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RESEARCH ARTICLE

Comparative research on different air conditioning systems for residential buildings

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Abstract
Two types of air conditioning (AC) systems generally exist, namely, centralized and decentralized AC systems. This study focuses on three actual engineering projects of residential communities where centralized AC systems are adopted. The applicability of centralized AC systems in residential buildings is discussed and analyzed. In addition, the key elements that lead to different building energy consumptions and system efficiencies between centralized and decentralized AC systems in residential buildings are investigated. This study shows that in residential buildings, at the point where the centralized feature of the system meets the decentralized feature of users' load, the problems of high energy consumption and low energy efficiency could easily occur.

1. Introduction

As a typical representation of a decentralized air conditioning (AC) system, the split-type air conditioner has been used in a majority of residential buildings in China for a long time. Recently, centralized AC systems have also appeared in residential buildings, and they are approved and supported by specific government policies (Zhang et al., 2009). Centralized AC systems reflect advanced and efficient energy usage. They consume less energy with better service; therefore, the development of future indoor environment control in residential buildings should take centralized AC systems into consideration (Aste et al., 2013). One of the main advantages of centralized AC systems is that they can satisfy the cooling requirements for multiple buildings at the same time (Chow et al., 2004b). In addition, they use refrigeration equipment with large capacity and high efficiency. Centralized AC systems also require lower power compared with split AC systems (Chow et al., 2004c; Shimoda et al., 2008; Soederman, 2007; Jordi et al., 2013). Moreover, for the usage of renewable energy sources, such as underground water or seawater, influenced by the type of cooling source, centralized cooling systems are simpler and less expensive (Rezaie

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and Rosen, 2012; Chow et al., 2004a). From an energy usage point of view and considering urban landscape, centralized AC systems are effective and should be promoted.

However, in some respects, decentralized AC systems are more advantageous than centralized systems. With a decentralized AC system, users have greater flexibility in controlling the AC terminals according to their requirements. Under this type of control method, the cooling energy supplied by the AC system would be reduced effectively (Li and Jiang, 2009). Moreover, no distribution system exists in decentralized AC systems, which means that the total energy consumption would not include the consumption of fans or pumps. Therefore, from the above analysis on system types, both centralized and decentralized AC systems have their own advantages. From the comparison, the centralized and decentralized AC systems can be concluded to represent two entirely different AC concepts.

As Fig. 1 shows, many studies (Li and Jiang, 2009; Hu et al., 2004; Ren et al., 2003; Long et al., 2003; Wu, 2005; Chen et al., 2008; Ma et al., 2007; Li, 2012; Building Energy Research Center in Tsinghua University, 2013; Sun, 2006) have been conducted to examine the energy consumption in residential buildings in different districts of China. From the comparison, the annual energy consumption of centralized AC systems is observed to be higher than that of decentralized systems in general. The largest difference between the energy consumption of the two systems could be greater than 10 times.

Thus, the theoretical analyses of district cooling systems differ greatly from the actual operating experience in many cases, and some important factors that lead to the large differences in energy consumption between centralized and decentralized AC systems have been ignored. To analyze the reason for the energy differences between these AC systems, three actual engineering projects in residential buildings with different types of centralized AC systems were considered in this study. The applicability of centralized AC systems in residential buildings is analyzed and discussed, and the key elements that influence the energy consumption differences between centralized and decentralized AC systems in the case studies are explored.

2. Methodology

The basic information of the three actual cases is graphically explained in Fig. 2. Centralized AC systems are applied in all the three cases; however, the levels of centralization are relatively different.

AC systems can be considered as three heat transfer segments, namely, (1) the heat transfer process between AC terminals and indoor environment, (2) the chilled water heat distribution process between refrigerating machines and AC terminals, and (3) the cooling water heat distribution process between refrigerating machines and the cooling side. In the segment of the heat transfer process between the AC terminals and indoor environment, users in Case 1 cannot adjust the AC terminals; however, in Cases 2 and 3, users can turn the AC terminals on or off according to their requirements. In the segment of the chilled water heat distribution process between the refrigerating machines and AC terminals, in Cases 1 and 2, all cooling energy consumptions are centralized to the cold site and processed by a unified refrigeration equipment with large capacity, while in Case 3, household heat pump systems are applied, and the heat pumps are distributed in each family. Given the different types of refrigeration equipment, the types of chilled-water distribution systems are also different. In Cases 1 and 2, the chilled water is supplied uniformly from refrigeration plants to each AC terminal, while in Case 3, no chilled-water distribution process exists. In the segment of the cooling water heat distribution process between refrigerating machines and the cooling side, all three cases use underground water as the cooling source, and the cooling water is collected together for heat dissipation. In Case 3, however, the cooling water is circulated between the underground cooling source and the heat pump in each household. Thus, the three cases can be summarized as follows:

1. Case 1: centralized refrigerating machines and distribution system of chilled water and cooling water; users cannot adjust the AC terminals;
2. Case 2: centralized refrigerating machines and distribution system of chilled water and cooling water; users can adjust the AC terminals;
3. Case 3: decentralized refrigerating machines, centralized distribution system of chilled water and cooling water; users can adjust the AC terminals.

Obtaining direct access to all three types of actual projects is difficult; therefore, we seek assistance from other researchers. Case 1 (Li, 2012) and 3 (Sun, 2006) have been analyzed in previous studies, and the details of energy data are sufficient for our analysis. For Case 2, we conducted field measurements in the community to obtain the primary data

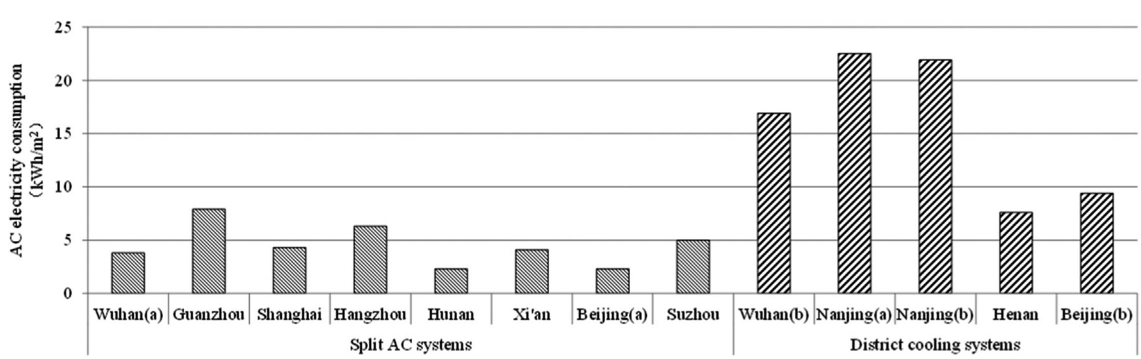

Fig. 1 Comparison of annual energy consumption for decentralized and centralized AC systems in residential buildings.

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