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Solar heating and cooling application potential and application case analysis in new-type urbanization in China

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Abstract

As the new government came to power, urbanization construction created waves in China, and it will produce hundreds of thousands of billion production value. New-type urbanization has the feature of ecological, energy saving. In this situation, renewable energy especially the lower cost solar energy will play a major role in the urbanization construction. In this paper, we analyzed application potential of SHC (solar energy heating and cooling) and typical cases of Beijing in urbanization construction.

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Keywords: solar heating; SHC; new-type urbanization;

1. Introduction

China has opened the prelude of the new-type urbanization, one of the themes of which is ecological, no longer limited to the construction of a cluster of high-rise buildings than devoted to building low density of ecological small towns, and we can put farmers nearby. Solar energy resources of China are abundant. The solar energy hot water system has been widely promotion. SHC system due to taking up larger installation area, it is difficult to spread in cities. But new type urbanization has low density of buildings, SHC system will be a lot of promotion.

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2. Application potential

Firstly, there are billions of farmers in China and they almost have no centralized heating and air conditioning. Along with the new type of urbanization construction, farmers are likely to be concentrated in the new community, focus on heating and air conditioning. Most parts of China have heating and air conditioning needs. Secondly, abundant biomass renewable energy resources exist in rural village, which can solve the solar energy heating, air conditioning system of auxiliary heat source. Rural residential areas generally have low building volumetric fraction, and there is no obvious cover. So, there is a good condition for solar energy heating project. And lastly, as the proportion of urban population continues to rise, the household consumption will maintain a rapid growth. Studies have shown that a rural population into urban, energy consumption will increase by 3.5 times. With the acceleration of urbanization, the city will have a substantial increase in consumption of energy resources. 2012 China New-type Urbanization Report predicts that urbanization increases by one percentage point will boost energy consumption of 80 million tons of standard coal. By 2020 China's urbanization ratio will reach 60%, which will boost energy consumption of 800 million tons of standard coal. So the new-type urbanization construction will provide huge market space for use of renewable energy. Besides, there are many policies to promote renewable energy development in China. The National Energy Board proposes the development goals of China's solar energy utilization, namely, the total areas of solar collectors will get to 400 million square meters by 2015 and to 800 million square meters by 2020.

Above all, in the course of China's new-type urbanization construction, SHC has enormous potential.

3. Application case

Urbanization construction case is introduced as follows (come from Huangshandian village of Beijing Fangshan district): In July last year, the village was affected by flooding. Now, a safe, ecological community will be built for villagers. Different from most buildings of Beijing, this project has low buildings, with almost 3 to 4 floors. There are enough place to install solar collectors. The project will choose seasonal storage solar thermal storage heating system, air conditioning comprehensive utilization of solar energy heating system, solar photovoltaic power generation system. This paper will describe the characteristics and designing about these systems. Heat pump system was chosen for supplement of space heating.

3.1. Construction scale

The construction contents of the project includes 2500 square meters of solar collectors, 150 kW of photovoltaic system, 500 GSHP (ground source heat pump) wells and GSHP units , which will meet winter heating demand, part of electricity demand, air conditioning demand in public buildings in summer. Solar thermal system and GSHP system will be used to provide heating and hot water for residents in winter. Heat generated by solar thermal system will be recharged underground in spring, summer and autumn to achieve inter-seasonal heat storage, which can improve the efficiency of GSHP system.

3.2. Resource conditions

3.2.1. Solar energy resources

Solar energy is inexhaustible, clean and renewable energy, which is one of mankind's most promising energy sources. China has abundant solar energy resources, theoretical reserves reaching 1.7 trillion tons of standard coal per year. Compared to other countries with the same latitude, solar energy resources of China are similar to the United States, much larger than Europe and Japan.

Beijing has abundant solar energy resources, in which the water level total amount of radiation reach 5000MJ per square meter and the total annual sunshine hours reach 2700 or more. The amount of radiation in summer is significantly higher than in winter in Beijing. The highest monthly amount of radiation is from April to August. Beijing monthly amount of solar radiation is shown in fig.1.

