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ORIGINAL ARTICLE

Fuzzy logic control of air-conditioning system in residential buildings

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Abstract There has been a rising concern in reducing the energy consumption in building. Heating ventilation and air condition system is the biggest consumer of energy in building. In this study, fuzzy logic control of the air conditioning system of building for efficient energy operation and comfortable environment is investigated. A theoretical model of the fan coil unit (FCU) and the heat transfer between air and coolant fluid is derived. The controlled variables are the room temperature and relative humidity and control consequents are the percentage of chilled and hot water flow rates at summer and the percentage of hot water and steam injected flow rates at winter. A computer simulation has been conducted and fuzzy control results are compared with that of conventional Proportional-Integral-Derivative control. It was found that the proposed control strategy satisfies the space load and at the same time to achieve the comfort zone, as defined by the ASHRAE code. Meanwhile PID control fails to adjust the room temperature at part-load operations. It has been demonstrated that fuzzy controller operation is more efficient and consumes less energy than PID control.

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1. Introduction

The analysis of the performance and operational strategies of HVAC systems becomes very important for the effective usage of energy [26]. The studies on the parameters of HVAC systems as temperature, volume and control strategies in the last 50 years were shown that the high performance of HVAC systems could be obtained by minimizing energy consumption. The different approaches to control systems for indoor building environments can be roughly classified into the following categories: conventional methods, and computational Intelligence techniques, [1–18]. Soyguder et al. [1] studied the classical PID control of HVAC system having two zones with different properties. The parameters of PID were obtained to minimize the system error in their study; however, the steady-state error was not totally eliminated. Although these controllers improved the situation, improper choice of the gains in the PID controller could make the whole system unstable. Therefore, designers resorted to optimal [1–5], predictive, or adaptive control techniques [6–9]. In intelligent control systems, no mathematical model of the system is required. Recently, the practical applications of intelligent control for Heating Ventilation and Air Conditioning (HVAC) systems have been discussed with the goal being performance improvement over classical control [10–18]. The techniques include

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Nomenclature

B_h	portion of hot water valve opening, %	OS	outside air ratio
B_s	portion of steam valve opening, %	Q	coil cooling capacity, kW
B_w	portion of chilled water valve opening, %	Q_R	room cooling load, kW
C_p, C_v	specific heats, kJ/kg K	RLH	room latent heat, kW
E_H	absolute humidity error, g_w/kg_a	RSH	room sensible heat, kW
E_T	room temperature error, °C	T	temperature, K
h_{fg}	latent heat of water, kJ/kg_w	t	temperature, °C
h_a	air specific enthalpy, kJ/kg	t_{db}	air dry-bulb temperature, °C
K_d	coefficient of derivative control	t_{wb}	air wet-bulb temperature, °C
K_i	coefficient of Integral control	W_a	humidity ratio, kg $_{vapor}$/kg $_{dry\ air}$
K_p	coefficient of proportional control	ρ_a	density of air, kg/m^3
m°	mass flow rate, kg/s	ρ_w	density of water, kg/m^3
m_{WR}	water mass flow rate ratio, kg/s	τ	time, s
M_{ar}	air mass flow rate ratio, kg/s		

expert systems, neural networks, fuzzy logic, and genetic algorithm.

A cooling and dehumidifying coil is an essential component of an air-conditioning system. Coil air bypass and chilled water flow control are common means for controlling space temperature in air-conditioning systems during part load operation. Many studies have been reported in the literature for the model of cooling coil [19–27]. Meanwhile, very little work is published regarding the performance of chilled water-cooling coils at part-load operations. In this case, the cooling coils suffer from significant fluctuations in their performance with large decrease in coil effectiveness.

The objective of this work was to synthesize a fuzzy-logic controller for the air conditioning system in residential buildings to control both the room temperature and humidity ratio. The performance of the proposed control is compared to that of a PID control during full and part load operations in both summer and winter.

2. System model

The Arab Academy Student Housing is considered as a case study for building management system. It is in Alexandria, Egypt at Latitude of 31.2. This building consists of five floors

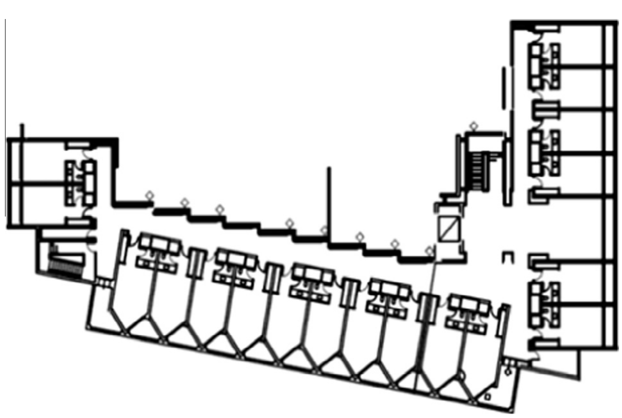

Figure 1 The five similar floors of academy building.

(zones) each floor has eighteen rooms, three paths and one hall as shown in Fig. 1. This building is similar to hotels, resorts, and banks. These buildings have zones with different setting points and sensible and heating loads. Central air-conditioning system consists of:

1. Two chillers, each has 100 ton refrigeration capacity with cooling tower to supply the cooled water to the cooling coils.
2. Boiler to supply the hot water to heating coils and to supply steam to the steam humidifier.
3. In each floor, there are 18 fan-coil units (FCU), one for each room.
   The fan-coil unit compact option simulates a four-pipe fan coil unit with hot-water heating-coil, chilled-water cooling-coil, and an outside-air mixer. The fan-coil units are zone equipment units which are assembled from other components. Fan coils contain an outdoor air mixer, a fan, a simple heating-coil and a cooling-coil. The fan-coil unit is connected to a hot-water loop (demand side) through its hot-water coil and to a chilled-water loop (demand side) through its cooling-coil. The unit is controlled to meet the zone heating or cooling demand as shown in Fig. 2.
4. In the addition of the FCU, there is a steam humidifier in each room to control the humidity ratio in winter.

2.1. Room heat balance

Rate of change of room temperature is equal to the temperature change due to the heat extracted from the space and the rate of change of temperature due to room sensible heat.

$$M \cdot C_v \cdot dT_r/d\tau = \text{RSH} - m_a \cdot C_p \cdot (T_r - T_s) \quad (1)$$

Similarly the rate of change of moisture in the room is equal to the moisture removed from the room and the room moisture load.

$$M \cdot h_{fg} \cdot dw_r/dd\tau = \text{RLH} - m_a \cdot h_{fg} \cdot (w_r - w_s) \quad (2)$$

where $M = \rho{\cdot}V$, T_s and w_s are the supply air temperature and humidity ratio, respectively.

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