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Experimental study on a duty ratio fuzzy control method for fan-coil units

Zhao Tianyi [a,*], Zhang Jili [a], Sun Dexing [b]

[a] School of Civil Engineering, Faculty of Infrastructure Engineering, Dalian University of Technology, Dalian, China
[b] School of Municipal & Environmental Engineering, Harbin Institute of Technology, Harbin, China

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ABSTRACT

This paper presents a novel energy-efficiency control method for a fan-coil unit, the duty ratio fuzzy control method (DRFCM), which employs the concept of duty ratio on the electric valve control to fully utilize the cooling and dehumidifying capacity of a fan-coil unit when the control valve is closed. By means of mamdani-type fuzzy rules and functioning-fuzzy-subset inference methods, the duty ratio of valve and fan speed signals are decided according to the deviation and deviation changes of the room temperature. This paper adopts a two-water-pipe FCU system with a three-fan speed control and an electric water valve on-off control as test objects to verify the application effect of DRFCM. Program controllers and software tools are employed to conduct DRFCM. The conventional control method is applied by individual FCU controllers. Experimental results show that DRFCM could obtain at least 30% energy savings (not including chilled pump power savings) over the conventional control method. A preferable room temperature control effect could be achieved as well.

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1. Introduction

Fan-coil units (FCU) are widely used in central air-conditioning systems, especially in office buildings and hotel buildings in China. By 2005, statistical data show that the sales volume of FCUs had exceeded two million units in China [1]. Because FCUs have played a very important role in air-conditioning terminal systems, particularly in reference to FCU related works, most studies or patents have been presented in recent years. Investigated issues include novel product development, optimal design methods of FCU systems [2,3], modeling and measurement of FCU coil performance [4,5], energy consumption metering of FCU systems [6], indoor air quality and thermal comfort in FCU-served air-conditioning space [7–9].

Although a single FCU generally uses low amounts of electric power, the total employed hours and quantity of FCUs are large enough that power usage may not be ignored. Therefore, the total electric power consumption of an FCU system is considered to be the main part of the electric power consumption of a building's HVAC system. Therefore, optimal operation regulation schemes or control strategies for FCUs are efficient ways to contribute a large amount of energy savings in a building's HVAC system. Moreover, the space temperature control effect and thermal comfort degree can be improved as well.

Chen [10] presented a novel skin-load control method using the application of a radiant temperature sensor to solve the control issues for perimeter zone FCU systems.

Ke [11] compared the operational performance of constant air volume (CAV) type FCUs to variable air volume (VAV) type FCUs experimentally. The results showed that the VAV-type FCU has greater energy saving potential. Ke [12] presented an innovative, low-temperature, differential FCU control method, which integrated the consideration of both the energy saving aspect and indoor air quality.

Some researchers focused on the combination of a fuzzy control approach with FCU energy-efficiency control. Jiang [13] developed an FCU fuzzy controller, which used fuzzy logic to regulate fan speed and the three-way valve bypass ratio of the FCU system. Ghiaus [14] adopted a T-S type fuzzy model to describe FCU operational performance and then presented a model-based control method for typical FCUs. A comparative work between PID control and fuzzy control on FCU control applications was conducted. The advantage of the fuzzy control approach was shown, especially in terms of energy saving potential and indoor thermal comfort.

Compared with other studies of FCUs, few reports have emphasized FCU optimal-control strategies; this is especially true for two-water-pipe FCU systems with three-fan speed control and electric water valve on-off control (shown in Fig. 1), which is widely applied in China. Most FCUs adopt a thermostat or an independent controller to adjust fan speed and on-off signaling of the electric water valve, using input parameters that are read from wall modules, such as seasonal mode, space temperature, space temperature set point and

* Corresponding author.
E-mail address: sebastian.zhao@gmail.com (Z. Tianyi).

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