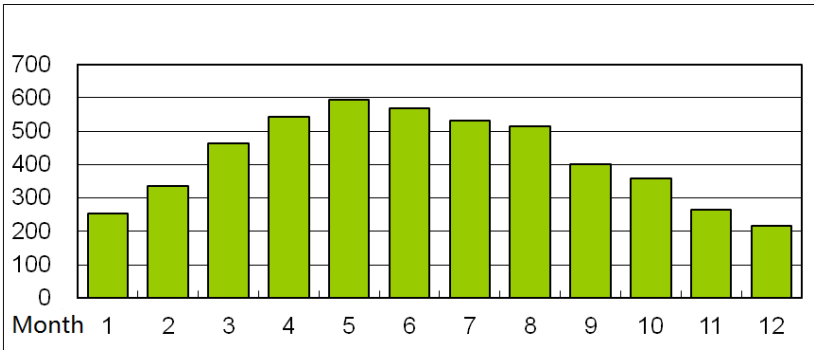

Fig. 1.Beijing monthly amount of solar radiation

3.2.2. Shallow geothermal resources

This project is located in Huangshandian village of Beijing at Fangshan district. Tested, the thermal conductivity of underlying rock of the region belongs to middle or higher level. The average thermal conductivity of deep rock is about 2.90W / (m•k). The underground heat transfer conditions are good, and the underground water is also abundant. So this project has the condition of laying buried pipe, and the GSHP system can be applied.

Above all, the solar energy and GSHP combined system is suitable for this project.

3.3. SHC system technical schemes

The renewable energy systems include solar heating system, GSHP system, solar energy, building integrated photovoltaic (BIPV). Solar heating system uses heat generated by the solar collector system to solve the needs of the building heating. The area of solar collectors will reach 2500 square meters, which will solve at least 30% of the project's energy demand for heating. GSHP system as an auxiliary heat source will meet the building heating needs. And the buried pipe system can save up heat generated by solar system in non-heating season. In summer GSHP system can solve the public buildings cooling demand. Solar energy and building integrated photovoltaic (BIPV) system is mainly constructed in public buildings. The operating cost of solar heating and cooling system is much lower than conventional system. Most of the villagers are poor, they will appreciate that the system will save more than 50% of heating costs for them. The system’s principle diagram is shown in fig. 2.

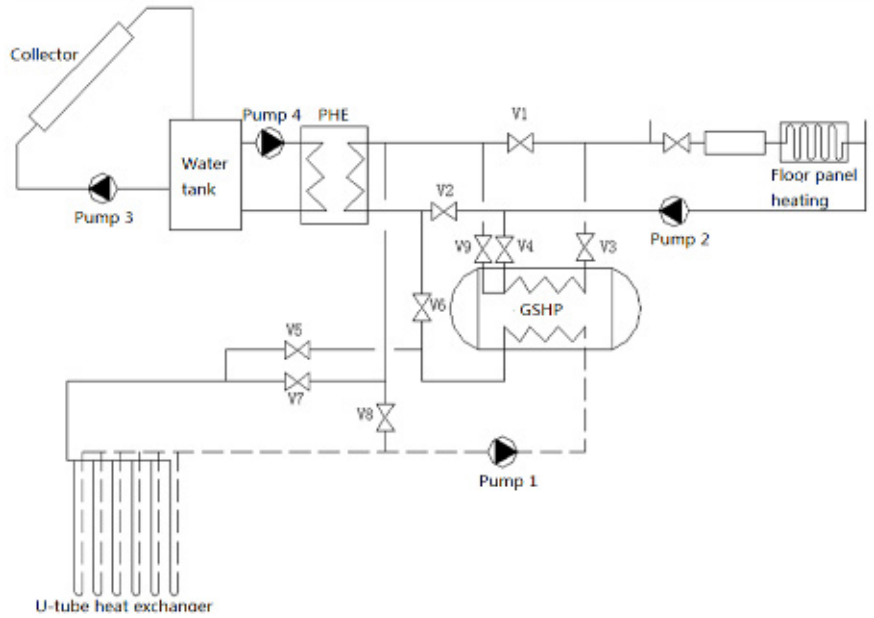

Fig. 2.System principle diagram

3.3.1. Solar energy system

3.3.1.1. Form of system

Forced circulation indirect heating system is used in the project. This system uses water pump as power. There are many kinds of forms of forced circulation system, mainly including direct and indirect system. Besides, forced circulation system can also be divided into single-tank and dual-tank forms. These systems are shown in fig.3. Forced circulation system generally uses variable flow, constant temperature control mode or temperature cycle control mode, which is the development trend of solar hot water systems combined with buildings.

