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A new operating strategy for economizer dampers of VAV system

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Abstract

The paper proposes a new operating strategy for the outdoor, discharge, and recirculation air dampers of the economizer in VAV system, *called split-signal damper control strategy*. The strategy controls the outdoor air by only one damper while keeping the remaining dampers full open. The discharge or recirculation air damper is modulated to control the amount of outdoor air introduced into the system while keeping the two remaining dampers full open. Since at least two dampers are always kept fully open during the occupied times, the strategy can provide a minimum static pressure drop in economizer dampers and results in minimum energy use in return and supply fans. An additional advantage is that the proposed strategy prevents reverse airflow through the discharge air damper of a VAV system that uses a volume matching control strategy. The proposed strategy along with the existing strategies such as the three-coupled dampers used in most existing system and the two-coupled dampers are evaluated on an existing system using 1-year long measured data set, along with an economizer damper model developed and validated in this paper. The simulation results show that the annual energy savings in supply and return fans of an existing system, compared to the traditional strategy of three-coupled dampers, are 12% and 5%, respectively.

Keywords: VAV system; Air side economizer; Damper control strategy; Air handling unit

1. Introduction

A significant portion of energy consumed in buildings is attributed to fan energy usage by HVAC systems. This fan provides the airflow rate required for meeting the thermal and ventilation loads and adequate pressure to cover all pressure drops in air ducts and dampers. In a VAV system, under low load, the fan air flow rate is decreased by way of using a variable speed drive to control the fan speed. In this regards, the supply duct static pressure sensor is normally used to control the fan speed. A control strategy could be also used on the supply air temperature and then the fan airflow rate to meet the required thermal load can be varied to control fan energy use. Lower supply air temperature causes lower fan airflow rates and results in lower fan energy use. Much has been researched on investigating the optimal supply air temperature to minimize total energy use including that for the fan such as [1–3]. In addition, the fan energy consumption could decrease by decreasing the pressure drop in air ducts and dampers. The pressure drop in air ducts, considered in the design stage, is limited by design conditions. However, during the system operation, the pressure drop through dampers could be considered by applying a certain strategy and that is to always have the operating dampers as fully open as possible. When considering VAV box dampers, significant fan energy savings can be realized if the duct static pressure set point is reset such that at least one of the VAV boxes remains open [4,5]. The same logic can be applied on economizer dampers in such a way as to minimize the pressure drop in those dampers by maintaining at least one or two of three economizer dampers full open while always providing the required control range of outdoor air. Therefore, the paper focuses on developing a robust operating strategy for economizer dampers in order to minimize the pressure drop required for ensuring a proper operation of the economizer dampers, and thereby decreasing the supply and return fan energy use. This could be achieved by always keeping the operating dampers as fully open as possible.

Most existing HVAC systems employing an air-side economizer using the traditional damper control strategy that links the discharge, recirculation, and outdoor air dampers. In terms of providing the required outdoor air control and achieving minimum fan energy, the traditional strategy may not yield the best solution. In previous studies, the performance of traditional strategy was investigated by Krakow et al. [6] and

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Seem et al. [7,8]. Krakow et al. found that the traditional strategy employing an economizer with nonlinear dampers requires higher fan energy than one with linear dampers. They proposed a new strategy in which only the outdoor and recirculation dampers were linked while the discharge damper always remained fully open. It was concluded that a system with this strategy required slightly less fan power. Seem et al. also proposed a new strategy in which only the discharge and recirculation dampers were linked while the outdoor damper always remained full open. They found that the strategy prevents air from entering the system through the discharge damper. However, the effects of the proposed strategy on fan energy use were not investigated. This phenomenon of reversed airflow rate through the discharge air damper has been noted in the literature [8–10]. This can have a negative impact on indoor air quality and thus, it should be taken into consideration when the proposed strategy is developed.

