the specific consumption of heat energy in heated to the appropriate level rooms in use, this value increases by 68.86%, compared to the normal mode, under the influence of heat exchange with unused premises.

In the future, it is appropriate to investigate what effect on energy consumption for heating has the provision of comfort in the conditions of quarantine restrictions during the partial operation of the premises of the educational building.

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