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SUPPLEMENTARY LIGHTING CONTROL IN OFFICE ROOM WITH MINIMIZED GLAZING AREA

UZUPEŁNIAJĄCE STEROWANIE OŚWIETLENIEM W POMIESZCZENIU BIUROWYM O ZMINIMALIZOWANEJ POWIERZCHNI PRZESZKLENIA

Abstract

The paper is dedicated to present and compare two methods of controlling supplementary lighting system in office with limited glazing area. The lighting energy demand was evaluated taking into account positioning of light sensors and room occupancy. Comparison of daylight conditions in the rooms with different orientations was carried out. The results shows the effect of occupancy scenario on lighting control strategy.

Keywords: control, daylighting, artificial lighting, simulation, office room

Streszczenie

W artykule przedstawiono dwie metody sterowania uzupełniającym systemem oświetlenia w budynku biurowym o ograniczonej powierzchni przeszklenia. Oszacowano zapotrzebowanie na energię do oświetlenia, biorąc pod uwagę rozmieszczenie czujników promieniowania oraz liczbę osób pracujących w pomieszczeniu. Dokonano porównania pomiędzy pomieszczeniami o różnej orientacji. Na podstawie otrzymanych wyników stwierdzono wpływ użytkowania pomieszczenia na strategię sterowania oświetleniem.

Słowa kluczowe: sterowanie, światło dzienne, oświetlenie sztuczne, symulacja, pomieszczenie biurowe

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1. Introduction

New artificial lighting technologies e.g. light emitting diode (LED) solution, give a new possibilities to control light intensity in offices and other public utility buildings occupied during a day [1]. Some limitations of artificial light intensity as well as shorter operating time, can lead to lower energy requirements. These savings are possible to be achieved through selected control strategies, when daylight is mixed with electrical light [2]. However, in buildings with minimized size of transparent components the daylight utilization is lower than for highly glazed facades. On the other hand limited surface of glazing also provides higher comfort level by avoiding of daylight glare effects and heighten solar heat gains [3].

Another issue related with supplementary lighting control is positioning of light sensors. Their location must be adjusted to the room geometry. Minimized glazing area imposes additional limitations. Furthermore, lighting in larger offices often works in groups, what further complicates sensor positioning [4].

The presented study was devoted to find the appropriate control strategy for supplementary artificial lighting in office rooms dedicated for work with computer. Additionally, changeable occupancy and daylight accessibility were taken into account. Finally, the energy which is necessary to power supplementary lighting system was measured and correlated with a sensor positioning.

2. Supplementary lighting control

As supplementary lighting the most commonly used are lights with the low power consumption, because such systems have to operate only periodically. Additionally, to achieve greater accuracy lighting should be able to work on the different levels of intensity [5]. Artificial light should have an ability to brighten or to dim for several levels. It is necessary to provide precise response to the continuously changing daylight conditions. Because of these two characteristics as supplementary lighting LED systems are the most suitable choice, they are a control subjects of this work.

Electric lights can be controlled according to the availability of natural daylight. When lighting control is switched on, illuminance levels are calculated to determine how much the electric lighting can be reduced. The daylight illuminance level in a zone depends on many factors, including sky condition, sun position, light sensor position, as well as glass transmittance, location and size of window, window shades and reflectance of interior surfaces. Reduction of electric lighting depends on daylight illuminance level, illuminance set point, fraction of zone controlled and type of lighting control [6].

Two control strategies were analysed in this work: linear/off and stepped models. With linear/off control, the lights dim continuously and linearly from maximum electric power, maximum light output to minimum electric power, minimum light output as the daylight illuminance increases. The lights switch off completely with further increase in the daylight illuminance. Linear/off control provides an idealised lighting control mechanism. Stepped control allows to switch lighting on/off according to the availability of natural daylight in discrete steps. Whereas the linear/off control provides precisely controlled illuminance by dimming the lights, the stepped control models blocks of lights switching on/off according to the electric lighting requirement. The electric power input and light output vary in discreet, equally spaced steps. The number of steps can be set individually [7].

