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Low-carbon Technology Application in Wuhan Based on Ground Source Heat Pump System

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Abstract. It is known that ground source heat pump system (GSHPs) takes the advantage of shallow geothermal energy which include the power of underground water, surface water or soil etc., and the system can not only provide heat apply but also provide cold making power in a high efficiency and energy saving way. The ground source heat pump only uses the shallow geothermal resources of the earth's surface (usually less than 400 meters deep) as cold and heat source, it takes less effect on earth and its environment. The GSHPs could replace air-conditioner heater and domestic hot water facilities. The running process of GSHPs is green without any pollution. It can be built in a residential area, no burning, no smoke, no waste, no stacking fuel waste sites, and no long-distance transport of heat. The system does not consume water or pollute water, no boiler, no cooling towers, does not need stacked fuel waste sites. It leads significant environmental benefits. With the experimental application in the project in Wuhan, it showed the advantages of GSHPs, the using feasibility of GSHPs and also the disadvantages and limitations of GSHPs. And with the developing of the GSHPs technology, the use of the system can have a considerable prospect.

1. Introduction

Ground source heat pump system (GSHPs) takes the advantage of shallow geothermal energy (including the power of underground water, surface water or soil etc.), and it can not only provide heat supply but also provide cold making power in a high efficiency and energy saving way.

Generally speaking, in the GSHPs, geothermal energy can respectively be as heat source of heating pump in winter and cooling in summer as cold source. During the winter, the GSHPs takes the heat power out of the shallow geothermal energy, raise the temperature for indoor heating supply; in the summer, it removes the indoor heat energy to release into the ground and transfer into geothermal energy.

Usually with the consumption of 1 KWH energy of the GSHPs, the user can get 4 KWH or more of the amount of heat or cold power. This is a kind of low carbon environmental technology.

With the introduction of GSHPs in China since the 1990 s, more and more projects come to use the technology all over the country, and they drew a lot of attentions.

Since 1998, some universities began to try experimental applications of GSHPs, such as Chongqing Jianzhu University, Qingdao Construction College, Hunan University, Tongji University and others.

When in 21 century era, China government promulgates the “Renewable Energy Law” on January 1st 2006. It is shown that government of China pay high attention to the renewable energy use during



the international energy crisis. With the development of GSHPS technology which could apply the clean, high effective renewable energy, it can be used in urban city thoroughly.

Wuhan city has got plenty water resources. With the unique condition the GSHPS would have further development.

In 2000, the GSHPS technology came into use in Hubei province, such as Wuchang railway station, Wuhan Tazi lake gym center. Wuhan art museum, Acrobatic gym, Zhongnan theatre, Hubei province Library, the main building of Ministry of land and resources of Hubei province, Wuhan railway station, Hankou railway station etc.

2. the Operation principle of ground source heat pump system

Ground source heat pump heating and air conditioning system is mainly composed with three parts: outdoor ground heat exchange system, ground source heat pump air conditioning units and indoor heating system terminal.

The GSHP machine has two main forms: water - water type or water - air type. Among the three systems, water or air is the heat transfer medium; water is the transfer medium between ground source heat pump and geothermal energy; and water or air could be the transfer medium of the GSHPS and the air terminals in buildings. The process flow diagram is shown in figure 1.

