Experimental Research of an Active Solar Heating System

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Abstract: Solar is an abundant renewable energy, which is used more and more frequently with the emphasis on environment protection, especially in building heating. The different devised methods between an active solar heating system and normal heating system are discussed in this paper. Based on the design, construction, testing and economic analysis of a demonstration project with the solar heating system, this paper discusses how to connect the solar energy collector with the electricity heater and heating system in order to achieve the best state of comfort and energy savings. The real cost of running is calculated and compared with that of other heating methods. The traits and the scope of applications of the solar heating system and the problems in designing, installing and operating are indicated in this paper.

Key words: regenerative energy, solar heating system, energy-saving

1 PREAMBLE

Solar energy is an important renewable energy and abundant in China. Fully utilizing solar energy could reduce emission of greenhouse gas and protect environment. With the improvement of accommodation conditions and sanitary habit, the portion of the energy consumed on bath water in total energy consumption has increased significantly, so the wide application of solar water heater could play a critical role for environmental protection. In China, main solar energy equipment is solar water heater. The solar heating system still needed more research.

Solar heating system is divided into passive solar heating system and active solar heating system according to different solar use method. Active solar heating system can work independently, which is used more and more popular, so this paper discusses active solar heating system mainly.

Active solar heating system is composed of heat collector, heat storage tank, supplementary heater, and pipe, valve, and pump and controller system. Heat collected by heat collector is transferred to house for heating, if there is extra heat, the heat can be stored in heat storage tank, if the heat is not enough for heating, the supplementary heater starts to work..

2 CHOICE OF HEATING SYSTEM

According to heat transfer theory, temperature of heat medium at solar heat collector's entry should not be high, or the heat collector efficiency will be low. And the heat medium flow cannot be very small, so the temperature of heat medium at solar heat collector' exit should be low for achieving high energy collector efficiency.

Low-temperature hot water floor radiant heating system is an energy saving, environment protection and comfortable new heating method. The temperature of floor surface should not be high, so supply water temperature should not be above 60 . Low supply water temperature is chief characteristics of low-temperature hot water floor radiant heating system. So low-grade-energy solar energy can be used in floor radiant heating system as a heat producer.

3 CHOICE AND INSTALL OF SOLAR ENERGY COLLECTOR

3.1 Choice of Solar Energy Collector

Heat pipe solar energy collector is more efficient

than other kind solar energy collector, so it is used more popular. Because heat for building heating is very much, so more heat energy collectors are needed. For reducing the floor area, the heat pipe solar energy collector is best choosing, but the investment is high.

3.2 Relationship Between Collector Pose and Collected Heat Quality[1]

Traditional option is that best collector installation obliquities are latitude adding 15 degrees, which is better for heating in winter. But someone [1] researched and believed that if the collector installation obliquity is above local latitude, the diffuse radiation will be collected less, so the collected total radiation is less.

As a whole, the total solar radiation qualities of scattered radiation and direct radiation, and scattered radiation are more than direct radiation at some cities. Especially in recently years, the atmosphere become corrupt step by step, which will keep on a long period. The result of atmosphere corrupting is that total solar radiation and direct solar radiation decrease. Obviously, the proportion of scattered radiation in total solar radiation increases gradually.

In cities, other buildings will keep out the solar collector on building's top, and if the solar collectors are laid in arrays, the back solar collectors will be kept out surely, so the solar energy loss is high. In this area, if the obliquities of solar collector are less the latitude, the scattered solar radiation loss much.

3.3 Obliquity of Solar Energy Collector

In order to decrease the loss of scattered solar radiation, in high latitude area or in dense cities, it is better to install solar collector in small obliquities. In most area except Qinghai-Tibet Plateau where the proportion of direct solar radiation in total solar radiation is very high, the best install obliquity is less local latitude, and the less direct solar radiation, the smaller install obliquity. The best install obliquity should be selected in local situation.

4 CHOICE OF SUPPLEMENTARY HEATER

For active solar heating system, when the solar radiation is weak or the water temperature is low, the supplementary heater is needed. When the weather is cloudy continuously, supplementary heater provides heat absolutely.

