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Heiselberg, Per Kvols

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Hybrid ventilation control strategies to reduce energy consumption in a small office building

Haolia Rahman, Hojong Hwang, Hwataik Han*
Mechanical System Engineering, Faculty of Engineering, Kookmin University, Seongbukgu, Seoul, South Korea, 136-702
hhan@kookmin.ac.kr

ABSTRACT
Weather condition is greatly influencing energy consumption of HVAC system. This paper investigates hybrid ventilation to develop control strategies to optimize HVAC system operation in summer season. The control strategy is combining natural ventilation and mechanical system to cool the occupied indoor spaces. The fraction of window opening is determined based on outdoor temperature when natural ventilation is applied. Mechanical ventilation works in case if airflow rate of natural ventilation is insufficient. A small office building is simulated using Energy plus with energy management system (EMS) feature based on Seoul weather data for one week of the summer period. The investigation includes comparison of energy consumption between conventional HVAC system and hybrid ventilation system. The result shows that the hybrid ventilation system able to reduce around 31-44% of a conventional HVAC system.

Keywords: Hybrid ventilation, natural ventilation, window opening.

1. Introduction

For many centuries, natural ventilation has been applied in a shelter to control indoor temperature, humidity, light availability and air quality[1]. However, it is difficult to quantify natural ventilation due to many parameters whose uncertainty varies significantly[2]. To date, when natural ventilation is insufficient, hybrid ventilation which integrating natural ventilation and mechanical systems along with intelligent controls is used to achieve comfort[3,4,5]. Despite all this, indoor thermal comfort has trade-off with energy consumption which increasingly attractive for academic researcher and industrial. Liping[6] has investigated kind of ventilation mode of open window and mixed-mode trough the effect of HVAC energy saving. The result show that HVAC energy savings of 17-48% using mixed mode ventilation during summer for various climates.

In the summer session, it is obvious that total building energy consumption can be reduced by controlling the combination of natural ventilation and mechanical system to achieve a satisfaction of thermal comfort. This paper is a preliminary study to develop control strategies of hybrid

ventilation in summer season for typical small office buildings. The HVAC energy consumption performance will be analyzed using simulation model.

2. Methodology

The building is a one-story office building[7] with 511 m^2 of total floor area. The floor-to-floor height and floor-to-ceiling height are 3.96 m and 2.74 m respectively as shown in Fig 1. The area has three thermal zones with glazing façade toward to the north, east and west. The window wall ratio (WWR) is 40% of all façade. The multizone VAV system with single-speed Direct-Expansion (DX) is used as HVAC system of the building simulation. Energy plus software is used to calculate the ventilation combination and energy consumption coupled with Energy Management System (EMS) feature which enable to control mode of HVAC system and windows opening. The occupant density[8] is 4 people/100m^2 and the schedule refers to the building occupant pattern[9,10]. The load densities given by light and electronic equipment are 10.9 W/m^2 and 14.4 W/m^2 respectively. The weather condition used Seoul weather data in summer period of 5-11 August.

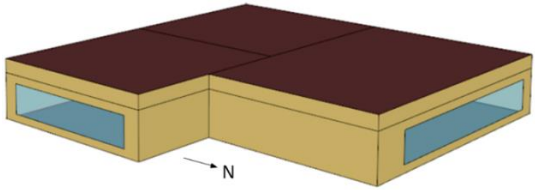

Fig. 1. Small office building model

The temperature of outdoor air used for cooling the space should be under 25°C. The required airflow for cooling is calculated using (1) with $q_{cond.}$ as conductive heat gain and q_{total} as the summation of internal and other heat sources. ΔT is represents temperature difference between outdoor and set temperature.

$$Q_{cool} = \frac{q_{cond.}+q_{total}}{\rho C_p \Delta T} \qquad (1)$$

The first control strategy is to simulate the building with a fraction of window opening linearly controlled by outdoor temperature as illustrated in Fig. 2. The window opening fraction is determined based on airflow required to cool the room as calculated in (1). The window is fully closed when outdoor temperature is below 20°C and open linearly until 25°C. The windows opening fraction is calculated using (2). While windows are open at any fraction, the HVAC system is totally off. If outside temperature is over than 25 °C windows are closed, then HVAC system starts to run. The temperature set point of the

HVAC system is applied based on 80 % acceptable adaptive thermal comfort of ASHRAE standard 55[11]. The next control strategy is mechanical ventilation activated at constant speed 1.9 m^3/s when windows is open at any time. The windows opening fraction is similar to the first strategy rules. This strategy is enable mix-mode ventilation when natural ventilation is insufficient.

