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Investigation and modelling of the centralized solar domestic hot water system in residential buildings

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Abstract

The solar domestic hot water system is currently widely applied as a building energy saving technique. Various forms of the system exist, which should be properly applied in practical engineering. It is significant to study the adaptability of the solar domestic hot water system as it accounts for the building energy consumption in a non-negligible proportion, which is still scarcely studied based on field measurements in current research. This study figured out the performance of the centralized solar domestic hot water system through field measurements, as well as built a sub-hourly simulation model, which has been validated with the field measurement. The model was used to analyse the influence of several factors on the energy consumption of the system, such as the water supply strategy, the use modes of occupants, the thermal insulation of pipes, and the forms of the system. The adaptability of the system was concluded.

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Keywords: Solar energy; Domestic hot water; Energy consumption; Model

1. Introduction

The centralized domestic hot water system is becoming popular in producing domestic hot water recently. The system utilizes solar energy and is supplemented by fuel gas or electricity. It makes full use of the field on the top of a building with large collecting panels, and is thought to be energy-saving and efficient. However, it is found that the performance in energy saving is not so satisfactory as designed in practical engineering, or it even performs more poorly than the split solar domestic hot water system, with a higher cost and lower thermal efficiency.

It is known from the literature that there are numerous researches on the solar domestic hot water system at present, which focus on the following aspects: 1) The qualitative or simple quantitative evaluation of the economical efficiency. For example, Zhao et al.[1] studied the performance of the solar domestic hot water system in residential buildings, concluding that the system performs with a low cost. 2) Performance evaluation of the system based on investigation and field measurement. For example, Li et al.[2] conducted a large amount of survey and measurements in Dezhou, Shandong, concluding that by using the solar system, the cost saved was 304 *RMB* per household, and the CO_2

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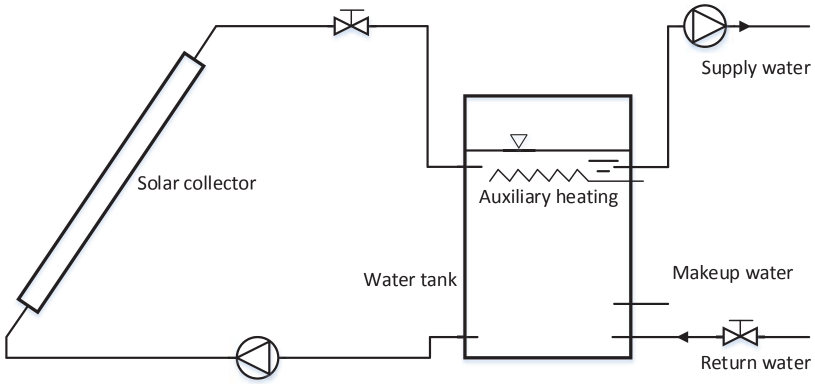

Fig. 1. The centralized solar domestic hot water system with centralized solar collection, water storage and auxiliary heating

emission was reduced by 199.6 kg/m^2. Gastli and Charabi[3] investigated the distribution and composition of solar water heaters in Oman, and analysed the case in Seeb District, demonstrating that the energy saving potential by applying solar water heaters was 335 GWh, with a payback period of 7 to 9 years, better than the current electric hot water system. The performance of the solar domestic hot water system is rarely studied based on detailed field measurement. We analysed the adaptability of the solar domestic hot water system from the field measurements and models based on the actual cases.

Considering the current research conditions, the technical approach of this research is: 1) To summarize the shortcomings in current studies and to decide the research points from literature; 2) To make research plans based on measurement techniques; 3) To interview occupants and conduct measurement in practical cases; 4) To simulate the performance under different conditions with models and find problems in practical engineering; 5) To evaluate the adaptability of the system and provide suggestions for design and operation of the system.

2. Measurement

Beijing University of Civil Engineering and Architecture and Tsinghua University have conducted detailed investigations and measurements in several centralized domestic hot water systems in Beijing and Inner Mongolia in 2014.

A measured case in Chifeng is introduced. The area of this district is approximately 195000 m^2, including 16 buildings with 6 to 18 stories. The district is composed of 46 units, each installed with a centralized domestic hot water system independently. The system is centralized in solar collection, water storage and auxiliary heating, and it circulates the whole day to provide hot water for end users at any time. The auxiliary heating source is electricity, installed in the centralized water tank. When the water temperature in the tank is lower than the set point, which is 45 $°C$ in this project, the auxiliary heating will be turned on. The structure of the centralized solar domestic hot water system is illustrated in Fig. 1.

The temperatures of the supply and return water, and the water flow rate were measured. Fig. 2 shows the sub-hourly water temperature and outdoor temperature during the measured period. The pump is operated in 24 hours, and the auxiliary heating is never turned on. The outdoor temperature ranged between 15 and 35 $°C$, with an average of over 20 $°C$. According to the measured water temperature and water flow, the heat dissipated through the pipe and the water tank can be calculated. The heat used by residents can be calculated by the hot water temperature, the tap water temperature and the hot water usage. Table 1 shows the measured results of the heating energy. The heating energy is divided according to the measurement, as is shown in Fig. 3. The heat used by residents accounts for 67%, while the heat loss 33%, within which the pipe accounts for 28%, and the water tank 5%. Approximately 1/3 of the total invested heating is dissipated through different ways.