We should select supplementary heater depending on real situation. The choices include coal-fired/gas-fired boiler, connecting with district heating system, connecting with substation, terrestrial heat water, and waste production hot water. In China, in order to encourage people to use electricity for heating in night, the electricity price in night is cheaper. If we use the electricity to heat water in night and store the hot water for heating when the solar energy is lack, which can save a lot of money. So when the heating area is small, the best supplementary heater is electrical heater.

5 EXPERIMENTAL RESEARCH

5.1 Outline of Project

The demonstration project, which has about 30 m^2 construction areas, is located at Beijing. The scheme of system is showed in Figure. 1.

The general situations of the demonstration project are below:

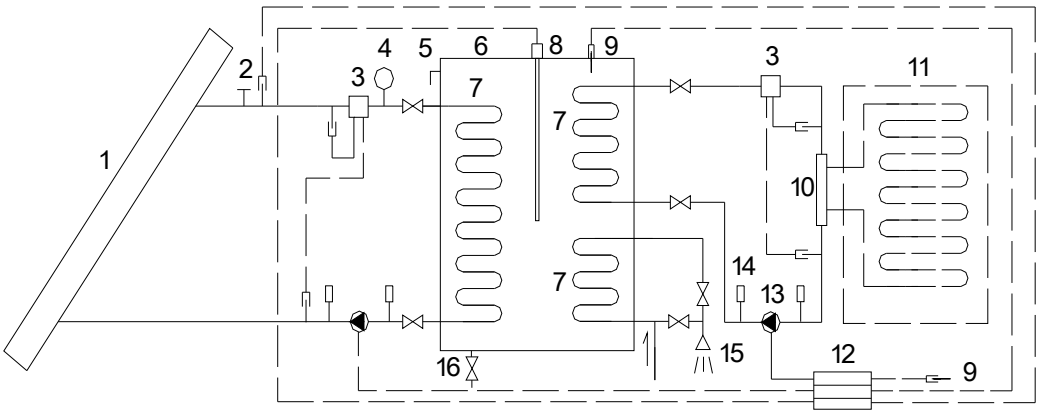
(1) Solar energy collector system and heating system are devised independently. The heat medium in solar energy collector system is antifreeze. The heat medium in heating system is water. Both two systems have a heat-exchanger unit made of copper pipe to exchange quantity of heat with the thermal storage material. Pump is necessary to provide driving force in two systems;

(2) The thermal storage tank is used in exchanging heat and saving up the extra quantity of heat. The cubage of the tank is 200 liters. The thermal storage tank is showed in figure 2;

(3) The obliquity of the solar energy collector is 35°. The solar energy collector is showed in figure 3;

(4) Heating mode is floor-radiate heating system;

(5) The supplementary heat source is electrical heater.



1—solar energy collector, 2—entrance of antifreeze, 3—thermal meter, 4—expansion tank, 5—vent-pipe, 6—thermal storage tank, 7—heat exchanger, 8—electric heater, 9—temperature sense, 10—distributor of medium, 11—low-temperature hot water floor radiant heating systems, 12—control center 13—circulating pump, 14—pressure gauge, 15—hot water, 16—discharge-valve

Fig.1 The sketch map of solar energy integration utilization system

When the sunshine is sufficient, solar energy collector as the main energy source undertakes the whole heat load of the building. During the time of night and less sunshine, electric heater starts, as supplementary heat source, to provide heating. By heating up water in the tank with low price electricity at midnight and using it in low sunshine conditions, the running cost could be reduced greatly.

Fig. 2 Indoor system

5.2 Experimental Research

The system was installed (the details are showed in Figure.2 and Figure.3) and operated in Jan. 2005. In that period, the indoor average temperature of was 15.4 and the outdoor average temperature was -3.6 . The solar energy collector system worked 7 hours averagely, and the electric heater worked 5 hours averagely. Table 1 shows the total amount and the cost of electricity during the period of the running of the system.

