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ScienceDirect

Energy Procedia 143 (2017) 283–288

Energy Procedia

www.elsevier.com/locate/procedia

World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference, WES-CUE 2017, 19–21 July 2017, Singapore

Energy saving potential of an air treatment system for improved building indoor air quality in Singapore

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Abstract

The design of air conditioning mechanical ventilation (ACMV) system affects the building energy performance and the indoor pollutant removal process. The present study aims to reduce energy consumption on ACMV systems by employing a renewable air treatment system (ATS). The ATS is able to purify the recirculated air through the ozone-based oxidation process and air scrubbing devices. The air purification performance of primary equipment in the ATS has been studied in order to demonstrate the capability to remove indoor air pollutants. Due to the air purification process, the ATS allows a reduced supply of outdoor-air translating to a lower cooling load. In addition, the reduced outdoor-air fraction results in an improved chiller efficiency. Therefore, the ATS is capable of achieving marked energy savings because of the reduced cooling load for conditioning outdoor airflow. The proposed ATS is particular adept during a period when Singapore faces periodic bad haze situations. Activating the ATS while decreasing the outdoor-air fraction can be an attractive solution. Based on Singapore climatic condition, an energy consumption analysis has been carried out to estimate the energy saving potential of the proposed ATS with varying outdoor-air intake. The "plug-and-play" ATS can be easily integrated into any new or existing ACMV systems to realize immediate improvement in indoor air quality and building energy efficiency.

Peer-review under responsibility of the scientific committee of the World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference.

Keywords: Air-conditioning; Building energy consumption; Cooling load; Ventilation; Indoor air quality.

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1876-6102
Peer-review under responsibility of the scientific committee of the World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference.
10.1016/j.egypro.2017.12.685

1. Introduction

In modern buildings, indoor air pollutants coming from building materials are of great concern. Volatile organic compounds (VOCs) is one of the major indoor airborne pollutants since some VOCs are related to the sick-building syndrome [1]. Cheng et al. [2] compared the characteristics of VOC emissions from several building materials. Sidheswaran et al. [3] proposed to purify the air by use the activated carbon fiber filters in the air-conditioning system.

The design of air-conditioning mechanical ventilation (ACMV) system influences the building energy consumption and the indoor pollutant removal process [4]. Several researchers have proposed alternative cooling and ventilation strategies for reducing energy consumption as well as improving indoor air quality [5]. Rackes et al. [6] provides guidelines and performance labelling for buildings in tropical climates. Lee et al. [7] proposed a combined system by incorporating the dedicated outdoor air ventilation (DV) into the dry cooling (DC) air-conditioning system. The DCDV was demonstrated to achieve an annual energy saving by 54% over CAV system with reheat. Hughes et al. [8] investigated an energy recovery system for natural ventilation based on heat pipe technology. The system was able to reduce the energy consumption loads in domestic buildings.

The conventional ACMV system usually relies on outdoor air ventilation to dilute and remove the indoor air contaminants. The outdoor air may sometimes contain high levels of pollutants. As a result, the conventional ventilation process using unhealthy outdoor air can deteriorate the indoor air quality. The present work aims to develop an air treatment system combining the air purification process, and investigate the energy saving potentials in tropical climate such as Singapore.

2. Description of the air treatment system

Fig. 1 presents an overview of the schematic diagram of the proposed air treatment system (ATS). The proposed ATS consists of three sub-systems, namely, (i) energy-efficient oxygen production sub-system; (ii) ozone-based oxidation treatment sub-system; and (iii) air scrubbing sub-system. The detailed description of each component is provided as follows.

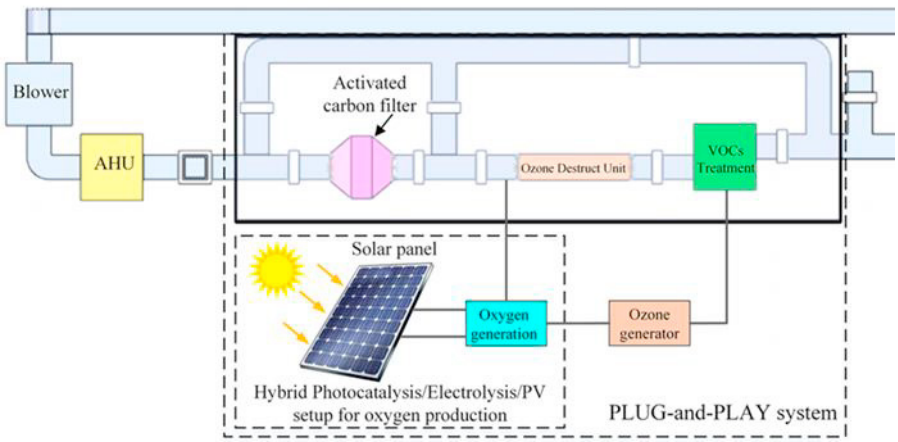

Fig. 1. Schematic of the air treatment system.