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In-situ implementation and validation of a CO_2-based adaptive demand-controlled ventilation strategy in a multi-zone office building

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A B S T R A C T

This paper presents the in-situ implementation and validation of a CO_2-based adaptive demand-controlled ventilation (DCV) strategy in a super high-rise building in Hong Kong. The adaptive DCV strategy employs a dynamic multi-zone ventilation equation for multi-zone air-conditioning systems, in which a CO_2-based dynamic occupancy detection scheme is used for online occupancy detection. This strategy is implemented in an independent Intelligent Building Management and Integration platform (IBmanager), which communicates with the main station of the Building Management System (BMS) through a communication protocol and interface. The performance of this DCV strategy is practically tested and validated by comparing with that of the original fixed outdoor air flow rate control strategy used in site. The implementation architecture and test results including energy and environmental performances represented. Since the accuracy and reliability of the major measurement instrumentations affect the actual performance of the DCV strategy significantly, the commissioning and calibration of major measurement instrumentations are presented as well.

1. Introduction

In modern commercial and office buildings, multi-zone VAV air-conditioning systems are commonly used. Since the outdoor ventilation air flow is one of the key factors affecting the indoor air quality (IAQ) and system energy consumption, outdoor ventilation control is therefore one of the major control functions in these air-conditioning systems. In the last two decades, many outdoor ventilation control strategies with different degrees of promise have been proposed [1–6]. Among them, the constant outdoor air flow rate control and the maximum return CO_2 concentration control are two basic strategies [7–9]. Both strategies are simply enough and can be easily implemented in practice. However, they may result in either excessive energy consumption or poor IAQ due to the varied indoor thermal and pollution sources of different ventilation zones.

To ensure the acceptable IAQ with minimized energy consumption, demand-controlled ventilation (DCV) strategy as an alternative approach, has been widely studied for outdoor ventilation control [1,10,11]. The DCV strategy optimizes the outdoor ventilation air flow rate based on the number of occupancy in air-conditioned indoor spaces and the ventilation demands related to occupied areas. ASHRAE Standard [12] proposed a multiple-zone equation to determine the designed outdoor ventilation air flow rate to meet the environment requirement with reduced energy consumption by considering unvitiated outdoor air in the over-ventilated zones. Kettler [13] described how to calculate the amount of outdoor ventilation air required from an air-handling unit (AHU) serving multiple spaces for system design purposes. When it was used for ventilation control, the number of occupancy needs to be pre-determined. Mumma and Bolin [14] reported the energy performance of the zone-level ventilation control by using the multiple-zone method presented in ASHRAE Standard [15]. In their study, the supply air flow to the critical zone was controlled to reduce the ratio of the required outdoor ventilation air to the supply air. This strategy was tested in the design conditions and off-design conditions. The results showed that over-ventilation phenomena still happened in some ventilated zones. Nassif and Kajl [16] presented a supply CO_2-based DCV strategy to reduce the system energy consumption while maintaining the acceptable indoor IAQ in each zone in multi-zone air-conditioning systems. The multiple-zone equation presented in ASHRAE Standard [15] was also used in this strategy. The supply CO_2 concentration set point was determined on the basis of the steady state mass balance. It is worthy noticing that the above DCV strategies were mainly developed based on the prescribed occupancy schedules and load conditions. A steady state mass balance was also assumed. However, the outdoor ventilation air flow rate determined by these

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