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A review of recent developments and technological advancements of variable-air-volume (VAV) air-conditioning systems

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A B S T R A C T

This study reviewed VAV systems modeling and simulations, control strategies and optimization tools, the airflow characteristics of VAV systems, some common VAV systems' faults, detection and diagnosis, energy usage and analysis, and the current applications of variable air volume (VAV) air-conditioning systems. VAV system modeling is very complex as it involves complex structures and parameters a result of which has led to lack of models that combine both the AHU and building with all the required parameters.

The most common controllers used in VAV systems are the PID controllers. We saw that supply air temperature and the flow rate of supply air are the best parameters that can be optimized in a VAV system as they greatly minimize energy consumption. Genetic algorithms have good robustness, and can be easily parallelized. However, they suffer from shortcomings such as slow convergence rates under some conditions, and have difficulty in adjustment of algorithms since there are no rules for determining the number of individuals in populations. FLCs boost of advantages such as less or minimum overshoot, oscillation and power consumption compared to conventional PID controllers, can be used in MIMO systems, and they do not require models as they can control non-linear processes.

Airflow control in VAV systems can be achieved through controlling static pressure and position of the damper. Literature survey shows that balancing and distribution of airflow in VAV air-conditioning systems can be considered to be one of the main challenging areas of research concerning VAV system control. Most methods used today for detecting and diagnosing faults are hybrid. These are superior to the conventional methods of FDD.

In conclusion, VAV air-conditioning systems are the most energy efficient systems in use today. Despite of their current strengths, VAV systems energy saving potential can still be improved.
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1. Introduction

The term variable air volume (VAV) first came into existence in the mid to late 1960s after studies by Urban [1]. After the world energy crisis of 1970s, these systems gained popularity in the United Kingdom (UK) and other countries across Europe in early 1980s as part of the efforts by engineers to come up with energy efficient air conditioning systems [2].This was necessary due to the cost of energy that was increasing at that time and has continued to increase up to date. VAV systems by definition are simply air conditioning (AC) systems that are designed to promote existence of constant temperature in a conditioned space by varying the volume of air supplied to the conditioned space instead of varying the temperature of supplied air [3].Therefore, these systems vary supply air volume at a constant temperature in order to meet the demand caused by the changing heat load in the conditioned space [4]. Generally, VAV systems can be broadly classified into two categories as chilled water VAV air conditioning systems and direct expansion (DX) cooling coil VAV air conditioning systems.

The basic components of a VAV air-conditioning system are: a central air handling unit (AHU) with a variable speed supply fan (can vary volume of air), coils used for heating or cooling, controls, filters, mixing box, return or relief fan, air supply duct, VAV terminal unit (device) connected to thermostats and supply diffusers and return duct or plenum.

VAV systems work on the principle of opening or closing mechanical dampers or by modulating the airflow through mixing boxes powered by VAV fans as loads in various conditioned spaces of a building. For instance, if a given conditioned space requires more cooling, the damper to that space is opened wider to increase the inflow of cold air until the required temperature is achieved. During the opening of the damper, there is pressure drop in the supply duct which signals the supply fan to increase air delivery. On the other hand, if an area is too cool and requires temperature rise, the damper is gradually closed so as to reduce the inflow volume of cold air. This is usually applied in combination with variable-speed drives (VSDs). The result is decrease in air flow which results in cutting down fan power needed thus saving energy [5]. In a further effort to reduce the energy requirements, most VAV systems utilize the return air in order to cut down the power requirement and energy use when the outdoor temperature is higher than exhaust air temperature [6].

These systems have several advantages over other HVAC systems [7–11]. These include, less fan capacity compared to constant volume systems since in VAV systems only the needed air is used; greater flexibility with respect to varying loads; improved indoor environment, the system can incorporate an economizer to utilize the outside air to provide cooling at times when temperature is appropriate; reduced size of the main ducts since there is no simultaneous coincidence of the maximum cooling/heating load demand in all spaces [12].

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