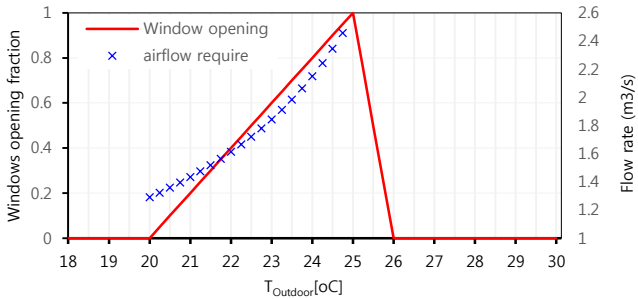

Fig. 2. Window opening fraction with respond to outdoor temperature and airflow require to cool the zones

$$Windows\ \ fraction\ \ = 1 + \{(T_{outside} - 25)\ \times\ 0.2\} \qquad (2)$$

3. Result and discussion

The outdoor temperature profile is relatively diverse in one week of August, while occupant pattern of weekdays is similar as well as cooling set point in all days as illustrated hourly in Fig. 3. Fig. 4 shows the indoor air temperature distribution varying hourly at different strategies. At the first strategy, temperature peak point on weekdays is 26,9°C. However, it is in the range of 80% acceptability for naturally conditioned spaces in ASHREA Standard 55 based on mean monthly outdoor. The average of indoor air temperature in the days is higher than the average of air temperature without any control strategy. This is due to the fact that the only outdoor temperature which is able to control windows opening, it may the ventilation given by window opening is not aligned with internal heat gains. Another factor such as wind speed and direction may have taken into account when natural ventilation is inadequate to flush indoor air. On the third day of weekdays, outdoor temperature is below 25°C it is so profitable for saving HVAC energy. However, the next study must be taken into account to prevent over ventilating. On the second strategy, temperature profile is superposing the first strategy. In some point, when outside temperature range of 20-25°C, it has slightly low peak points of indoor temperature compare to the first strategy due to additional cooler air supply served by mechanical ventilation.

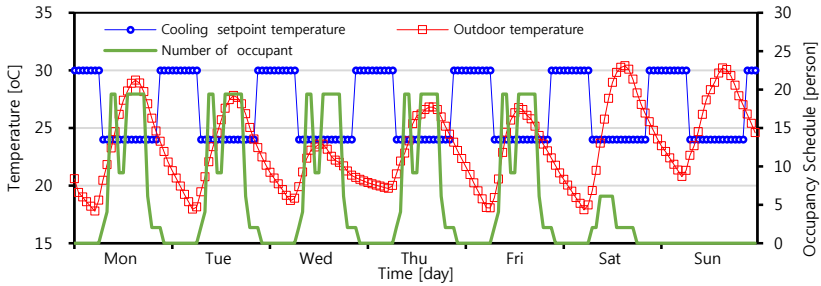

Fig. 3. Outdoor temperature, cooling set point and occupancy schedule

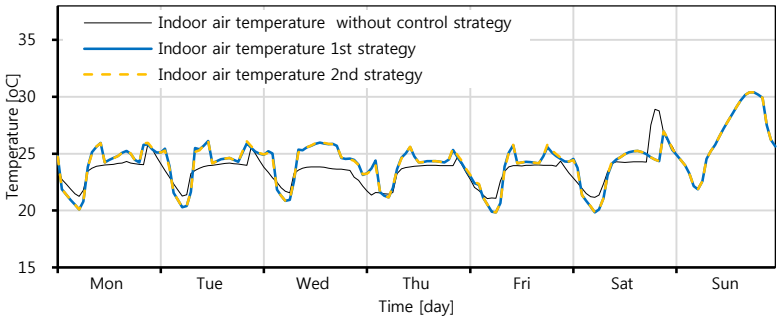

Fig. 4. Indoor air temperature of each strategy

The comparison of total HVAC energy consumption can be seen in Fig. 5. The energy consumption reduced by applying first control strategy is 44%. Compared to the second control strategy which has 31% of energy saving this consume too much energy by fan when temperature in range of 20-25°C.

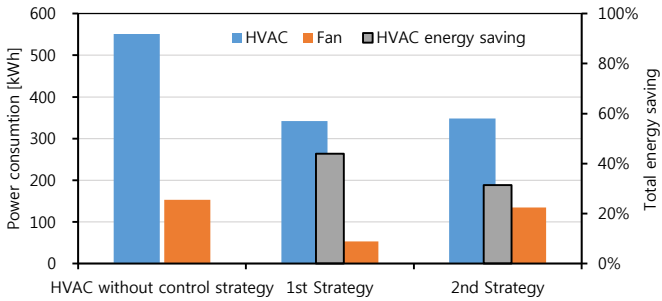

Fig. 5. Energy consumption of each strategy

4. Conclusion

This preliminary study simulates the small office building with the aim to compare HVAC energy saving of two proposed control strategy with existing HVAC system. The first control strategy is combining the natural ventilation and mechanical system in accordance with window opening base on outdoor temperature. The second strategy is employing the mechanical ventilation to support the natural ventilation. The results show that energy saving reach to 44% and 31% of first and second strategy respectively. When applying both control strategy, Indoor air temperature is still in range of 80% acceptability for naturally conditioned spaces in ASHREA Standard 55. However, Indoor air temperature, wind speed, wind direction and CO_2 concentration must take into account for further study to control the ventilation.

Acknowledgements

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