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Application status and development trend of geothermal energy heating technology

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Abstract: *With the rapid development of economy, people have higher and higher requirements for the quality of life. The traditional heating mode has serious pollution, uneven temperature, inconvenient installation, poor comfort, large energy consumption and low social benefits. It has been unable to meet people's pursuit of modern quality of life and the construction needs of environment-friendly and resource-saving society. The northern part of China is cold in winter, so it needs indoor heating. As the traditional heating mode has the problems of high energy consumption and environmental pollution, it needs to be updated and optimized. Based on the classification of geothermal energy heating technology, this paper expounds in detail the basic concepts, development and application status of shallow ground source heat pump technology, hydrothermal heating technology and middle-deep buried pipe heating technology. The emergence of geothermal energy heating technology has effectively solved a series of problems existing in traditional heating and has been widely used. In order to explore the heating potential of geothermal resources and its value in the "dual carbon" goal, the endowment and distribution characteristics of geothermal resources in China are briefly described, and the applicable geothermal energy supply models in different regions are given. By summarizing the existing reported research directions and related achievements of geothermal energy heating technology, from the perspective of operation mechanism and application practice, the technology development in this field is prospected.*

Keywords: *Geothermal heat pump; Heating technology; Development trend*

1. Introduction

In order to meet the growing energy consumption demand of mankind, the traditional energy structure dominated by non renewable fossil energy needs to be adjusted [1]. Although the intensity of heating energy consumption in northern cities and towns has continued to decline in recent years, the total amount of primary energy consumption is still increasing [2]. The increasing demand for energy has brought great challenges to the ecological environment, and it is an inevitable way to find a clean and efficient heating mode to meet the heating demand. Geothermal energy, as a kind of green, low-carbon, recyclable and renewable energy, has the characteristics of large reserves, wide distribution, cleanness, environmental protection, stability and reliability, etc. It is a realistic, feasible and competitive clean energy. Domestic geothermal heating applications are mainly concentrated in Tianjin, Beijing, Hebei, Xi 'an and other places [3]. The application of geothermal heating in Tianjin is relatively common. At present, the geothermal heating area has reached 5 million m2. According to the calculation of replacing coal-fired boiler heating, more than 110,000 tons of coal is replaced in each heating season, and good environmental protection benefits have been achieved [4].

Under the background of energy structure adjustment and environmental protection, it is timely and necessary to explore the feasibility and potential of medium and deep geothermal heating technology according to the application status and limitations of existing geothermal heating technology [5]. The temperature in the earth's interior flows through groundwater and lava flows to the crust 1 ~ 5 km above the ground, so that the heat can be transferred to a place closer to the ground. The hot lava heats the nearby groundwater, and the heated water will eventually seep out of the ground. The simplest and most cost-effective way to use geothermal energy is to directly take these heat sources and extract their energy [6].In the early 21st century, China began to pilot the development of shallow soil source heat pumps and groundwater source heat pumps in some regions, and then gradually promoted them nationwide. So far, China has become the world's largest user of geothermal energy resources, ranking first in the world in terms of direct utilization of shallow geothermal energy and hydrothermal geothermal energy resources, heating area, and installed capacity. Adhering to the principles of "advanced technology, environmental friendliness, and economic feasibility", this paper conducts case analysis and development potential research on the application of mid-deep geothermal heating technology in Beijing's heating market to ensure that heat is not taken from water, and water resources are not polluted. Clean development and sustainable utilization of geothermal energy [7].

2. Application status of geothermal energy heating technology

2.1. Classification and application of geothermal energy heating technology

In the field of geothermal energy heating technology, it can also be divided into the following three categories according to the different geothermal resources used: shallow ground source heat pump technology, hydrothermal heating technology and medium and deep buried pipe heating technology [8]. Traditional shallow ground source heat pump technology takes shallow rock and soil, groundwater or surface water as low-level heat source, and converts low-grade heat energy that can't be directly used into high-grade heat energy by paying a small amount of electric energy cost, thus providing the required cooling and heating loads for buildings [9]. Underground hot water is the main occurrence form of hydrothermal geothermal resources, which can be divided into three categories according to the temperature of the fluid medium. Source [10]. As shown in Table 1.

Table 1: Classification of hydrothermal geothermal resources by temperature

Classify	Temperature /°C	Fluidform	Mainapplication
Lowform	20~35	Warmwater	Agriculturalbreeding, Greenhouse, Haveabath
	32~45	Warmwater	Building, heating, Breed, greenhouse, Kangyang
	50~75	Hotwater	Buildingheating, haveabath
Mediumtemperaturetype	75~120	HotwaterorWater vapour	Oven-dry Generateelectricity, Industry
Hightemperaturetype	150	Steam	Generateelectricity