3.3.1.2. Way of collectors connection

In general, the collectors are connected in three ways: series, parallel and series-parallel. For collectors in parallel, the number of collectors in parallel in each group should be the same, which is conducive to the collector group flow equalization. For each group of collectors in parallel, the number of collectors is not more than ten. Multiple collector groups are joined together to form solar collector system. Overall, the stability of RRS (reverse return system) is inferior to DRS (direct return system). Therefore, to ensure each collector group hydraulic balanced, the way of connections among the collector groups generally is RRS in this project. When the way of connections has to be DRS, balance valves are used in the branch of each group to regulate the flow balance. Two kinds of ways of connections are shown in fig.3.

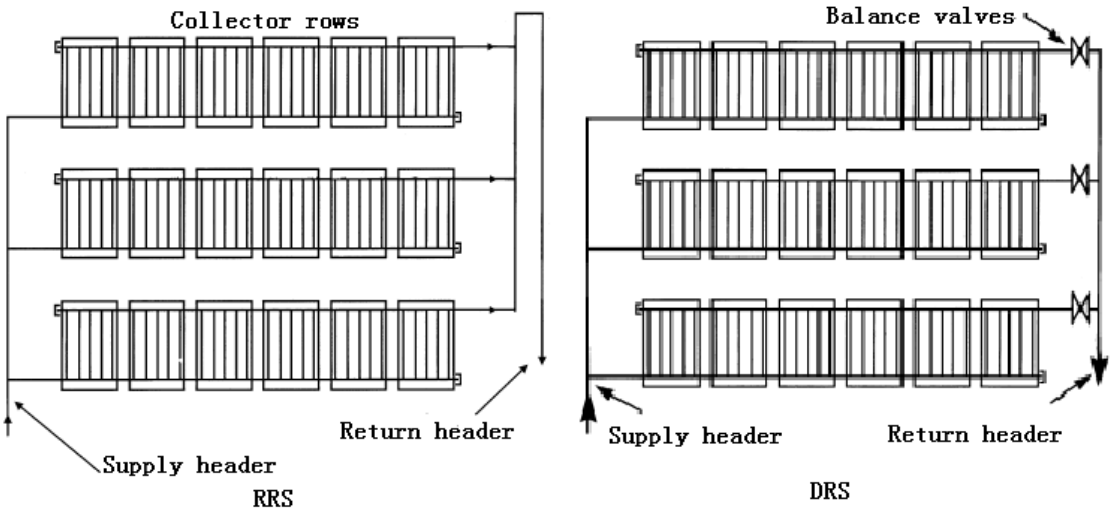

Fig. 3.Way of connection of collector groups schematic diagram

3.3.1.3. Solar energy and building integrated design

From the perspective of building integrated, the way of embedded installation is more beautiful than that of overhead sloping roof installation. But for architectural and structural design, the way of overhead sloping roof installation is low cost, easy to replace and maintenance. Therefore, the way of overhead sloping roof installation is chosen in this project.

3.3.2. GSHP system

GSHP buried pipe system is an efficient, energy saving, environmentally friendly technology, which can be used for heating and cooling by exploiting earth's surface shallow geothermal energy resources. And it is a system that makes low-temperature heat energy transfer to the high-temperature heat energy by inputting a small amount of high-grade energy, namely electric power. The underground soil is used as a heating source in winter and a cooling source in summer for heat pump. When 1kW of energy is consumed, generally the system can get around 4kW of heat or cold.

Buried pipes system will be used in this project, which is divided into two forms, namely, horizontal and vertical buried pipes system. The system is also called closed-loop ground source heat pump, in which the carrier(usually water or mix of water and antifreeze) circulates to make heat exchange to provide heating source for heat pump or cooling source for refrigeration units. Buried pipes system can store heat generated by solar system in the non-heating season. In summer GSHP system can solve cooling demand for the public buildings.

The load of the project is about 2900kW. Three rooms, six sets of heat pump units will be set up, and each room has a prepared unit, whose single heating capacity is 990kW, heating rated power is about 240kW. The EER of the system is 3.5 under heating condition.

3.3.3. Coupling analysis on Solar energy system and GSHP system

Annual cooling and heating load imbalance will cause temperature in buried pipes zone to continue to increase or decrease, thus to affect the buried pipes heat exchanging performance and reduce its efficiency. Therefore, when designing buried pipes heat exchanger system, the impact of annual cooling and heating load should be considered. Namely, heat absorption and release of GSHP should be balanced in order to make the units maintain a high operating efficiency.

