Research on Mid-deep Geothermal Heating System Based on Cascade Utilization

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ABSTRACT

The development of mid-deep geothermal resources has great potential, but there is still much room for improvement in the efficient and sustainable utilization of geothermal energy. In order to ensure the efficient utilization and sustainable development of geothermal resources, this paper takes a mid-deep geothermal heating project in a certain area as an example, and uses three-stage cascade utilization of geothermal water. During the whole heating season, the COP of the project system can reach 6.87, and the unilateral operating cost is relatively Compared with municipal heating, the use of geothermal heating saves 68,100 yuan in environmental treatment costs, expands the heating capacity of the system, improves the utilization efficiency of geothermal water, and fully utilizes and rationally develops geothermal resources basis is provided.

1. INTRODUCTION

China 's economic and social development has entered a large number of energy consumption stage, energy shortage has become the focus of China 's social development. The development and utilization of renewable energy and new energy occupy an increasingly important position. Geothermal energy has huge reserves on the earth. As a clean energy, it has the advantages of low carbon and environmental protection compared with traditional fossil energy. The utilization of geothermal energy in China is the most in-depth in the field of geothermal heating, which effectively alleviates the energy consumption of building heating in China [1].

The main problems in geothermal utilization are the high discharge temperature of geothermal tail water and the low utilization rate of thermal energy, which cause the waste of geothermal resources and surface thermal pollution. At present, researchers at home and abroad have done a lot of research on this. Zhang Wenshuai [2] used EnergyPlus energy consumption analysis software to compare the power consumption and geothermal water consumption of the project. It was found that the cascade utilization scheme can save 28 % energy compared with the mixed water scheme, and make full use of low-temperature geothermal water. Liu Qiming et al.[3] took a geothermal heating renovation project in Beijing as an example to realize the cascade utilization of geothermal water.

After the renovation, the operating cost per square meter in the heating season was saved by 17.28 yuan, and the energy saving effect was remarkable, which provided a reference for the diversified comprehensive utilization of geothermal water. Taking a project in Tianjin as an example, Wang Wenfei [4] et al.designed a four-level utilization system of geothermal resources by using water source heat pump and water loop heat pump. The research shows that the project adopts geothermal cascade utilization scheme. The geothermal water temperature is reduced to 22 ℃ and then recharged to the underground, which makes rational use of geothermal resources.

The development and utilization of geothermal energy should be combined with the actual situation of local geothermal resources, building use functions, heating equipment, etc. Aiming at the phenomenon that the discharge temperature of geothermal tail water is too high, resulting in the waste of resources, this paper combines the deep geothermal heating project in a certain area, according to the local geothermal resources and the end heating form, building heat load and other needs, through the cascade utilization of geothermal water, the heating effect of the project and the system energy consumption, economy and other aspects are analyzed.

2 PRINCIPLE OF MIDDLE - DEEP GEOTHERMAL HEATING CASCADE UTILIZATION SYSTEM

In geothermal heating projects, the temperature of geothermal water that can be used by a single unit or a single set of equipment is limited, which leads to the direct recharge of water extracted from medium-deep geothermal wells at a higher temperature after one use, resulting in a waste of geothermal resources. In order to solve the problem of high discharge temperature and low utilization rate of geothermal tail water, the series mode can be used to make the geothermal water through the multi-stage plate for direct or indirect heat exchange, step by step extraction, in accordance with the ' taste counterpart, cascade utilization ' energy idea, the geothermal water to the ideal temperature and then recharge to the ground, to achieve the purpose of making full use of geothermal energy, improve the utilization of geothermal resources.

The cascade utilization of deep geothermal gives full play to the advantages of floor radiant heating and geothermal heat pump. Through the floor radiant heating and heat pump technology, the recharge temperature of geothermal water is greatly reduced, thereby improving the utilization rate of geothermal energy. The geothermal water is first heat exchanged through the primary, secondary and tertiary high-efficiency plate heat exchangers for the end floor radiant heating system. When the geothermal water is heat exchanged by the secondary and tertiary high-efficiency plate heat exchangers, the heat pump technology can be used again to increase the temperature or direct heating or peak shaving.

