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Lighting controls and energy savings potential in tropical zone

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Abstract

Reducing global energy consumption is a challenge to limit the rise in average earth temperature. The use of lighting controls in the building leads to energy savings. The objective of this study is to evaluate the energy savings potential in buildings in tropical zone due to lighting controls. The results of the simulations show that 47.6% of energy savings could be obtained with a dimming control and 33.3% with an on/off control in this office considered.

Keywords: *Dimming control, On/off control, Lighting controls, Energy savings, Tropical zone*

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1. Introduction

Energy is the basis of economic and social development. However, consumption of large amounts of this energy means a threat to men [1]. Reducing energy consumption is therefore a challenge that needs to be addressed for several reasons :

- at the environmental level : Greenhouse gas (GHG) emissions are the main cause of the rise in average earth temperature ;
- at the energy level : fossil fuels which represent by far the largest share of global energy consumption are limited and non-renewable.

All sectors of activity are concerned, especially the building sector. In 2010, 32% of final energy consumption was attributed to the building sector, as well as direct and indirect emissions amounting to 8.8 $GtCO_2$. Energy demand is expected to double and CO_2 emissions will increase by 50-150% by mid-century [2].

Lighting accounts for about 20% of global building electricity consumption. The latest IEA scenarios show the total electricity savings potential in building lighting by 2030 could be equivalent to all the electricity consumed in Africa in 2013 [3].

The use of the lighting control can lead to great energy savings in this sector [4]. These lighting control systems reduce energy consumption by reducing the operating time of the lamps depending on various factors such as occupancy, schedule, and availability of daylight [5].

In recent decades lighting control systems have been extensively studied. Sermin et al studied the amount of energy saved from an office with and without lighting control. The amount of energy saved is calculated over a year. The results show that 30% energy savings could be achieved under the climatic conditions of Turkey [6]. Danny et al. presented a study on the energy and light performances of lamps in a school building. Energy

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savings were determined for different levels of illumination based on lighting controls [7]. Fernandes et al. determined the annual energy savings by daylight for offices open in daylight on three floors. The savings from the lighting controls were 12.6 kWh/m^2 / year for the three floors [8].
These studies presented above are interested in buildings located in temperate zones. To our knowledge, there are no studies investigating the use of lighting control systems in buildings in tropical zones.
This study complements the knowledge gained on lighting controls studied in temperate zones. The objective of this work is to evaluate the energy performance of lighting control systems in a tropical office.

2. Methods

2.1. Lighting control systems

There are two types of lighting controls according to the daylight : on/off control and dimming control. The first type of control provides for either on or off state of the lamps and the second one allows to adjust the level of the luminous flux of the lamps according to the daylight.

2.1.1 on/off control

The principle of controlling the on/off control is based on the fact that when the light level of the day is above the desired level, the lamps are switched off and when the daylight level is below the desired level the lamps are switched on.
The particular problem of this lighting control is the rapid and frequent switching of lights on and off, especially in unstable weather conditions when the daylight levels are changing around the desired illumination. This can disturb occupants and reduce the lamp life [7].

2.1.2 dimming control

The high-frequency dimming control can vary the light output of the lamps in accordance with available daylight level. For this type of control light output being perfectly proportional to power consumed but the lamps cannot be dimmed to total extinction.

When the total illuminance on the working plane exceeds the desired illumination, the lamps will be dimmed to the minimum light output fraction (FL, min) with the corresponding power fraction (FP, min) [7].

These lighting control systems can also be divided in accordance with the control algorithm: closed-loop and open-loop systems.

A closed loop system detects the lux levels of the control zone which includes light from both daylight source and lamps. The change in the light levels of the lamps due to the availability of daylight is fed-back to the continuously control system. It can make necessary adjustments based on feedback. Thus it makes a closed loop [5].
The open loop system does not receive any feedback from the level of the electric lighting, it only detects available daylight levels. Based on the level of daylight, it sends a corresponding signal to the controller to provide the corresponding output [5].

2.2. Geometry and Light environment

In this study, an office is considered. The office perimeter space are (18 m x l0 m x 4 m high). The office is located in Dakar (latitude 14.73 °N, longitude -17.50 °W). To better evaluate the potential for energy savings with lighting controls, simulations are carried out for the day of 21 June. This day is the summer solstice, which is the longest day of the year, and corresponds to a maximum solar height.

The ceiling, floor and wall reflectance values are 0.5. The window is a single glazing with a light transmittance of 0.85. The window is square and is located to the east. No shading, furniture and other accessories are present in the office (Figure 1).

