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Comparison of sensorless dimming control based on building modeling and solar power generation

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ABSTRACT

Artificial lighting in office buildings accounts for about 30% of the total building energy consumption. Lighting energy is important to reduce building energy consumption since artificial lighting typically has a relatively large energy conversion factor. Therefore, previous studies have proposed a dimming control using daylight. When applied dimming control, method based on building modeling does not need illuminance sensors. Thus, it can be applied to existing buildings that do not have illuminance sensors. However, this method does not accurately reflect real-time weather conditions. On the other hand, solar power generation from a PV (photovoltaic) panel reflects real-time weather conditions. The PV panel as the sensor improves the accuracy of dimming control by reflecting disturbance. Therefore, we compared and analyzed two types of sensorless dimming controls: those based on the building modeling and those that based on solar power generation using PV panels.

In terms of energy savings, we found that a dimming control based on building modeling is more effective than that based on solar power generation by about 6%. However, dimming control based on solar power generation minimizes the inconvenience to occupants and can also react to changes in solar radiation entering the building caused by dirty window.

1. Introduction

Buildings sector account for about 25% of the total non-industry usage in Korea [1,2], and 30% of a building energy is used for lighting [3–5]. Lighting in buildings has the largest primary energy conversion factor [6–8]; therefore, lighting must be considered when reducing energy consumption in buildings. LED dimming controls that use daylight entering the building are being studied [9–12]. Studies demonstrate that up to 70% of lighting energy savings can be achieved with dimming control [13–15]. To apply dimming control, illuminance sensors are needed to measure illuminance of daylight entering the building. In new buildings, sensors and equipment are easy to install by incorporating dimming control into the design during planning. For existing building, installing sensors and new equipment is not easy [16]. For this reason, dimming control methods using building modeling which does not need illuminance sensors are being developed [17–19]. However, simulation program do not accurately reflect real-time weather conditions around the building, causing discomfort for occupants [20,21]. Therefore, current research studies attempt to reduce the error of dimming control in simulations [20]. For existing buildings with PV systems, the PV panel can serve as the illuminance sensor. Using PV panels as the sensor improves the accuracy of dimming control in buildings, because they reflect the real-time weather conditions around the building, thereby maintaining the comfort of occupants.

Therefore, in this study, we compared dimming controls based on solar power generation using PV panels as sensors and those based on building modeling, in terms of energy consumption and occupant comfort.

2. Method

2.1. Building and artificial lighting system

For this study, we selected the office building at that Korea Institute of Energy Research in Daejeon, the Republic of Korea. This building faces south and is located at latitude N36° and longitude

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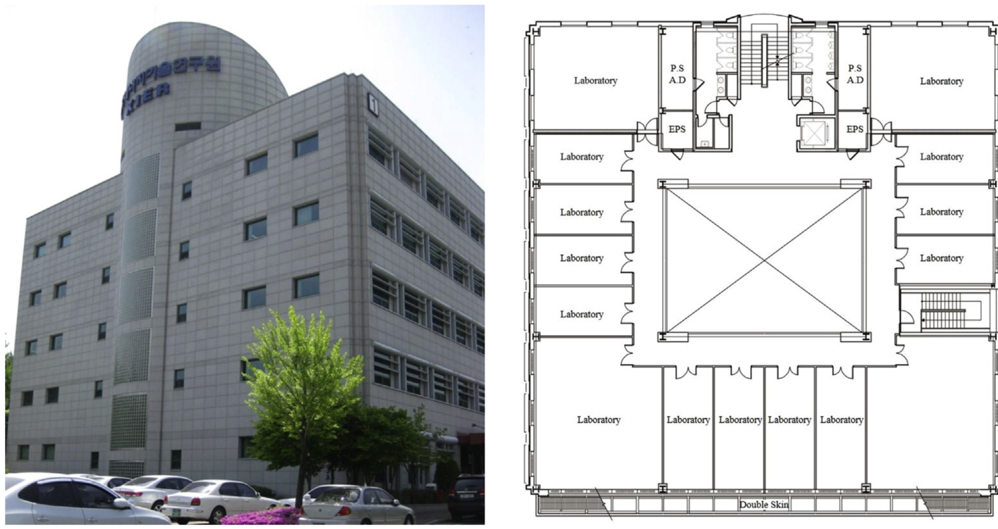

Fig. 1. Front view and typical floor plan of the building.

E127°. It has a total floor area of 6164.8 m^2 and a maximum height of 24.1 m. It has five floors above ground and one underground.

The building was designed to have a double skin on the south side and a central atrium to allow natural light in. However, daylight entering through the atrium is currently only used to light the hallways. In addition, the PV system installed on the roof is used only for emergency electric power. Fig. 1 shows the front view and the typical floor plan of the building.

Most lights in the building are fluorescent, and the average lighting power density of offices is about 9.3 W/m^2. Lights in two south offices and one northwest office on the fourth floor were replaced with LED for dimming control. The LED lights in the three offices had the following specifications: 40 W, 220 V, 3000 lm (luminous flux), 6000 K (color temperature), and 75 lm/W (luminous efficiency). The lighting power density per unit area is approximately 8.13 W/m^2. In this study, we compared sensorless dimming controls based on solar power generation with PV panels and based on building modeling using one of the offices facing south on the fourth floor. Fig. 2 shows the floor plan and the internal lights of the test office, which was 3.6 m wide, 10.6 m long, including the double skin, and 2.5 m high.

2.2. Building modeling

In this study, the building was modeled using EnergyPlus (Department of Energy, US). The lighting, equipment, and occupants in an office building affect its heating and cooling load. We quantified and applied these factors as input data for the simulation. Detailed operating patterns and elements causing internal heat were identified by monitoring the building operation and interviewing the facility manager. Input parameters for lighting and equipment were obtained by referring to the Input Output Reference of EnergyPlus [22]. We applied the Ideal Loads Air System of EnergyPlus because HVAC systems for heating and cooling are beyond the scope of this study. Nevertheless, considering that the lighting schedules depend on the occupancy rate of the office, we supposed that lights were turned on from 8:30 a.m. to 5:30 p.m., what are regular business hours. Fig 3 shows the modeling of the building using OpenStudio v8.0 of EnergyPlus. The lighting energy consumption was obtained by performing modeling of the building as shown in Fig. 3, and then, dimming control was applied to the test office. The conditions for dimming control are listed in Table 1.

Fig. 2. Floor plan and internal lights of the test office.

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