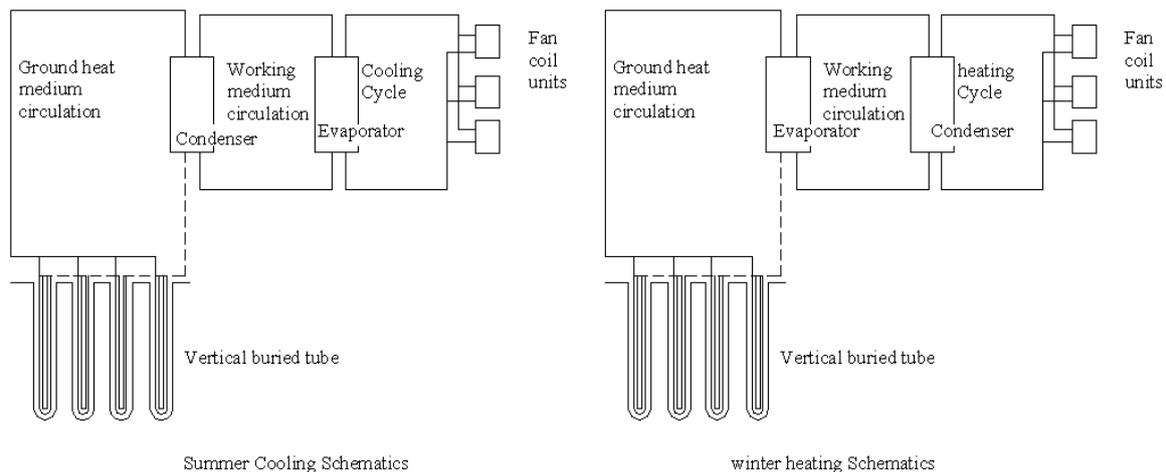


Figure 1. Summer Cooling Schematics and winter heating Schematics

The ground source heat pump main unit can combine the functions of air-conditioner, heater and domestic hot water supplier into one. That is to say, a multi-purpose ground source heat pump provides a complete solution for the traditional HVAC system.

The HVAC plant room of the GSHPS provides the power that supply circulating water; with the help of hydraulic balance dispenser which can balance the hydraulic system, all the terminals and components of the system get balanced with no extra press which can reduce the leakage possibility greatly. Hot-water tank is part of the system which provides domestic hot water all year round.

Frankly speaking, ground source heat pump system is essentially a heat lifting device, which consumes a small amount of electric energy during operation, but can extract 4-7 times of electric energy from environmental media (water, air, soil, etc.) for use.

In winter, with the consumption of 1kw electric power, the GSHPS can extract 4-5 KW heat power from soil or water underground. But in summer the process is opposite, indoors' heat is transferred into the soil or water underground by GSHPS and the indoors become cooler.

During the operation, there is no waste of energy. The GSHPS is a energy-friendly system and a eco-friendly system.

3. the GSHPS applications in Wuhan

3.1. features of engineering projects application in Wuhan

According to the survey of the actual GSHPS projects built or under constructed in Wuhan, it shows the features below:

1) Wuhan is composed of three towns, Hankou district Wuchang district and Hanyang district. The three districts have different geological structures. Because of the geological features in Wuhan, the majority of the projects which locate in Hankou district area choose the groundwater source heat pump system, other projects located in Wuchang and Hanyang district area choose the ground source heat pump exchanger system and the surface water ground source heat pump system, but the surface water ground source heat pump system used less.

2) The floorage of the projects using GSHPS are from 2,000 square meters to 210,000 square meters. Among them, the project which floorage is 10,000 square meters or more occupies 70% of the overall. Most projects are using buried tube heat exchanger.

3) Generally speaking, the depth of drilling well is 40 to 50 meters, the water withdrawal of each well is about 20 to 120 m³/h. the quantity of the recharging well is 1 or 2 times of the water withdrawal well. According to the statistical data in Wuhan, the water withdrawal is 6,600 m³/h, and the quantity of the water recharge is 70% to 100% of the water withdrawal.

4) The GSHPS use plate heat exchangers in order to prevent the corrosion and sediment of the pump and meanwhile the use of heat exchangers can improve the efficiency of the pump. And there always equips a Cyclone bed cleaning device or Physical water treatment device in front of the plate. Therefore, the GSHPS equipment runs well and only seldom recharge wells are congested. In order to keep the routine running, heat source well should be washed every 3-5 years.

5) Most GSHPS use buried pipe, the depth of the drilling hole is about 22 to 100 meters, the diameter of the well is 3.5 to 5 meters. Most buried pipes are using single U type or double U type HDPE pipe. It has the advantages of easy connection, corrosion proof, long-lived use. However, cause the long duration, higher cost and more complex process, the GSHPS using buried pipe is seldom used in Wuhan.

