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Experience on integration of solar thermal technologies with green buildings

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Abstract

The green buildings of Shanghai Research Institute of Building Science include an office building for the demonstration of public building and two residential buildings, which are for the demonstration of flat and villa, respectively. Here, a solar-powered integrated energy system including heating, air-conditioning, natural ventilation and hot water supply was designed and constructed for the office building. However, only solar hot-water systems were installed for the flat and villa. All the three solar thermal systems have continuously run for 2 years. Two different integrated approaches have been put into practice in the two green residential buildings. It is shown that, for new buildings, solar collectors can be mounted on balconies and awnings besides roofs, on condition that solar systems become part of the general building design. The solar-powered integrated energy system has the advantage of high utilization ratio with different functions according to different seasons. It is testified to be capable of taking on about 70% of the yearly building load regarding the involved space under the weather condition of Shanghai.

Keywords: Solar energy; Green building; Integrated approach; Solar thermal technology

1. Introduction

1.1. Concept of green building

The concept of green building has stirred extensive interest among the building and energy researches all over the world. Green buildings are examples of applied ecology, where designers understand the constitution, organization, and structure of ecosystems, and the impacts of architecture are considered from an environmental perspective. By utilizing the concepts, methods, and language of ecology, designers can create architecture that intentionally engages the natural system of a site [1]. As for energy consumption of green buildings, it is highly suggested to reduce fossil fuel by making use of renewable energy, such as solar energy, wind energy and geothermic energy. Being abundant and clean, solar energy is receiving much attention in green building energy system. Generally, the newer green buildings combine several of solar technologies. They may be both energy efficient, solar heated and cooled, and PV powered, i.e. they are simply "solar buildings" [2].

1.2. Solar thermal technologies based on solar collectors

Solar collectors can be integrated into building facades due to the fact that integrating solar systems in the building envelope often is a necessity if the systems are to be economically feasible. Presently, solar collectors have been used in a variety of applications including solar hot-water supplying, solar space heating and cooling. Solar water collectors have undergone a rapid development; they are installed with the main purpose of preheating domestic hot water and/or to cover a fraction of the space heating demand. With regard to air-conditioning system, considering the problem of peak load of electricity consumption in summer due to electric chillers, the idea of solar cooling is intriguing from demand side considerations: the chilling demand at least to a significant extent runs parallel to the

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availability of solar radiation. Therefore, the interest in solar cooling by sorption systems has been prevalent for several decades [3].

In most of the solar cooling systems, hot water driven single-stage lithium bromide absorption chillers were commonly used. Evacuated tubes or other high-grade solar collectors were adopted to provide a hot water temperature of 88–90 °C as a heat source to drive the chiller. Experimental results on the performance of such systems were reported by several researchers [4,5]. Compared with the existing absorption systems, adsorption systems can be built in small scale and can be operated with no moving parts, which means that the rectifier or solution pump is not needed. Also, there exists no corrosion problem in adsorption systems. Theocharis Tsoutsos et al. [6] reported that the combination of an adsorption chiller with solar collectors offers a technically simple and energy saving solution. Wang [7] suggested that for the minitype solar air-conditioning system, solar adsorption cooling system will be a better chance. Because of the intermittent nature of solar energy, intermittent adsorption refrigeration cycles have long been considered as logical approaches to solar cooling systems [8]. Therefore, up to now, the solar-powered adsorption systems have mostly been intermittent and used only for ice making application. For applications such as air conditioning, two or more adsorption beds can be used to produce a cooling effect continuously. Numerical simulations have been done to investigate the performance of a solar-powered adsorption air conditioning system driven by simple flat plate solar collectors [9]. As for working pairs, a silica gel/water adsorption refrigerator uses waste heat at below 100 °C, which would be suitable for a wider range of solar collector types [10].

1.3. Main work of this paper

The green buildings of Shanghai Research Institute of Building Science include an office building for the demonstration of public building and two residential buildings which are for the demonstration of flat and villa, respectively. As demonstration projects, they contain multiple green energy technologies, such as solar thermal technology, solar photovoltaic, natural ventilation, natural lighting, indoor virescence, and the like. Here, we designed a solar-powered integrated energy system including heating, air-conditioning, natural ventilation and hot water supply for the office building. However, only solar hot-water systems were designed for the flat and villa. All the three systems have continuously run for 2 years. In this paper, the integration of solar thermal systems with green buildings was introduced and main performances of the systems were summarized.

2. Present state of solar thermal utilization in buildings of China

In China, solar collectors have undergone a rapid development with an annual average growth of 30% since 1980. By the end of 2005, a total of over 60,000,000 m^2 solar collectors have been put into use nationwide. They are installed with the main purpose of hot water supply in residential buildings. Currently, solar water heaters have accounted for about 10% market of the water heating devices. There is still a great market potential for solar water heaters in China. Solar collectors have become an important symbol of green buildings. In the 2008 Olympic projects of Beijing, about 90% domestic hot water will be provided by solar collectors, which contributes greatly to the concept of green Olympics.

However, this application mainly for obtaining hot water through solar energy is not very consistent with the order of nature. In winter, it is convenient to combine hot-water system with floor heating system just through increasing the collector area. A typical instance of solar-powered floor heating system is the newly built Lasa Railway Station in the famous Qingzang Railway project. Whereas, for summer with high solar radiant intensity and high ambient air temperature, the demand for air-conditioning is in preference to hot water, this phenomenon is obvious especially in the south of China. Solar-powered air-conditioning system would be a perfect scheme because it not only makes the best use of solar energy, but also converts low-grade energy (solar energy) into high-grade energy for comfort. The research of solar cooling systems in China were mainly centered on the solar absorption air-conditioning systems. A large-scale solar absorption air-conditioning system driven by evacuated tubular solar collectors was built in Rushan, Shandong Province. The cooling capacity of this system is about 100 kW, with the average COP of 0.57 in 6 h effective operation [5]. Another influential solar absorption air-conditioning system with the same cooling capacity driven by flat-plate solar collectors was constructed in Jiangmen, Guangdong Province. The experimental results showed that average COP is 0.4 [11]. As for mini type solar-powered air conditioning system, Shanghai Jiao Tong University broke through key technological difficulties in 2004, and invented a silica gel-water adsorption chiller, which has been put into practice in the green office building of Shanghai Research Institute of Building Science.

The main problems resisting the further development of solar thermal utilization in buildings include (a) neglect of integration of solar collectors with buildings in the design processes; (b) lack of highly efficient solar-powered integrated energy system. Therefore, our experience in the green buildings aims at investigating feasible approaches for the integration of solar thermal systems with buildings in China.

3. Experience on integration of solar thermal utilization with green residential buildings

Solar heating could be an important contributor in the residential buildings for hot-water supply. Currently, the familiar approach for integration of solar collectors into