By the end of 2019, the total installed capacity of direct geothermal utilization in the world was 107.727gw, and the installed capacity of direct geothermal utilization in China ranked first in the world. Middle-deep buried pipe heating technology, also known as middle-deep ground source heat pump technology and middle-deep undisturbed geothermal heating technology, refers to a new type of geothermal heating technology in which a middle-deep buried pipe heat exchanger is arranged 2 ~ 3 km underground, the heat stored in deep rock and soil is extracted by the closed circulation of the flowing medium inside the heat exchanger sleeve, and the energy grade is further improved by the heat pump to provide heating for buildings. In addition to the shallow geothermal energy, the utilization of hydrothermal geothermal energy in the middle and deep layers also shows a good development trend. As the utilization method with the largest share of hydrothermal geothermal resources, heating and heating has a history of thousands of years. After the reform and opening up, the development and utilization of hydrothermal geothermal heating have developed greatly in scale, depth and breadth. Among all geothermal heating areas, Tianjin is the city with the largest use of geothermal heating in China. The city has 140 geothermal stations, the annual geothermal water extraction volume is 26 million t, and the geothermal heating area reaches 25 million m2, accounting for about 25 million m2 of the city's total central heating. 6% of the area

2.2. Application of hydrothermal energy geothermal heating technology

The main heat source of hydrothermal geothermal heating is groundwater. Hydrothermal geothermal heating technology is to obtain groundwater resources by excavating underground wells, convert the heat in groundwater resources, transfer it to the heating pipeline and provide it to all users. With the continuous development of science and technology, this technology is gradually developing towards large-scale and high efficiency, and has become an important technical means of new energy heating in China. At present, the application of hydrothermal geothermal heating technology in China has reached the forefront of the world, and the utilization of geothermal energy ranks first in the world. Different from wind energy, water energy and solar energy, geothermal energy will not be affected by seasonal factors, so there is no need to store energy, and its operation stability is high. Steam from geothermal energy wells and high-temperature hot water can be directly applied to production. Research shows that geothermal energy can be used for 72% of the time in a year, while hydropower generation is only 43%, and solar energy and wind energy are only 14% and 21%. Compared with this, the utilization rate of geothermal energy is the highest. Compared with fuel oil, coal-fired, and natural gas, the pollutants produced by geothermal power generation are significantly lower, and the related equipment after the construction is completed, the maintenance workload is not large, and the service life is long. Therefore, it has received extensive attention.

As the core technical direction and application mode of shallow ground source heat pump technology, the concept of ground source heat pump can be traced back to the early 20th century. However, due to the low technical level of heat pump equipment and abundant fossil fuels at that time, this technology did not attract much attention. It is very important for the system design of ground source heat pump to accurately evaluate the heat transfer capacity of buried tube heat exchanger (bhe).The research on the ground heat exchanger itself is even earlier than the ground source heat pump technology, which can be traced back to the analysis of pure heat conduction of line/column heat source and the calculation of heat transfer capacity of industrial pipelines. All the above work is based on numerical simulation. Because of the huge difference in the horizontal and vertical spatial scales of the middle and deep ground heat exchangers, the numerical simulation uses a large number of grids, and the long-time scale operation simulation takes a long time.

3. Development trend of ground source heat pump technology

3.1. Strengthen low-cost and high-efficiency geothermal resource exploitation technology

The mining and application of geothermal resources should adhere to the principle of “adapting measures to local conditions and sustainable mining”. It is necessary to combine the characteristics of geothermal resources to ensure that the mining methods correspond to the types of geothermal resources, the temperature of energy use corresponds to the temperature of geothermal resources, and the intensity of energy use matches the reserves of geothermal resources. . Geothermal is the basic heat source for heating, which meets the basic heat load requirements of the heating system. In the severe cold period, the geothermal heat can not meet the requirements of heating heat load. Heat pump peak shaving is enabled to improve the heating circulating water supply temperature and meet the requirements of peak shaving heating. According to relevant statistical data, there are a lot of hydrothermal geothermal resources in sedimentary basins, while the area of sedimentary basins in China is as high as 4.2 × Therefore, the geothermal resources in each province account for about 40% of the total area, accounting for about 104km2.

Ground-source heat pump heating technology can convert low energy into high-efficiency heat, which is in line with the development concept of energy conservation and environmental protection, and helps to alleviate the current situation of energy shortage in China. Therefore, we should attach great importance to the research and development of this technology. At present, central heating is mainly used for heating in urban areas. Since central heating is mainly realized by small and medium boilers, the actual heating often faces a lot of energy consumption and environmental pollution, which does not conform to the concept of green development. In northern China, due to the low temperature in winter, it is more critical for the development of heating methods. In the northern region, there are usually many dry geothermal wells, and the utilization and development of these wells will effectively reduce energy consumption. China has abundant reserves of hot dry rock resources. The hot dry rock resources that can be exploited account for about 2% of the total reserves in the period, which is about 170 times the total amount of hydrothermal geothermal resources. The development of hot dry rock resources has a very large space. Technically speaking, as long as the mining depth reaches a certain value, dry and hot rocks can be mined without regional constraints. Therefore, as long as China has the advanced technical means of dry hot rock development, dry hot rock heating technology will be widely promoted and applied throughout the country.

3.2. Explore the coupling energy supply mode of ground source heat pump and multi energy

The ground source heat pump is coupled with various energy sources, and the optimized configuration of multi-energy coupling system is developed, so that various energy sources can be fused, complemented and output in an orderly manner. Based on this system, the energy efficiency model of related energy equipment is constructed, and on this basis, the optimal operation scheduling platform of energy stations is established, as shown in Figure 2.

