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Energy performance of direct expansion air handling unit in office buildings

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ABSTRACT

Buildings and their occupants generate a large amount of carbon emissions. In Korea, buildings contribute to about 30% of the total greenhouse gases emissions, and the proportion has been rapidly increasing to the level of the developed counties (i.e., more than 40% of the total emissions. A direct expansion air handling unit, of which a refrigerant is directly delivered to the heating and cooling, has a potential to save cooling and heating energy use, compared to water-based central air conditioning systems. The aim of this study is to compare heating and cooling energy uses of an identical office building but with different air conditioning systems, i.e. direct expansion and water-based air conditioning systems. Dynamic building energy simulations that reflect the actual use of a monitored building and its air handling unit operation have been conducted in this study. Simulation results show good agreement with the actual energy consumption obtained from the field measurements of the building. Our study quantifies the amount of cooling and heating energy uses saved by a direct expansion air handing unit and reveals reasons for this savings, i.e. higher energy efficiency of the unit and reduction in pump and fan energy demands.

1. Introduction

The building sector generates a large amount of greenhouse gas emissions and accounts for 30–40% of all primary energy in the world. In Korea, buildings contribute to about 30% of the total greenhouse gases emissions, and the proportion has been rapidly increasing to the level of the developed counties (i.e., more than 40% of the total emissions). Thus, energy reduction in buildings is a key factor in reducing national greenhouse gas emissions. Recently, the Korean government has set an environmental target to reduce CO_2 emissions in the building section by 29% by 2020. The understanding of energy use in buildings is thus a significant focus for study [1–6].

Key components of energy use in buildings are composed of building characteristics including the design and construction of the building and materials, the mechanical and electrical systems, and finally building occupants [7–11]. The influence of the building and system factors on energy use can be easily examined due to the rapid advance in building physics and simulation algorithms. Now, it becomes a common practice to utilize building simulation tools to design energy efficient building and system designs.

The energy efficiency of environmental control systems has been significantly increased. One example is a direct expansion air handing unit, of which a refrigerant is directly delivered to the heating and cooling coils. The direct expansion air handling unit has a potential to save cooling and heating energy use, as the pump energy use in the direct expansion air handling unit can be minimized, compared to water-based central air conditioning system [12,13].

It is evident even to non-technical and scientific people but also confirmed by recent studies [6,8] show that occupants can change the energy use of similar buildings by a factor of 2–3 and the wide variation in energy consumption of identical building were mainly due to the behaviour of occupants, such as different occupancy patterns and temperature settings. Still, there is a gap in knowledge on the relationship between the occupant factors and the energy use of the direct expansion air handling unit.

The aim of this study is to compare heating and cooling energy uses of an identical office building but with different air conditioning systems, i.e. direct expansion and water-based air conditioning systems. The focus is to reveal the influence of the occupant use of buildings on heating and cooling energy consumption of an office building equipped with direct expansion air handling units, and to

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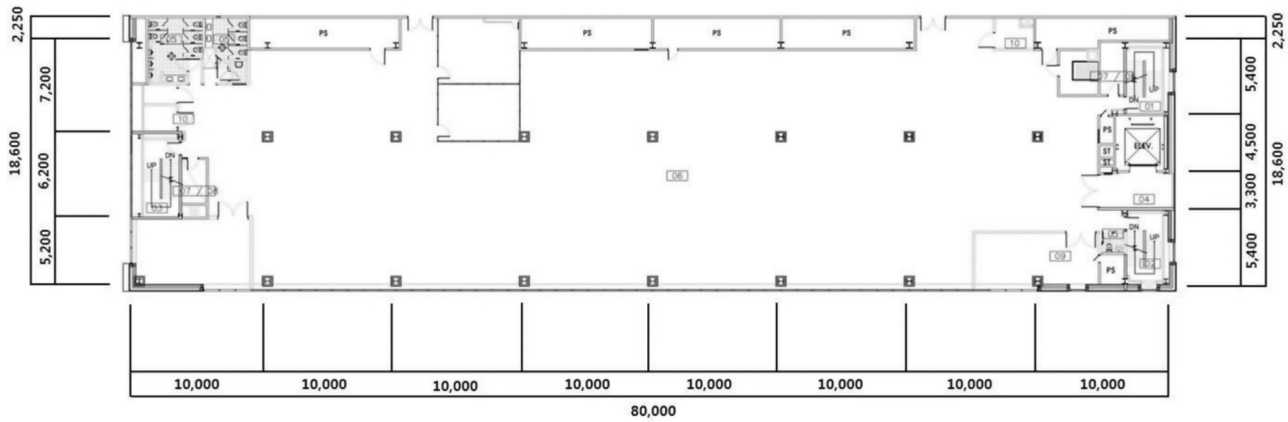

Fig. 1. Plan of a case study office.

investigate the interrelationship between the building energy consumption and occupant factors such as the density of occupants, the pattern of occupancy, the use of lighting and equipment, and the changes in indoor setting temperatures for heating and cooling.

