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Optimal operation condition division with profit and losses analysis of energy recovery ventilator

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ABSTRACT

Energy Recovery Ventilator (ERV) is one of the efficient ways to reduce fresh air load. However, there is a major concern, which energy recovery cannot trade off ERV's fan power consumption, even with causing counteraction to precool (preheat) fresh air in winter (summer). In this study, energy recovery is quantitatively evaluated during cooling season and heating seasons for an office building in Chongqing by employing TRNSYS. Based on the ERV's fan power consumption and energy saving which is converted to chiller's electricity consumption, outdoor fresh air is divided into four zones (zone I, zone II, zone III and zone IV) on a psychometric chart (ID chart). The results show that ERV which only operates in profit zones (zone III and zone IV) can increase electricity saving by 65.23% and reduce operating time by 31.18% than that operating throughout heating and cooling seasons. The proposed operation condition zones method can help identify profit pattern, minimize the energy consumption of ERV and air conditioning system.

1. Introduction

Heating, ventilation and air conditioning (HVAC) system operation energy consumption is a major concern for building energy consumption. About 20–40% of the overall energy consumption of HVAC system is fresh air load [1], especially in the hot and humid or cold zone. Energy recovery ventilator is proposed as an effective solution to decrease fresh air load.

Previous research indicated that ERV has a great energy saving potential in HVAC system. Rasouli pointed out that an ERV device might reduce heating energy and cooling energy annual usage up to 40–60% and 20% respectively, while ERV's performance depends on parameters such as climate and building design maintenance. Both of effectiveness and capital cost are the most sensitive aspects to ERV's payback period [2,3]. Juodis [4] reported that the expected heat recovery effectiveness has to be calculated in view of the local climate and the ratio heat gain/loss. Hence, it was not enough to evaluate ERV's performance under rating conditions. Zhou [5] investigated ERV's performance with various weather and indoor temperature set-points in Beijing and Shanghai. The result showed that there were possibilities of precooling fresh air in winter and preheating in summer. Zhang and Niu [6] found that energy recovery could save up by 58% fresh air load, which was much higher than only sensible energy recovery. With the different indoor temperature and humidity set points, annual energy requirements were classified into six zones according to the weather data to describe different energy requirements. Applied theory and research on ERV's operation have been kept active over the recent years. Roulet [7] measured thirteen units' real energy recovery ventilators and obtained the results that the global efficiency of three worst cases among them were less than 10%, and the recovery system used more energy than it saved. Liu [8] studied the performance of ERV under different operation conditions. It was found that powerful fan, reasonable fresh air change rates and proper operation period should be carefully considered. Ke [9] evaluated annual composition fresh air's energy consumption for per unitary flow rated by testing data and gave the applicability of ERV for different operation conditions. Laverge [10] showed that ERV increase the pressure drop and fan power consumption, ERV had no clear advantage than natural ventilation in moderate climate, low specific power fan was needed to save operating energy cost. Fouih [11] reported that adequacy of ERV depends on the building types, loads and device characteristics. Sensitive analysis was undertaken to investigate the ERV's fan power and efficiency. Rasouli [12] found that

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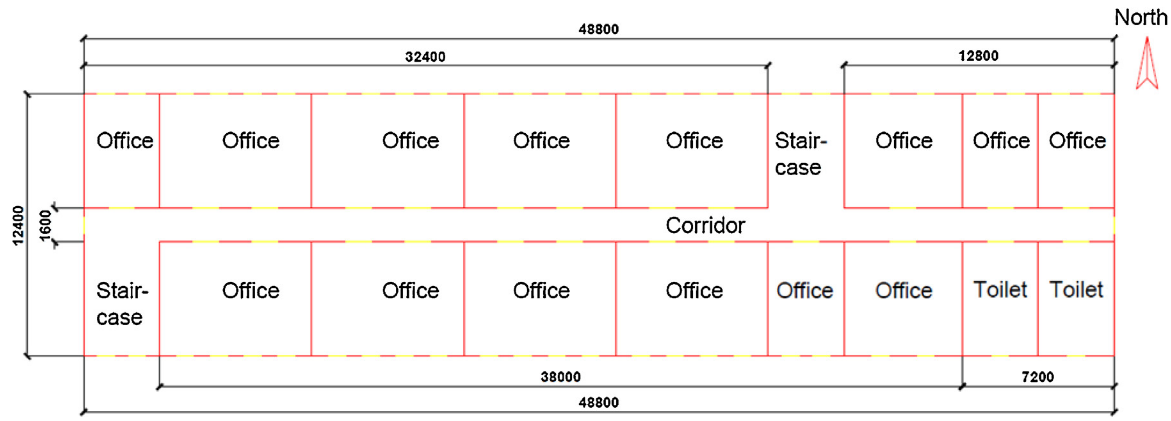

Fig. 1. Architectural plans for the office building.