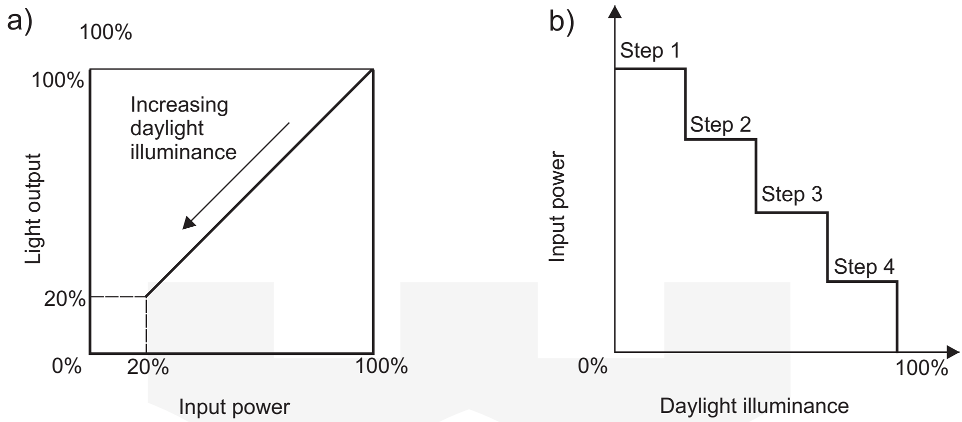

Fig. 1. Control a) linear/off, b) stepped model

3. Experimental office room

For the purpose of the comparative analysis two office rooms were taken into consideration: one faced east, other west direction. Its dimensions were assumed as 5.0 m length and 3.0 m width and height. The rooms are painted with light grey colour. They represent typical offices for work with computer for up to two persons. These rooms used in the analysis are a models of real offices located at the Lodz University of Technology.

Rooms have only a single window with a minimized window area (1.2 m width and 1.2 m height) estimated based on the maximum UDI and the proper view of the external environment. During morning hours the west oriented room was lighted by a diffuse daylight while during afternoon for specific weather conditions also some direct light were available inside. Opposite situation appears for east oriented room. Because of small window's surface during cloudy days it will not provide a necessary access to the daylight. To deal with that problem the room was equipped with three LED luminaires. They are operating in two groups: one closest to the window acts as single lamp, two next are coupled. This solution gives an opportunity to implement a complex control systems described in the previous section.

Rooms are equipped with two light sensors each. Their height is on 0.8 m (working plane), first is located in the distance of 1.0 m from window, second 1.5 m deeper. It represents groups of lamps as well as spaces of office workers.

Furthermore, the analysis includes 3 occupancy variants. Scenarios are based on the three characteristics: occupancy, minimum illuminance required for work and control by the use of one or two light sensors. It was assumed, that for a single person only one sensor is required, while for two persons second sensor will be also introduced. Variants with the minimum required illuminance are listed in (Table 1). Additionally, assumption was made for scenario III, that work space closer to window does not require 500 lux to meet requirements for work with computer due to vicinity of window and additional light emitted by computer screen.

The software used for simulation of lighting conditions in rooms was DesignBuilder, which is developed on Energy Plus, therefore radiosity method was used to calculate effects of light.

Table 1

Office occupancy variants

Name	Occupancy	Minimum illuminance [lux]	
	[Persons]	Sensor 1	Sensor 2
Variant I	1	500	–
Variant II	2	500	500
Variant III	2	250	500

4. Results and discussion

In order to examine presented lighting control method, two types of control algorithm were taken into consideration. Conducted analysis showed that total lighting energy demand has different values for linear/off and stepped control. In general, power demand obtained for stepped control method is higher in each case, regardless of chosen occupancy variant. The major reason is that linear/off is idealized method, that enable to control lighting with perfect accuracy with amount of daylight illuminance actuated by sensor. On the other hand, stepped control is closer to typical office LED controls, which do not offer such precision and require more power to operate.

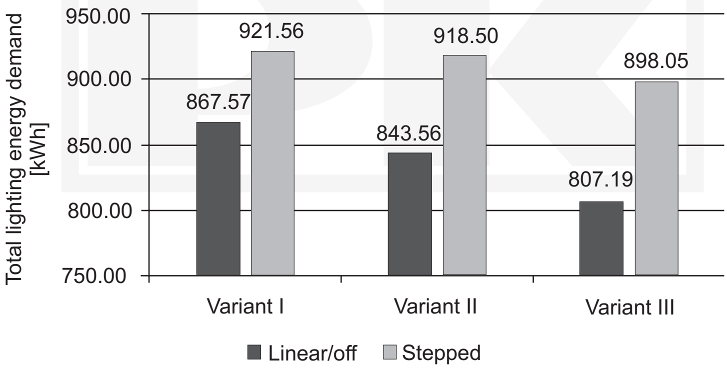

Fig. 2. Total lighting energy demand

Furthermore, it can be noted that lighting energy demand values obtained in calculation differ depending on the occupancy variant. Introduction of second light sensor and its implementation into control method allow for significant reduction in lighting energy. What is more, by lowering minimum required illuminance in the working plane closer to the window another energy savings can be noted. It is positive for both control methods, however for stepped control differences are much lower.