Two lighting controls: on/off and dimming control are studied. The objective of this work is to evaluate the energy performance of lighting control systems in a tropical office.
We used three simulation software that are coupled to perform the calculation of the levels of daylight illumination and the energy consumption of electric lighting.
The modeling of 3D building geometry was done under SKetchup, OpenStudio allows to import the building under the environment EnergyPlus. The finalization of the scenarios, the parameterization and the launch of the simulation were carried out using EnergyPlus.
EnergyPlus is a building simulation software developed by Lawrence Berkeley National Laboratory of the University of California [9]. The illumination threshold is 500 lux (standard NBN EN 12464-1 [10]) and the artificial lighting system will be used when the lighting level falls below this threshold. The sensor of the illumination is placed in the middle of the office at the height of 0.85 m. During the simulation of natural light, the installed lighting power density is 18 W/m^2 [11], according to the European standards on interior lighting of an office. The office operates from 7:00 am to 8:00 pm

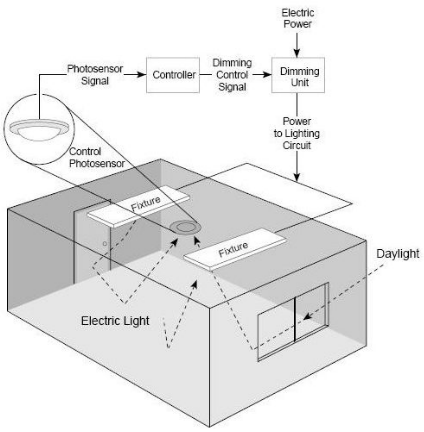

Figure 1. Geometry Buildings

3. Results

Figure 2. shows the evolution of illuminance as a function of time.

We can see that the illumination of daylight 500 lux is only reached over a few hours between 09:00 and 14:00. Electrical lighting is not required for this interval. At 10:00, illumination reaches the maximum 2000 lux which is lower than the glare threshold 2500 lux. For other hours, the illumination varies between 0 and 100 lux so the use of electric lighting is necessary to reach the 500 lux recommended in this office.

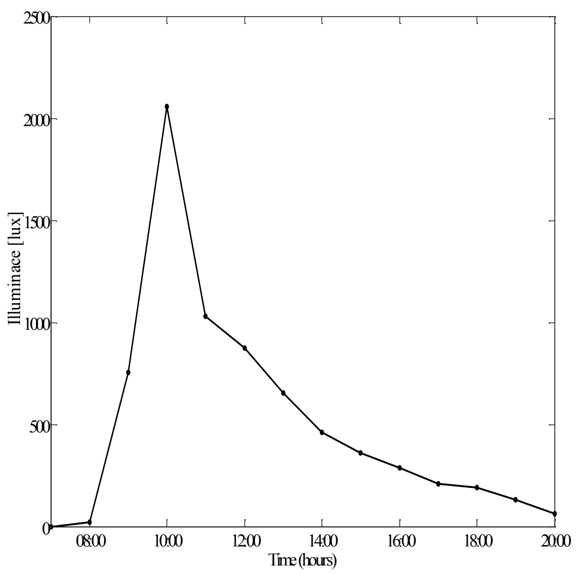

Figure 2. Illuminance of daylight on the work plane

Figure 3. shows the evolution of the energy consumption of the electric lighting with and without gradation control as a function of time.

Without the lighting control, we can see that the lamps are switched on regardless of the level of daylight illumination. This shows that the consumption of electrical energy (1.8 kWh) remains constant throughout the day.

For the dimming control, the lamps are switched on according to the available daylight level. The energy consumption of the lighting varies depending on the daylight illumination on the work plane. Between 9:00 and 14:00, the illumination 500 lux is reached by daylight. The lamps are dimmed to the minimum fraction of power FP_{min} = 20 %. For the other hours, the consumption of electric energy varies according to the daylight illumination. For the day of 21 June, 47.6 % of energy savings could be achieved with the dimming control.