ERV might increase cooling and heating consumption, and an optimum control strategy depending on latent to sensible effectiveness ration was developed. Fernández-Seara et al. [13] conducted an experiment on the influence of fresh air temperature, the exhaust air relative humidity and the air flow rated to ERV performance. San [14] and Simonson et al. [15] set up mathematic model to study the influence of the operating conditions.

The above reference studies have provided valuable information on ERV design, energy recovery influence parameters and ERV's performance influence parameters. However, for the existing building ERV devices, their operational efficiency is not clear. Therefore, the aim of this study is to find optimal operating conditions for the existing office building with ERV system. An economic quantitative analysis is implemented with the full operating condition and optimal operation. This is crucial because the ERV's objective is to save energy as much as possible. The situation that pre-cooled fresh air in winter and pre-heated in summer should be avoided. In addition, energy recovered by ERV should compensate ERV fan power consumption. Optimum operation zones are defined to ensure that profit is larger than losses during recovery process. For operator and maintenance workers, the premise of ensuring system function at the optimum status is to figure out the optimum operating condition quickly.

In this paper, TRNSYS [16] will be used as an energy simulation tool to provide indoor and outdoor air state parameters for an office building with ERV devices located in Chongqing, China. First, the specific energy recovery including sensible heat and latent heat is output by TRNSYS during heating and cooling seasons. Second, heat recovery fan power and electricity that transferred from ERV saving are compared to determine four operating conditions (zone I, zone II, zone III and zone IV) of the outdoor air parameters on the psychometric chart, then the optimum operating conditions are defined. It is expected that the optimum operating condition provides valuable operation strategy for local designers and terminal users who expected energy saving.

2. Methodology

2.1. Building description

A five-floor office building with a total floor area of 3025 m^2 in Chongqing was selected. The dimensions of the building, 48.8 m (L) × 12.4 m (W) × 4 m (H) are shown in Fig. 1.

Detailed information of the building is given in Table 1.

The schedule was from 9:00 to 17:00 during Monday to Friday. Occupancy and equipment usage rate are shown in Fig. 2 [17]. The desired indoor temperature from 9:00 to 17:00 during working time is listed in Table 1. Because of the inertia of the building, it will take a certain time to reach the desired temperature after the first people arrived at work and switched on the air conditioner.

In accordance with China design code "Heating ventilation and air conditioning of civil buildings" [18], the minimum fresh air volume per person for office building shall meet 30 m^3/h. However, human activities, the type of work and indoor residence time should be considered. The minimum fresh air volume for this building model case was set at 44 m^3/h/p. Total fresh air flow rate of the building was 13,532.21 m^3/h, and the density of air is 1.2 kg/m^3. Hence, the mass flow rate was 16,238.25 kg/h.

2.2. Meteorological data

Typical Meteorological Year (TMY2 weather data format) contains typical hourly weather data required for yearly building energy analysis. TRNSYS interpolates the hourly weather data for time steps by hour. Fig. 3 illustrates the variation of outdoor air temperature and humidity ratio throughout the year [3]. In general, it is hot and wet in summer and cold wet in winter in Chongqing, which is suitable for the application of energy (both sensible and latent) heat recovery device.

2.3. Energy recovery ventilator model and validation

Energy wheel heat recovery device was used with sensible and latent effectiveness of 0.6 and 0.3, respectively. The two values for this study were set for energy effectiveness at the lower limit value. The subsequent analysis is specific for the extreme adverse effectiveness situation, which provides insight into the energy saving when the performance of the ERV is poor, thus providing a

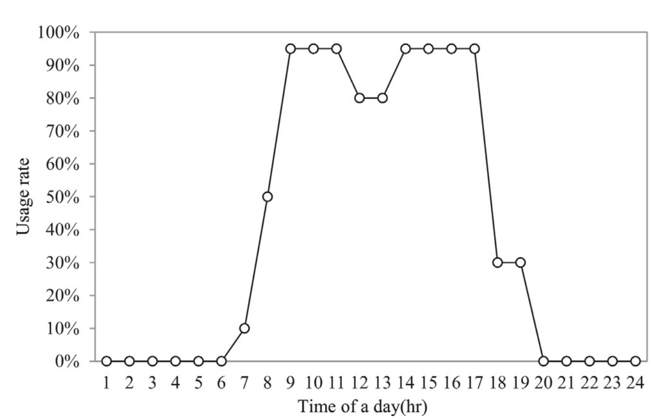

Fig. 2. Schedule for lighting, occupancy, and equipment from Monday to Friday.