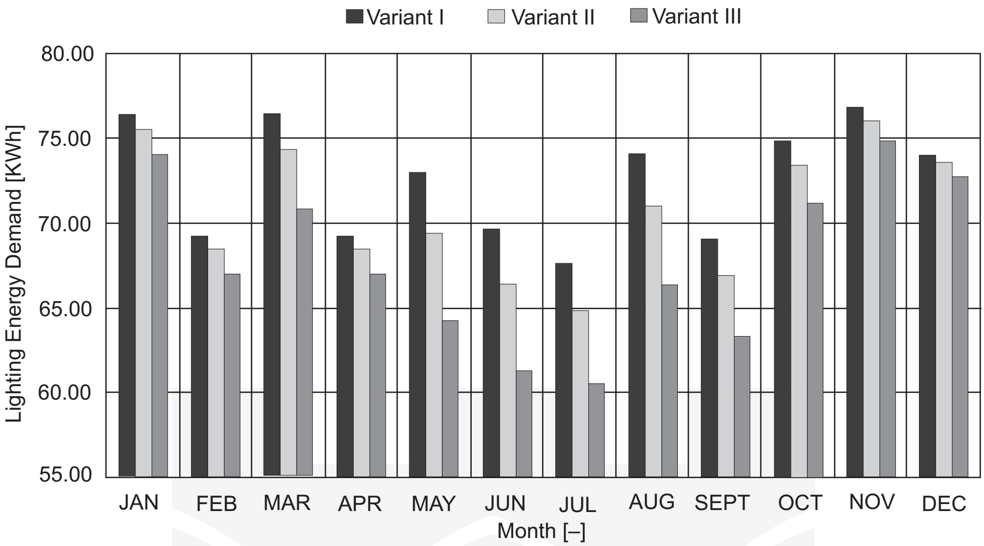

Fig. 3. Lighting energy demand for linear/off control

Final analysis was related to office rooms oriented on the east and west. Results (Fig. 4) show the daylight illuminances actuated by light sensors. It can be noted that east room receives slightly more daylight, especially in the summer period. Furthermore, sensor 1 located closer to the window acquire more daylight than one placed deeper, therefore controlling supplementary lighting only on the basis of one sensor may be unreliable and can lead to insufficiency of light in the further parts of the room.

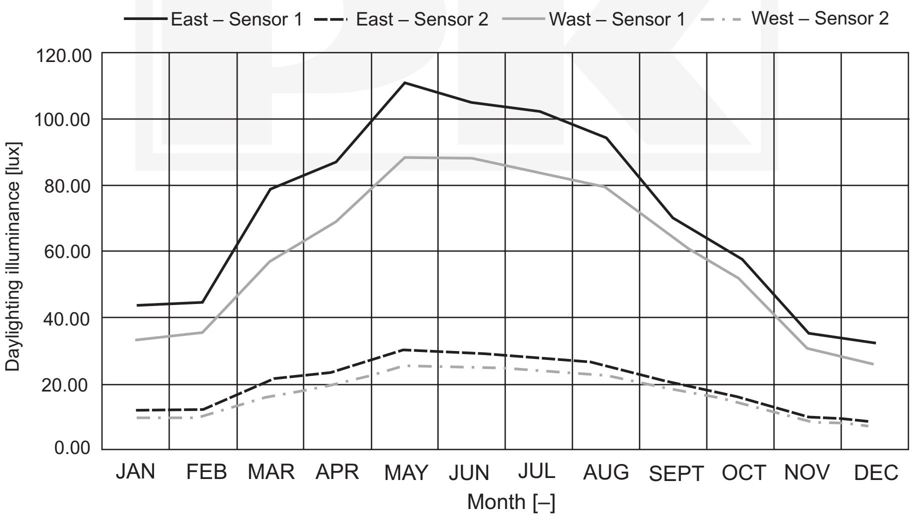

Fig. 4. Values of daylight illuminance for office rooms

5. Summary

Performed analysis showed that selection of an appropriate control strategy for supplementary lighting has a great impact on the quality of light in office room. Control method should include indoor daylight conditions, electric lighting should operate only when it is required to reach necessary illuminance level. Moreover, room occupancy scenario strongly influence control method as well as the positioning of sensors. For rooms with limited glazing area location of sensors should be carefully thought, their insufficient number or too large distance between them may lead to incorrect operation of electric lighting. Furthermore, the proper window orientation (even with minimized glazing area) may have positive effect on supplementary lighting system, decreasing its light intensity, therefore reducing energy costs.

Based on the obtained results it was possible to justify the effectiveness of lowly glazed office buildings considering energy efficiency of indoor lighting. Additionally, the most proper control strategy could be applied and analyzed taking into account irregular presence in the office.

Acknowledgements

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