In this paper, a new damper control strategy called split-signal control strategy is proposed. This strategy provides the required outdoor air control with a minimum pressure drop in the economizer damper and resulting minimum supply and return fan energy use. Since the strategy keeps always two dampers full open during the occupied period and controls outdoor air using only one damper, the pressure drop in economizer dampers and both return and supply fan energy use are decreased. Another advantage of the proposed strategy is that it also prevents air from entering the system through the discharge damper.

To understand the performance of the investigated control damper strategies, a model that simulates the airflow rates and pressures in the AHU as a function of damper positions is developed. One-year of monitored data gathered on an existing VAV system were used to validate the developed models and evaluate the investigated strategies.

The paper is organized as follows. The economizer damper model is presented first. Next, the damper control strategy developed in this paper is discussed along with other existing strategies. This is followed by studying the performance of the strategies investigated in this paper. The simulation results made on an existing VAV system are presented and discussed. Finally, conclusions from this study are presented.

2. Economizer damper model

To evaluate the performance of the investigated control damper strategies, a model that simulates the airflow rates and pressures is developed. It should be noted that the objective is to make meaningful comparative evaluations of the various damper control strategies not to have a very accurate model for airflow and pressures calculations. Thus, some simplifications assumptions are made.

The model is based on Detailed Damper Model/Valve Model presented in HVAC 2 Toolkit [11] and originally from Ref. [12], in which the pressure drop across the damper (ΔP) is related to the mass flow rate ($\dot{m}$) by a flow resistance coefficient:

$$\Delta P = K\dot{m}^2 \tag{1}$$

where the flow resistance coefficient K varies with the damper position θ and is given [11]:

$$K = K'\left(\frac{W_{\mathrm{f}}}{[(1-\lambda)\theta-\lambda]^2} + (1-W_{\mathrm{f}})\lambda^{2(\theta-1)}\right) = K' f(\theta) \tag{2}$$

The damper position θ is presented as a fraction of fully open position. The damper is fully open when $\theta = 1$ and the damper is closed when $\theta = 0$. The resistance when the damper is fully open (K') is a design parameter for damper selection. The first term within the bracket of Eq. (2) is the resistance of a linear damper and the second term is that for an exponential damper. W_{f} is a weighting factor that combines theses two terms to specify the damper flow characteristics. The term λ is a leakage parameter and is defined as the ratio of flow through closed damper to flow through an open damper at fixed pressure differential.

The HVAC 2 toolkit model is specified for one damper arrangement. However, in the economizer arrangement as shown in Fig. 1, three dampers are worked together to control the amount of the outdoor air that depends then on the three

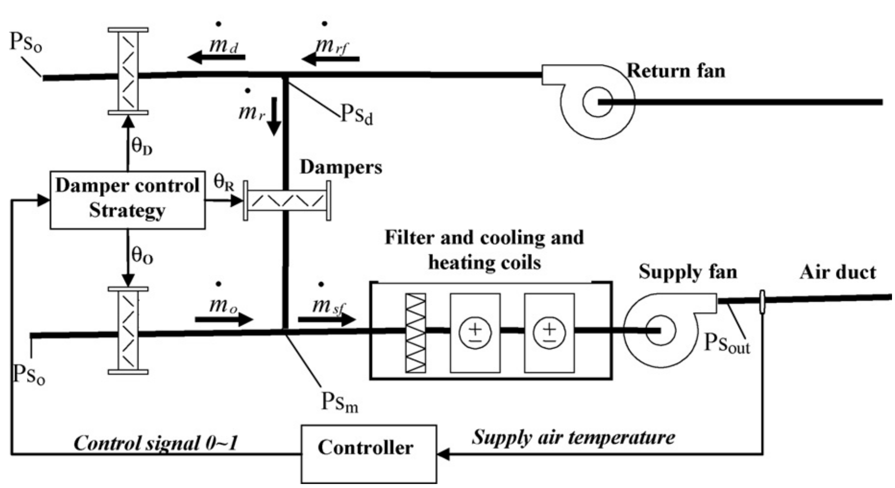

Fig. 1. Schematic diagram of a variable air volume AHU with the key variables used.