6) According to the building load characteristics and the thermal balance needs of the underground stratum, some projects choose the hybrid ground source heat pump system, such as ice thermal storage cooling system or water thermal storage system combine with the groundwater source heat pump system. It decreases the capacity needed of the system and at the same time, it has the advantages of peak load shifting of the power, improve the efficiency of the network.

7) Till now, GSHPS runs properly. There is no big issue happened. No abnormal land subsidence occurs. There is no abnormal decline of water table based on the data provided by Wuhan building energy saving and monitoring center. From the report of the municipal water department, it draws out that no abnormal change occurs in the groundwater temperature or the groundwater quality.

3.2. Practice and Case Study-- a small project using GSHPS in Wuhan

The project is a toll lied on a super highway in Hubei province. The designing institute proposes two programs, one uses traditional air-conditioning system and one uses GSHPS.

3.2.1. Back-ground of the project—a toll station and its subsidiary facilities. The toll station is composed of main building, auxiliary building and 7 toll booths. And floorage of main building is 744 square meters, floorage of auxiliary building is 80 square meters, floorage of the 7 toll booths is 47 square meters. The total floorage is 871 square meters. The auxiliary building is a kitchen.

3.2.2. Load design of GSHPS. According to climate condition and the maintenance of the structure, the design maximum cooling load is 113 KW, maximum heating load is 92 KW, the maximum heating load of the buried exchanger is 146 KW.

3.2.3. Interior terminal design of GSHPS. On account of the concentration of toll station and its auxiliaries, the interior terminal system is designed as the central air-conditioning system. And there is

an individual heating pump room in the auxiliary building—the kitchen. The interior terminal system applies fan coil unit system in order to keep the temperature needed of each room.

3.2.4. Design of the buried pipes outdoors of the GSHPS. According to the surrounding of the building, and the function of heating in winter, cooling in summer, the buried pipe is designed as the U type pipe. Based on the maximum heat load, it should drill 45 wells when using vertical U type pipe, the depth of the well is about 100 meters, occupy the area of about 300 square meters or so. And the toll station got enough room for the design. Anyhow above the buried pipes, there could build parking lot, landscape engineering or floor decoration. That is to say, there is no disturbance or waste of the active area. Via using four-way valve, the GSHPS could control the alternative between winter condition and summer condition.

3.2.5. Running cost of GSHPS. Compare with the 100 days performances of GSHPS and ordinary air-conditioning system under the situation of 24 hours per day, we can see the data in table 1.

Table 1. the operating cost comparison between GSHPS and air conditioning system

season	GSHPS		Ordinary air conditioning system	
	winter	summer	winter	summer
performance coefficient (COP)	4.5	4.1	2.9	2.1
Power consumption (KWH)	43,846	36,538	93,997	121,050
cost	25,737	21,448	55,175	71,057
Cost per year	47,185		126,232	
Cost saving using GSHPS			62.6%	

The data unit is yuan

3.2.6. Conclusions. From the forgoing, it can save 62.6% of the total investment when using GSHPS instead of traditional air-conditioning system, as it is shown in table 1 above. That is a heating and cooling combined system. No need to build stokehold, no carbon emission of the fuel, no pollution problem. That is a kind of energy conservation and environmental protection engineering. That is worth popularizing.

4. The advantages of GSHPS

4.1. High energy efficiency

As we all know that the temperature in the shallow earth keep 12-22°C in winter and 18-32°C in summer. And the GSHPS takes less energy to heat in winter and cool in summer. It is reported that it can save 30-40% of the running cost.

Ground source heat pump is a cost-effective energy-saving technology. Its COP (Coefficient of Performance) value reaches 4 or more.

4.2. Significant environmental benefits

The surface shallow layer of the earth is a big solar collector, it collects 47% of the solar energy, more than 500 times of the energy used by humans every year. The shallow geothermal energy stored in the earth's surface is almost infinitely renewable energy, it can be a form of renewable clean energy.

The running process of GSHPS is green without any pollution. It can be built in a residential area, no burning, no smoke, no waste, no stacking fuel waste sites, and no long-distance transport of heat.

The system does not consume water or pollute water, no boiler, no cooling towers, does not need stacked fuel waste sites. It leads significant environmental benefits.