Fig. 3 Solar energy collector system

The heating season in Beijing is from previous year Nov. 15th to next year Mar. 15th. It is well known that outdoor temperature is not very low and the heating load is less in the prophase and anaphase of heating period. So the solar energy collector system can collect enough quantity of heat for heating. Because of thermal inert, room can be kept warm without supplementary electricity heater in the night. The operating cost can be decreased greatly. This characteristic has been validated in the experiment.

The calculation electricity price is that normal

electricity price is 0.39 ￥/kWh, lower price electricity is 0.2 ￥/kWh. Calculating data come from the experiment, we can got that the average operating cost is 0.18￥/(m^2·d) as the active solar heating system working normally. If supplementary electricity heater does not work, the corresponding cost is 0.05￥/（m^2·d）(just pump consumes electricity). In somber day and snow day, the operating cost is 0.33 ￥/(m^2·d).

The hours of sunshine in Beijing is showed in table 1. If one sunshine day has 10 hours sunshine, there are about 105 sunshine days and 15 somber/snow days every heating season in Beijing. On the assumption that there are 50 sunshine days, in which the supplementary electricity heater does not work, the total operating cost of heating system is about 18.30￥/(m^2·a) in Beijing.

Tab. 1 Hours of sunshine in Beijing from 1961 to 1970[2]

Month	11	12	1	2	3	Total
Hours of sunshine	193.0	193.4	209.2	201.8	248.6	1046.0

Table 2 shows the cost of building and running of several different heating methods. Because cost of fuel is different, and solar energy heating system uses less electricity for heating, so the operating cost of solar energy heating system is higher than that of district coal-fired heating but less than that of others.

We can draw a conclusion that, although the cost of solar energy system is expensive than that of district heating, but it is cheaper than the other two systems (household gas-fired boiler and household electric radiator). The initial cost of solar energy heating system is the most expensive system，but, because it uses mainly solar energy, so it can save a lot of fossil fuels, and at the same time, it can reduce the emission of greenhouse gas, such as CO2. Not only the solar energy heating system works well, but also it can protect environment. The other advantage of the system is economic aspect.

So the solar energy heating system is fit for heating in areas where there is no district heating, especially in the mountainous areas and beauty spots where the other heating methods, which can pollute environment, are forbidden.

Especially now, the new rural construction is developed in Chinese villages, the solar energy must will be used more and more popular, so we should research the method how to use the solar energy heating in village greatly.

7 ACHNOWLEDGEMENTS

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6 CONCLUSION

Tab. 2 Analysis of several heating methods[3]

Heating method	District coal-fired heating	Household gas-fired boiler	Household electric radiator	Solar Energy Heating System
Cost of building（yuan/ m^2）	50	110	40	450
Cost of running（yuan/a）	735	1941.76	1753.6	585.6
Cost of running（yuan/m^2·a）	23	60.68	54.8	18.3

Note： The cost of the running includes the cost of electricity for pump. The price of gas is 1.4 yuan/m3. 3. The price of electricity is 0.45 yuan /(kWh).

REFERENCES:

[1]. Rao KUANG, Yongyun Zhou, Shaoyu Shao. The relation between PV modules' gesture in BIPV and absorbed solar irradiation [J]. Acta Energiae Solaris Sinica, 2004, 25(4): 447-451.

[2]. Rongsheng Fang, Licheng XIANG, Tinghan. Solar Appliance Technology [M]. China Agriculture Mechanism Press, 1985, 65-67. (In Chinese)

[3]. Yi Jiang. Heating schemes analysis for medium and large cites in the North China. Heating ventilation and air conditioning, 2000, 30(4): 30-32.

[4]. Hong Ye, Jun WANG, Shuangyong ZHUANG. Experimental Study on the Radiant Floor Heating System Utilizing Form-stable PCM As the Thermal Mass [J]. Acta Energiae Solaris Sinica, 2004, 25(5): 651-656.

[5]. Zhengxin Qi, Yajun Lu. Dry-type method of hot-water floor heating system [J]. Building Energy & Environment, 2002, 23(5): 32-34.: 32-34.