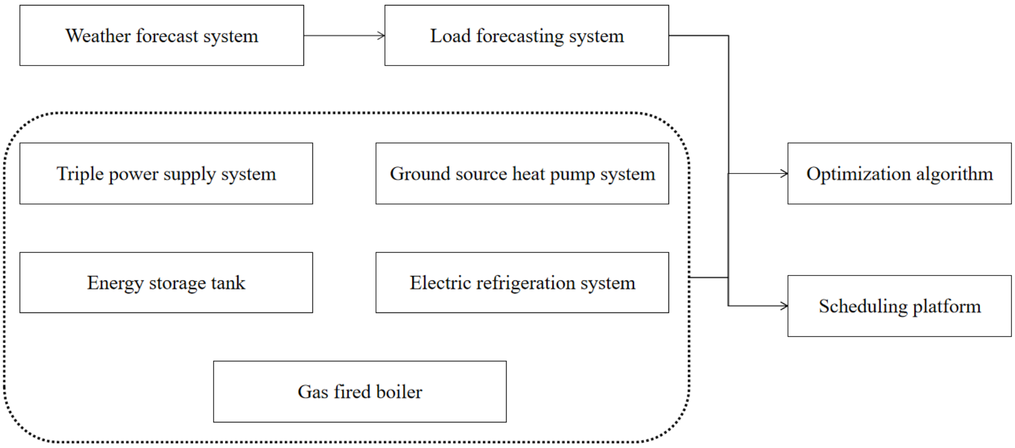

Figure 2: Optimal Operation Scheduling Platform of Energy Station

The platform establishes a simplified cost model based on the energy efficiency model of each energy subsystem, substitutes the operating parameters of the equipment and the energy price system to obtain the operating cost of each subsystem under different load rates, and obtains the operating cost of each subsystem by comparing and analyzing the operating cost. The principle of priority scheduling and the operation interval of the equipment with the appropriate load rate. From the perspective of applicability, it can be expected that the soil source heat pump in the shallow ground source heat pump technology will be the focus of application and research in the future.

Considering that the ground source heat pump system can be compared to "heat accumulator", its core operation mechanism is irrigation in summer and winter, and the stable operation of the system can be realized by maintaining the annual energy balance on the soil side. The results show that the load migration phenomenon may occur during the operation of large shallow buried pipe group, that is, the load borne by each single pipe in the pipe group is inconsistent, which is related to the soil temperature where the buried pipe is located in real time and controlled by the hydraulic distribution of the pipe network system. This provides a new idea for the analysis of heat transfer characteristics of shallow buried pipes, and is worthy of further study. Water-based heating technology is mainly restricted by the local natural resources endowment. For example, it is more appropriate to develop this technology for karst hot reservoirs with sufficient groundwater resources. In the future, efforts should be made to study its recharge safety and explore efficient recharge technology and methods. At present, the relevant research mostly uses numerical simulation or analytical solution as the simulation method, combined with the verification of the measured data, to analyze the heat transfer performance and long-term stability of the medium-deep buried tube heat exchanger, and to analyze the design parameters of the tube well, system operating parameters and geothermal properties. Sensitivity analysis of parameters, etc. At the same time, considering the general usage scenarios of the medium-deep buried pipe heating system and the shallow soil source heat pump system, the biggest difference between the two is that the former is only used for heating, while the latter needs to meet the heating and cooling needs at the same time. At this stage, through technical research, a cascade energy utilization device and an information automation management and control system have been developed, which continuously promotes China's geothermal mining technology to move closer to the world's advanced level

4. Conclusions

With the steady development of China's economic construction and the continuous advancement of urbanization, the emergence and vigorous development of geothermal heating technology can inject

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new vitality into the field of building heating. At present, the shallow buried pipe ground source heat pump heating technology is the most widely used and mature engineering application form. Therefore, shallow geothermal energy will make a great contribution in the process of achieving the goal of peak carbon dioxide emissions and carbon neutrality. For geothermal heat pump heating system, the heating unit cost is 15.41 yuan /m2 when geothermal wells are included, which is equivalent to that of coal-fired boilers, and only 7.70 yuan /m2 when geothermal wells are excluded, which is only about 60% of that of boilers, indicating that the peak-shaving heating cost of geothermal heat pump with geothermal tail water recovery is very low. The geothermal heat pump peak-shaving heating improves the utilization rate of geothermal heat, and at the same time reduces the temperature of geothermal drainage, so as to meet the environmental protection emission standards. Geothermal heat pump heating instead of coal-fired boiler heating has the benefits of water saving, coal saving and environmental protection. As a clean energy, geothermal energy is of great practical significance and value when applied to heating projects. Therefore, relevant departments and enterprises need to pay enough attention to effectively improve China's heating efficiency and quality. At the same time, it is making continuous efforts in the upstream and downstream design, construction, operation and maintenance of the technical field to achieve greater progress and contribute to national development, social progress and the improvement of people's living standards.

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