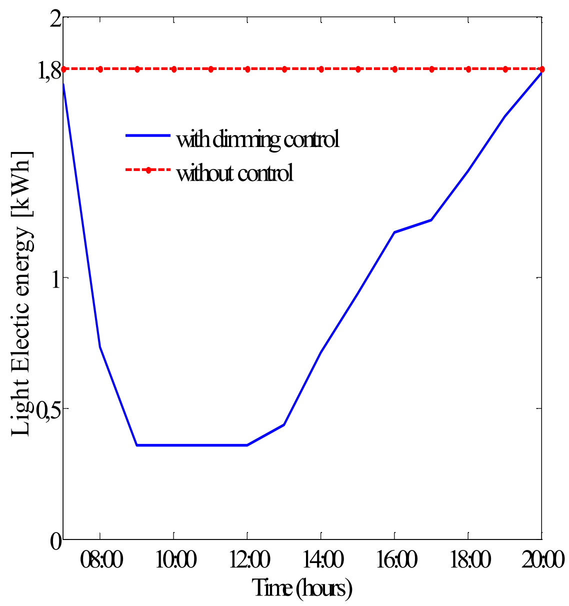

Figure 3. Electricity consumption of the lighting with dimming control

Figure 4. shows the energy consumption of the lighting without and with on/off control as a function of time. For the on/off control, the lamps are switched on if the daylight level is less than 500 lux. Between 9:00 and 14:00, the daylight illumination 500 lux is exceeded therefore the lamps are switched off. For the hours during which daylight illumination is less than 500 lux the lamps are switched on as shown in Figure 4. The on/off control gives energy savings of 33.3 %.

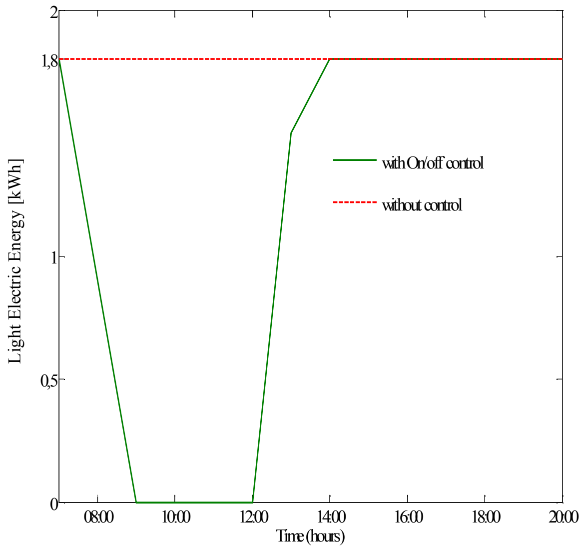

Figure 4. Electricity consumption of the lighting with on/off control

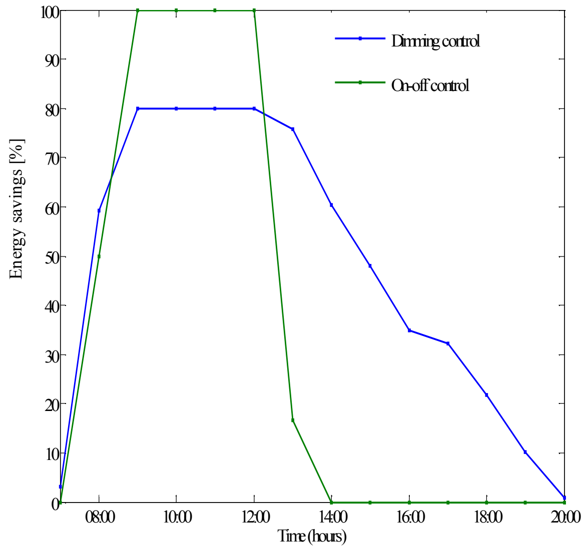

Figure 5. Energy savings with on/off and dimming control

Figure 5. shows the energy savings at different times of the day with the dimming and on/off control. Energy saving can be achieved 100% with the on/off control and 80% with the dimming control.
Between 09:00 and 14:00, with daylight illumination much higher than the desired values, the on/off control switch off the lamps, while for the dimming control the lamps are switched on for a minimum power fraction. Consequently, the savings achieved by the on/off control are greater than those achieved with the dimming control. In addition, both types of controls have reached their maximum energy savings over this range.
When the daylight is dimmed for the rest of the day, energy savings are reduced. For an illumination of daylight greater than 500 lux on the work plane, the on/off control tends to give more energy saving than the dimming control and vice versa when the illumination is lower at 500 lux illumination.
For the day of 21 June, a dimming control would give more energy saving than an on/off control.

4. Conclusion

We have presented in results the energy consumption of electric lighting with and without lighting controls and interesting results in some cases.
In our case study we are measured the performance of lighting controls in energy terms in tropical zone. We have shown that the energy consumption of electric lighting can be reduced by the use of lighting control. In tropical zone, the use of lighting control allows to save at least 33% of energy during the summer.

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