2. Methods

2.1. A case study office

A four story office building in Suwon, Korea has been selected in this study (Fig. 1). The office is 1588 m^2 in floor area and the main facade faces southeast. Thermal properties of construction materials are given Table 1. The building is well insulated. For instance, the external wall with its thickness of 238 mm consists of linear board, arson gypsum board, waterproof gypsum board, mineral wool, tile and aluminum panel. The *U*-value of the external wall is 0.307 W/m^2 K, which is well below the minimum standard of the Korean government regulation.

Two direct-expansion air handling units (AHU) were located in the AHU room on the office floor (Table 2). Heating and cooling coils of each AHU was connected to two electric heat pumps (EHP). The nominal capacity of the EHP is 69.6 kW for cooling and 78.4 kW for heating. Each AHU had two propeller-type fans with the airflow rate of 201 m^3/min. The AHU had been operated by the central building management system and the setting temperature was 23 °C for the heating season and 26 °C for the cooling season.

2.2. Investigation of occupant factors and electric energy consumption

Internal heat gains from occupants, lighting, and equipment is an important element that influences cooling and heating loads of a building. In this study the number, clothing level and activity of office occupants and the use of lighting, computers, monitors, and printers were monitored at an hour internal for two week days. Portable electricity meters were used to measure the actual use of electricity of computers, monitors, and printers. This was useful to reflect the electricity reduction during stand-by modes.

Hourly electric energy consumption from two AHUs was obtained from a digital power meter, Accura-2500^{TM}, which measured and recorded electric power. Accura-2500^{TM} is Class 0.5S of IEC 62053-22, which indicates the percentage error is less than ±0.5%. The sum of electric energy consumption by two AHUs was available at an hour interval. This included energy consumption by supply and return fans and electric heat pump. Measured electric energy consumption of the AHU was compared with the simulated results. The Building Management System (BMS) data also included the information on the operation of the AHU such as the opening ratio of an outdoor air damper and indoor setting temperatures. Those data were used as input values for energy simulation.

2.3. Energy simulation

Two energy models were created using EnergyPlus. Two models shared the same office building as shown in Fig. 2. The difference was the HVAC system, i.e. one model was equipped with the direct expansion AHU while another had the water-based AHU. EnergyPlus was chosen to evaluate annual energy consumption of the building. Fig. 2 shows the EnergyPlus modelling of the office. Each AHU located at the two ends of the office served the half of the office and thermal zoning of EnergyPlus modelling was made accordingly. The office was divided into 14 thermal zones including non air-conditioned zones.

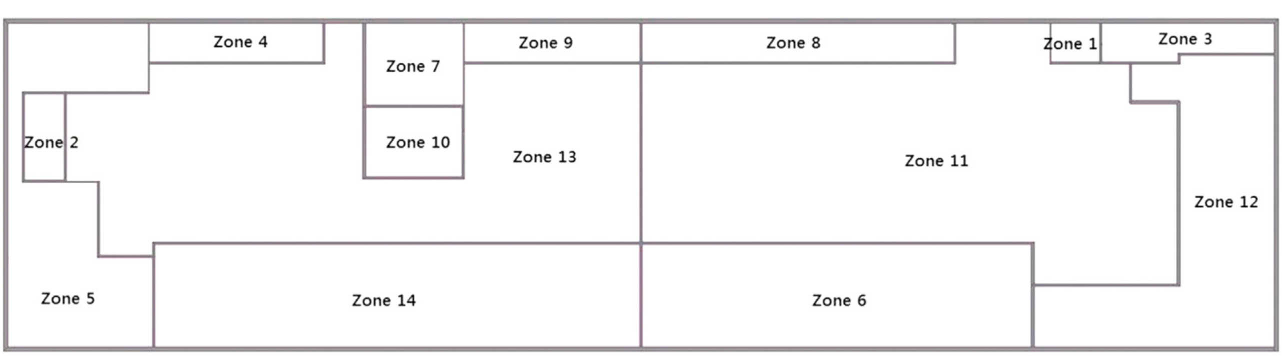

Fig. 2. EnergyPlus modelling of the office.