3 ENGINEERING EXAMPLE

3.1 Project Profile

The project is a geothermal heating project in a district of Henan Province. The district belongs to a conventional energy-saving building and is a civil residence. The total construction area is 143,000 m^2, of which the residential area is 105,000 m^2, of which the high area is 43,000 m^2, the low area is 61,000 m2, the floor area ratio is 2.8, the building density is 22.14 %, and the green space ratio is 35.6 %. The required heating load is 3360 kW. The project designs three geothermal wells, including one production well and two reinjection wells (to ensure 100 % reinjection). The end of the residential area is floor radiant heating, and the supply and return water temperature of the second network is 45 °C / 35 °C.

3.2 System Flow

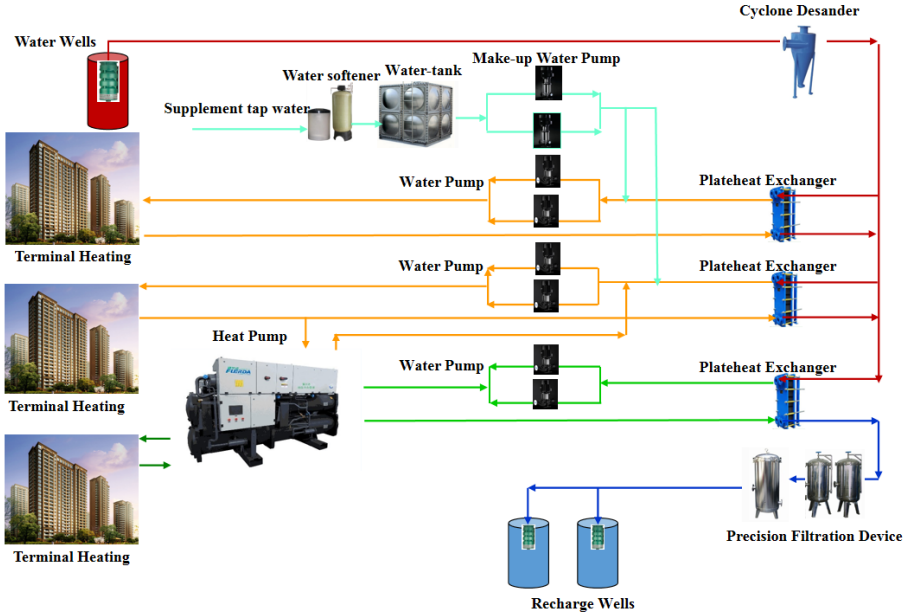
According to the heating demand of the project, the system uses medium-deep geothermal heat as the heat source for the district heating, and combines the water source heat pump to cascade utilize the geothermal water. The direct heat exchange part bears the winter load during the basic operation, and the heat pump unit can be used as a peak shaving and heating system in cold weather. Geothermal heating project system schematic diagram is shown in Figure 1, you can see from the figure system is divided into three geothermal utilization system :

(1) Direct heat transfer : geothermal water extracted from the geothermal well, the water temperature can reach 45 °C, after the cyclone desander into the primary plate for direct heat exchange with the circulating water in the secondary pipe network to provide heat load for the end of the high area.

(2) Secondary direct heat transfer : geothermal water is exchanged from the primary plate and enters the secondary plate for heat exchange with circulating water to provide heat load for low-area users.

(3)Three-stage indirect heat transfer : the geothermal tail water from the two-stage plate exchange enters the three-stage plate exchange, and the geothermal water temperature is reduced to 10 °C through the three-stage plate exchange. Finally, through the precision filtration device, the ideal temperature is recharged to the underground. When the heat source is insufficient or the heat load demand is relatively high, the heat pump host can be used to increase the temperature, provide the load for the end user, and realize the peak shaving function of the heat pump.

The project makes full use of the geothermal water cascade and recharges the geothermal tail water to maximize the utilization rate of geothermal water. The whole system is simple and reliable, saving the consumption of fossil energy.