In this project, the total number of heat absorption of GSHP system is 5893858MJ in winter and that of heat emission into the buried pipes system is 2132846MJ in summer, so the total number of annual heat absorption is 3761012MJ. Therefore, in order to ensure the operation of GSHP system, solar system should at least supplement corresponding number of heat to buried pipes system. The average annual solar collector system thermal efficiency is about 0.40. Considering the system loss, solar system can provide 3535542MJ of heat supplement to the buried pipes system.

Therefore, the difference of heat absorbing and heat emission of the buried pipes system is 3535542-3761012 =-225470MJ, whose unbalanced rate is -3.8%, meeting heat balance requirements for the buried pipes system.

3.4. Power supply system

The project has annually approximately 1.5 million kWh of electricity consumption. Solar photovoltaic power generation system is intended to be installed to solve about 10% of electricity demand of the project, which is about 150kWh. Crystalline silicon solar panels will be selected in the project, exchanging efficiency 14%, installation area of 1071 square meters, which has an annual about 181,000 kWh of power generation. Each building need an inverter, of which power generation is directly into the power system.

4. Analysis on the project

4.1. Analysis on operating costs

When solar system operates, only the heat collector circulating pumps consume electricity. This system has heat collector circulating pumps and heat storage circulating pumps, whose total electric power will be 25kW, if one-square meter of collector (total 2500 square meters of collector in this project) corresponds to 0.01kW of pump electric power. So the total number of power consumption will be 68,000 kWh per year, if the solar system runs continuously for 7.5 hours a day. The GSHP system requires an annual consumption of about 998,000 kWh. Solar photovoltaic system generating capacity is 181,000 kWh per year. Therefore, the total annual electricity consumption will be 885 000 kWh and the annual electricity costs will be 675,000 Yuan, if the electricity price is 0.7625 Yuan per kWh. The maintenance costs of the system are 200,000 Yuan per year. In summary, the total operating costs are 875,000 Yuan per year, and the cost of one-square meter building is 15 Yuan per year.

4.2. Analysis on energy saving and environmental protection

In the project, solar collector system provides about 1528202MJ of heat, compared with conventional coal-fired boilers, which will save energy of 86.9 tons of standard coal. GSHP (Ground source heat pump) system provides about 7934039MJ of heat, compared with conventional coal-fired boilers, which will save energy of 224.6 tons of standard coal. Solar photovoltaic system generates electricity around 181,000 kWh per year, which will save energy of 65.2 tons of standard coal.

In summary, the project of renewable energy systems will save energy of 377 tons of standard coal per year. In addition, by reducing the consumption of conventional resources, the project will reduce annually emissions of around 920 tons of carbon dioxide, 7.5 tons of sulfur dioxide and 3.8 tons of dust.

4.3. Analysis on economic benefit

After investigating, the villagers are now primarily using coals for heating in winter, which is of inefficiency, poor indoor comfort and environmental pollution. In this project, the total annual heating costs will be about 2.92 million Yuan. The annual operating costs are 875,000 Yuan, which will have savings of 2.045 million Yuan per year. Besides, compared with the costs of conventional system 8.7 million Yuan, this renewable energy system will increase investment of 19.25 million Yuan, so the simple payback period is 9.4 years. Because the life of this system is about 20 years, increased investment in this project can be recovered in the life.

After the implementation of the project, indoor comfort will get better, the residents' costs will be less, and their standard of living will be improved notability. The renewable energy project is expected to be a model pattern for new-type urbanization construction in China.

5. Promotion prospects

At present, China's building energy consumption accounts for more than 25% of the national energy consumption, and the percentage will get larger and larger in the future. Therefore, in the case that fossil fuels are getting less and less, the energy crisis and environment pollution is getting more and more serious, the application of new energy and renewable energy in buildings is of great significance.

On the one hand renewable energy can replace limited fossil fuels, which can reduce the consumption of fossil fuels, protect existing energy resources and optimize China's energy structure.

On the other hand renewable energy with no or little pollutant emissions to the atmosphere and environment is green energy, the application of which is beneficial to the protection of the ecological environment. Above all, SHC system using large renewable energy will be a lot of promotion in China.

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