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ORIGINAL ARTICLE

Management of air-conditioning systems in residential buildings by using fuzzy logic

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Abstract There has been a rising concern in reducing the energy consumption in buildings. Heating, ventilation and air-conditioning system is the biggest consumer of energy in buildings. In this study, management of the air-conditioning system of a building for efficient energy operation and comfortable environment is investigated. The strategy used in this work depends on classifying the rooms to three different groups: very important rooms, important rooms and normal rooms. The total mass flow rate is divided between all rooms by certain percentage using a fuzzy-logic system to get the optimum performance for each room. The suggested Building Management System (BMS) was found capable of keeping errors in both temperature and humidity within the acceptable limits at different operating conditions. The BMS can save the chilled/hot water flow rate and the cooling/heating capacity of rooms.

1. Introduction

Building Management System (BMS) is a high-technology system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as air handling, fan-coil unit, cooling plant systems, lighting, power systems, fire systems, and security systems. The objective of a BMS is to achieve more efficient building operation at reduced labor and energy costs and to provide a safer and more comfortable working environment for building occupants [1–6]. Modern buildings and their heating, ventilating and air-conditioning (HVAC) systems are the biggest consumers of energy [7–10]. These buildings are required to be more energy efficient, while considering an ever-increasing demand for better indoor air quality, performance and environmental issues. Building automation systems have a hierarchical structure consisting of field, automation and management layers [10]. Energy management is achieved by means of schemes such as the duty-cycling of loads to conserve energy; peak load management to regulate total power consumption during peak hours; scheduled start/stop of building HVAC systems at the beginning and end of each day; and real-time control of building systems in response to occupancy detection [11–17]. However, most of existing supervisory and optimal control strategies are either too mathematical or lacking generality.

HVAC system must be complemented with an efficient control scheme to maintain comfort under any load conditions. Efficient control will also reduce energy use by keeping the process variables (temperature, humidity, etc.) to their set points. Fuzzy logic control (FLC) is designed on the basis of

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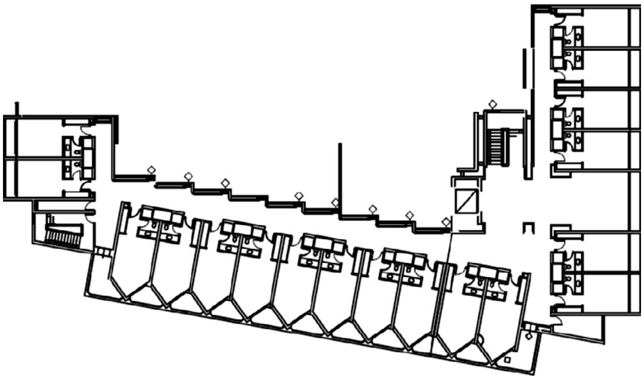

Figure 1 The five similar floors of academy building.

human experience, which means that a mathematical model is not required for controlling a system. Fuzzy logic-based control schemes were implemented for many industrial applications and HVAC systems [18–24]. Huang et al. [18] presented a robust model predictive control for improving the robustness of the temperature control of air-conditioning systems by taking account of the process gain and time-delay uncertainties as well as the constraints on the control input. This strategy was evaluated in a dynamic simulation environment of a typical AHU VAV system. Intelligent controllers, optimized by the use of evolutionary algorithms were developed for the control of the subsystems of an intelligent building [19]. A fuzzy controller for the regulation of indoor temperature of a discontinuously occupied building is compared with a classical controller by Fraisse et al. [22]. Kolokotsa et al. [23] designed and installed a fuzzy logic controller of indoor thermal and visual comfort as well as indoor air quality, using the European Installation Bus (EIB) system through interconnection with Matlab. It was found that fuzzy logic control was not applied to the management of air conditioning systems of buildings which have several rooms.

The objective of this paper was to investigate the management of air-conditioning systems in buildings using fuzzy logic technique. A building management strategy is suggested in an attempt to improve energy efficiency and occupant comfort for different loading conditions. The proposed strategy is taking into consideration any fault in temperature or flow rate either in chilled water during summer or in hot water during winter. The study is limited to the application in residential buildings.

2. Case study

In this study, 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. The building consists of five floors (zones). Each floor has eighteen rooms, three paths and one hall as shown in Fig. 1.

The central air-conditioning system consists of the following:

1. Two chillers, each has 100 ton refrigeration capacity with cooling tower to supply the cooled water to the cooling coils.
2. A 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.

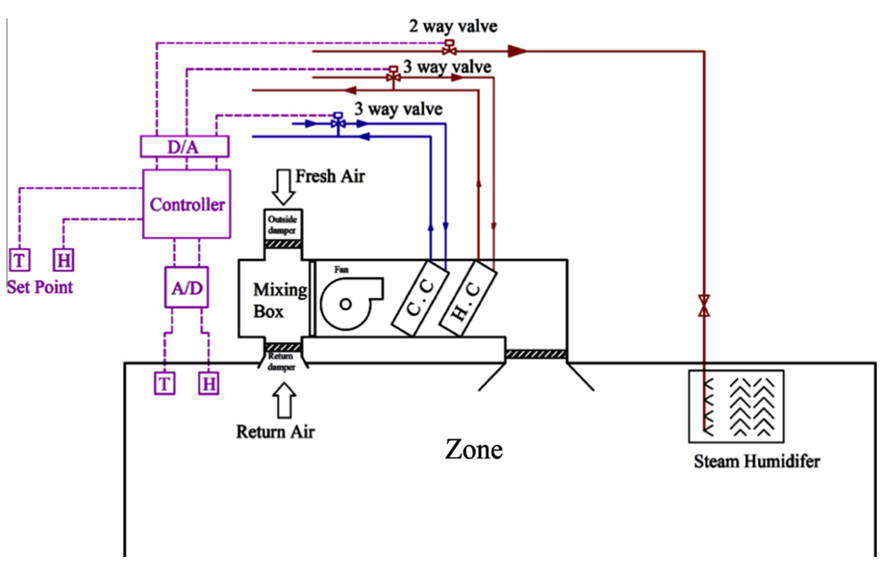

Figure 2 Schematic of control FCU with control signal.