The GSHPS takes the heat power out of the shallow geothermal energy (usually less than 400 meters deep of the earth), raise the temperature for indoor heating supply. In the summer, the indoor heat energy is removed, released into the ground and transferred into geothermal energy. The emission of the GSHPS is much less than other systems. It takes less effect on earth and its environment. It is an environmentally friendly system.

4.3. *Low maintenance cost*

Ground-source heat pumps have very few mechanical moving parts. Most components are not buried in the ground, they are installed indoors, thus this kind of system design can avoid the harsh outdoor weather. Due to stable working conditions, the ground source heat pump unit can be designed into a simple system with fewer components, reliable unit operation, low maintenance costs, high automatic control and long service life.

The underground buried pipes of ground source heat pump is made of polyethylene and polypropylene plastic pipe, a life span of 50 years, 35 years longer than ordinary pipes.

4.4. *Better than other traditional systems*

We chose four more popular traditional air conditioning systems and ground source heat pump systems for comparison. We consider conditions, energy consumption and environmental pollution levels. We have selected four traditional air conditioning systems and GSHPS for comparison. We consider about conditions, energy consumption and the level of environment pollution. With the comparison below, consider the energy consumption and the level of environmental pollution we can draw the conclusion that GSHPS is a much better choice as shown in table 2.

Table 2. Comparison with other traditional systems

Device type	Conditions of use	Energy consumption	Level of environmental pollution
central air conditioning and heating system	High initial investment, heating system constraints outside	Non-renewable	environmental contamination
central air conditioning and Coal-fired boilers	policy restrictions, large area needed	Non-renewable	Heavy contamination
central air conditioning and Oil-fired boiler	Restricted by the fire protection requirements, high running costs	Non-renewable	environmental contamination
central air conditioning and Gas Boiler	high running costs	Non-renewable	environmental contamination
GSHPS	High initial investment, Low maintenance cost	renewable	Free from contamination

Considering about the cost, we made another comparison of 6 kinds of conditioning systems as shown in table 3.

Table 3. Comparison of 6 kinds of conditioning systems

Device type	Total investment			function
	Initial outlay	Other cost	footing	
groundwater heat pumps	80	110	190	Cooling, heating and hot water
Soil source heat pump system	80	200	280	Cooling, heating and hot water
The sewage-source heat pump system	80	150	230	Cooling, heating and hot water
Municipal water chillers	70	150	220	Cooling, heating
Direct-fired machine	120	130	250	Cooling, heating
Boiler and Water chilling unit	160	100	260	Cooling, heating

The data above is the cost per 10,000 square meters
The data unit is 10,000 yuan

5. Limitations and deficiencies

At present, the biggest deficiency of the technology of ground source heat pump is the problem of “soil thermal imbalance”. In the south, it is mainly for cooling, and it injects heat into the ground all the year round. In the north, there is a large demand for heating in winter, and a large amount of heat is absorbed from the soil. After years of operation, the soil temperature will be unbalanced and affect the surrounding ecology.

Secondly, ground source heat pump applications will be affected by energy policies and fuel prices in different regions, different users and countries; one-time investment and operating costs will vary from user to user; groundwater utilization will be subject to local groundwater. Restriction of resources; drilling wells are relatively restricted by the site, and there must be sufficient area for drilling and burying; in design and operation, there is a greater demand for the annual hot and cold balance, and it is necessary to discharge into the underground in summer. The heat is roughly balanced with the heat taken from the ground in winter.

6. Conclusion Recommendations and Prospects

Utilizing geothermal energy can realize heating, cooling and hot-water and entertainment care.

The local government and relevant departments should formulate incentives and preferential policies for shallow low-temperature energy exploration and development as soon as possible, optimize the development environment, change the resource advantage to economic advantage, and provide more practical experiences for transforming the economic development mode.

As for the real estate development department, we should also adhere to the direction of sustainable development, promote and popularize ground-source heat pumps, which are energy efficient low-carbon environmental protection facilities, and serve the public to feedback to the society.

With the continuous improvement of ground source heat pump technology, its development prospects are considerable.

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