3.3 Choice Of Equipment

The project is based on the principle of geothermal cascade utilization. According to the climate characteristics, geographical environment and building heat load demand in the region, the energy system of direct geothermal heating and multi-stage heating of high-efficiency heat pump units is adopted. The main equipment in the geothermal heat exchange station is mainly automatic control, including water source heat pump unit, high efficiency plate heat exchanger, circulating pump, submersible pump, etc., among which circulating pump and submersible pump adopt frequency conversion control. The main equipment of the geothermal heating project is shown in table 1.

Tab1 Main equipment table

equipment name	technical parameter	quantity
First stage plate heat exchanger	heat capacity：1516kW	1 set
Secondary plate heat exchanger	heat capacity：933kW	1 set
Three stage plate heat exchanger	heat capacity：1235kW	1 set
Water source heat pump host	power：251kW	1 unit
cyclone degritter	handling capacity：100m^3/h	1 unit
Precision filtration device	handling capacity：100m^3/h	1 unit
Intermediate circulating pump	power：7.5kW	3 sets
End circulating pump	power:22kW	2 sets
submersible pump	power：37kW	1 unit

4 SYSTEM ANALYSIS

4.1 Operation Effect Analysis

The water flow rate of the production well is 100m^3 / h, the inlet water temperature of the first-stage plate heat exchanger is 60 °C, the outlet water temperature is 47 °C, the available heat is 1516 kW, the outlet water temperature of the second-stage plate is 39 °C, the available heat is 933 kW, the outlet water temperature of the third-stage plate is 27 °C, the available heat is 1235 kW, the available temperature difference of geothermal water is 33 °C, and the total available heat of the geothermal system is 3850 kW. During the whole heating season, the system runs well, and the indoor temperature of the user is 20 ~ 23 °C.

4.2 Financial Analysis

The operating costs of the system mainly include electricity, labor costs, maintenance costs, water resources taxes, etc. The winter heating cycle is based on 120 days and runs 24 hours a day. The operating cost of the whole heating period is shown in Table 2. The annual operating cost of the system is 652,000 yuan, which is about 6.21 yuan / m2.

Tab2 Project annual operating costs

serial number	item	Annual operating cost (ten thousand yuan)
1	electricity expense	52.4
2	labour cost	3.6
3	water resources tax	8.0
4	maintenance cost	1.2

4.3 EnvironmEntal Analysis

The use of medium-deep hydrothermal geothermal heating system can effectively reduce the environmental pollution caused by fossil fuel combustion. Geothermal wells can provide 3850 kW of heat. (According to the emission of pollutants from coal-fired boilers, each ton of standard coal is burned to produce 2.62 tons of carbon dioxide, 0.0074 tons of nitrogen oxides, 0.0085 tons of sulfur dioxide, 0.00699 tons of solid particulate matter such as soot, and 32.71 yuan of environmental management fees). Compared with conventional coal-fired boiler heating, this project can reduce CO_2 by about 5456.28 tons and SO_2 by about 17.70 tons per year. Dust emission reduction of about 14.56 tons, NOx emission reduction of about 15.41 tons, reduce environmental governance costs of 45.5 thousand yuan.

5 COMPLIMENTARY CLOSE

Aiming at the problems of high discharge of geothermal tail water and waste of resources, the geothermal heating project has carried out three-level cascade utilization of geothermal water according to the energy consumption idea of taste counterpart, cascade utilization, which greatly improves the utilization rate of geothermal

energy and fully explores the potential of geothermal resources. Compared with gas boiler heating, the COP of the project system can reach 7.52 during the whole heating season, and the unilateral operating cost is reduced by 4.42 yuan compared with municipal heating. At the same time, the use of geothermal heating saves 45,500 yuan of environmental management fees compared with municipal heating. It can be seen that the middle and deep geothermal heating based on cascade utilization can effectively expand the heating area, greatly improve the geothermal utilization efficiency, and achieve sustainable development, which has good social and environmental benefits.

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