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Study on demand-side design parameters of solar domestic hot water system in residential buildings

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Abstract

Solar domestic hot water system is widely used and developing fast in recent years in China. However many problems occur at the same time, for example more energy consumption by circulation pump, water reheating, long investment payback period, and etc. Through analyzing the field-testing data of projects and investigating of different residential consumers, it was found that compared to actual hot water consumption the solar domestic hot water systems were generally designed too large in capacity, which means the designed hot water demand is much greater than actual user consumption. This study compared different specifications and recommended design parameters value of hot water related standards, and analyzed the calculation methodology and design parameter of hot water quota. Finally problems in the system design are summarized and suggestions are proposed for designers and different stakeholders.

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Keywords: Solar domestic hot water system; hot water demand; Design parameter; field-testing

1. Introduction

With the fast development of national economy, there is an increasing demand for people's living standard and comfortable degree. While the use of hot water is one of the most important factor affecting living and comfort level.

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Living hot water accounts for 10% ~ 20% of total building energy consumption, which is the fourth largest amount after the energy consumption of heating, air conditioning and lighting. In order to promote the application of sustainable energy in building energy efficiency, solar hot water system has been gradually promoted to supply domestic hot water in residential building. However, comparing with the systems using traditional heat source such as gas or electric, the utilization rate of solar hot water systems is still far lower and gas or electric is still the main heat source for heating domestic hot water in cities and towns. The reasons which lead to the low utilization come from two aspects, on the one hand, solar energy is instable and greatly influenced by climate and region; on the other hand, there are still some technical problems which need to be improved remains in solar domestic hot water system.

Nomenclature

A_{jz}	direct heating collector area
q_r	designed daily consumption of water (L/d)
m	designed daily hot water consumption
t_r	hot water temperature (60°C)
t_l	cold water temperature
f	solar assurance
J_t	annual average daily solar irradiation on heat collector lighting surface (kJ/m^2·d)
η_j	annual average collection efficiency
η_1	heat loss rate of storage tanks and pipeline
V_{rx}	effective volume of storage tanks
q_{rjd}	average daily hot water output by per square meter of heat collector area (L/m^2·d)
A_j	gross collector area

2. Application status of solar hot water system

Chinese government strongly support and encourage the development and utilization of sustainable energy in the face of contemporary energy crisis. Solar energy has been widely used as a cleaning and inexhaustible energy, which is developing rapidly especially in the use of solar photovoltaic/thermal system. Solar energy resource is very rich in China; the region which has the year round sunshine time of 2500 hours is more than two thirds of the total land area, which create the advantageous conditions of our country for the development and utilization of solar energy. After nearly 20 years of development, our country has become the world's largest solar thermal application market, the ownership of the solar water heater in 2015 is expected to reach about 400 million square meters. Currently solar energy heat utilization is mainly used for domestic hot water supply, which account for 82% of the total. However, there is still some phenomenon worth our deep thinking in the practical application of solar water heating system.

From the perspective of the owners, there are some problems such as overcharges, temperature instability and other issues in the solar hot water heating system. Compared the costs that heating 1 ton water of 40 degrees only with electric with the price that heating the water with solar energy in Beijing, it can be observed that 46.2kWh will be used with pure electric heating, in other words, 22.5 yuan will be cost with a price 0.488 yuan/kWh. The cost of centralized solar water heating system varies widely with the change of seasons, the price even more than 17 yuan / ton in the winter. A survey of 144 residents that from Henan, Yunnan, Beijing, Guangdong and Shandong shows that the price of hot water in 18 percent households is more than 20 yuan/ton, which shows no advantages over electrical system. Besides, the research showed that, only 37% of the users thought that solar domestic hot water system was “very comfortable” while the remained 63% thought it was “very general”(see Fig.1). Compared with the solar domestic hot water system, there are 42% and 44% of the users thought that the electric water heater and gas water heater were “very comfortable” respectively, which is relatively higher than the solar hot water system. One of the reasons is that the system design is not reasonable and the time for cold water before using hot water is too long.