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Energy Saving Measurement and Verification Method of Ground Source Heat Pump System based on Numerical Simulation and Control of Thermal Equipment Process

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Abstract: In this paper, the energy-saving measurement and verification of ground source heat pump system(GSHPS) are studied and analyzed by means of numerical simulation(NS) and control of thermal equipment process. The classification of GSHPS and the composition of energy consumption(EC) of GSHPS are briefly introduced; Through the NS and control of thermal equipment process, the EC calculation model of GSHPS is proposed. Finally, the energy conservation of GSHPS is measured and verified based on the NS of thermal equipment process. The test results show that the measurement accuracy of the method proposed in this paper is high, which has important reference significance for the energy conservation optimization of GSHPS based on the NS of thermal equipment process in the future.

1. Introduction

At present, land-based heat pump projects operating in China are developing rapidly. However, the basic technical requirements for developing the ground source heat pump industry are not complete, especially the information and specifications for measuring and certifying the energy conservation of heat sources are still needed. It is very important to promote the metrological certification methods and standard design capabilities suitable for the implementation of heat source energy conservation renewal services and energy management project contracts. Therefore, this paper presents a method based on NS and control of thermal equipment process, and studies the energy-saving measurement and verification method of GSHPS.

Many scholars at home and abroad have studied and analyzed the energy-saving measurement and verification method of GSHPS based on the NS and control of thermal equipment process. Minqiang P aims to analyze and compare the fluid flow and heat transfer characteristics of microchannel heat exchangers with different notches. It is found that the microchannel heat exchanger with notch has better heat transfer performance and smaller pressure drop in the flow range [1]. Kastrinos Jr described the field measurement and quantification of the influence of advection groundwater flow on the thermal performance of the column well heat exchanger. Geothermal heat pump system installers and practitioners rarely quantify the advection groundwater flow, and usually mistakenly believe that if a large amount of groundwater is encountered during the drilling of SCW (or other types of borehole heat exchanger), the groundwater horizontal flow flow is also very high. Therefore, compared with the case of simply conducting heat transfer, it is allowed to reduce the design borehole length. Researchers studied the advection heat exchange potential of groundwater in the vertical device by introducing and circulating bromine tracer solution and monitoring its concentration within five days [2].

According to the international energy-saving effect measurement and certification regulations, this paper gives the basic concept of energy saving of GSHPS; According to the design stage and operation stage, the calculation method and formula of energy saving of GSHPS are discussed; Aiming at the GSHPS with operation test data, a NS and control method of thermal equipment process is proposed; SPSS software is used to analyze the operation data of the ground source heat pump reconstruction project, which plays a certain reference and promotion role in making up for the lack of relevant specifications of the ground source heat pump industry and the relevant renewable energy saving measurement standards [3-4].

2. Research on Energy Saving Measurement and Verification Method of GSHPS

2.1. Classification of GSHPS

GSHPS does not refer to a specific system. In a narrow sense, it can also be divided into three categories. The first is to take the soil as the "source", that is, to take heat from it and release heat to it, and we can also divide it into horizontal and vertical buried pipes. The principle of groundwater ground source heat pump is essentially similar to the first one, but it is to change the heat exchange medium in the above content from soil to groundwater, and use groundwater to bear the corresponding cooling capacity or heat. After using the groundwater, certain measures need to be taken to avoid direct discharge. In order to protect the environment, reinjection is required. Because this system form does not need large-scale drilling, the cost is lower; Moreover, due to its early development, the technology is relatively perfect; However, this system form does great damage to the external environment of the system. Therefore, in recent years, the development of this system form is generally limited; When using this form in some special areas, groundwater must be protected according to relevant standards [5-6]. Surface water ground source heat pump is to change groundwater into water resources that are in direct contact with the atmosphere, such as river water. In this form, because surface water does not involve underground structure problems, the used water resources can be directly discharged to the original place, so the system is also divided into open and closed types. The open type is to directly design the surface water into the pipeline to participate in the circulation, and the closed type is not in direct contact with the surface water [7].

2.2. EC Composition of GSHPS

Ground source heat pump unit is usually composed of four parts, namely compressor, condenser, expansion valve and evaporator. It consumes electric energy to complete the exchange of cooling capacity (heat). Compressor is the main energy consuming equipment [8]. The circulating water pump on the user's side will deliver cold water or hot water from the unit to the end of the user's air conditioner. So as to achieve the purpose of transporting and transferring the cooling capacity (heat), and finally air-conditioning the indoor space. The water pump connects the heat pump unit with the end user of the air conditioner to transmit power to the user's side water system.

The function of the circulating water pump at the buried pipe side is to realize the water circulation at the buried side, provide power for the circulating medium at the buried pipe side through the circulating water pump, realize the cold and heat transfer from the heat pump unit to the buried pipe side, and then achieve the purpose of transferring the indoor cold and heat and the heat between the buried pipes. The water pump connects the heat pump unit with the ground source side to provide power for the water system at the buried pipe side. In the GSHPS, it usually appears in the make-up loop for the air conditioning system 9-10].

Constant pressure expansion device is used in heating and air conditioning systems as pressure stabilizing expansion and water replenishment equipment. It is usually used for constant pressure water replenishment of air conditioning system and constant pressure water replenishment of ground source side system. The differential pressure automatic filter can remove many impurities in the water through the filter screen in the instrument, such as floating objects and particles in the water. In this way, it can effectively reduce the turbidity of the water body, achieve the purpose of purification, inhibit the emergence of pollutants and algae in the water body, and ensure the working environment of precision equipment in the system [111-12]. Due to the intelligent design of the instrument, when the instrument works normally, after the water enters the body, the detector in the body can monitor the mixing degree of the water body, and the sewage will be discharged when necessary. It also exists in the loops at the air conditioning side and the ground source side at the same time, which consumes electric energy to drive.

Terminal air-conditioning equipment refers to the terminal devices that regulate the cooling and heating of the regulating room. There are a wide range of categories, including not only power consumption devices such as fan coil, but also non power consumption devices such as floor heating circulating coil [13-14]. In general, the type of energy consumed by the GSHPS is electric energy. When this paper explores its energy saving, the most important thing is the energy saving of power consumption. In short, the GSHPS can be summarized into three aspects, which are explained in detail below. The schematic diagram is shown in Figure 1:

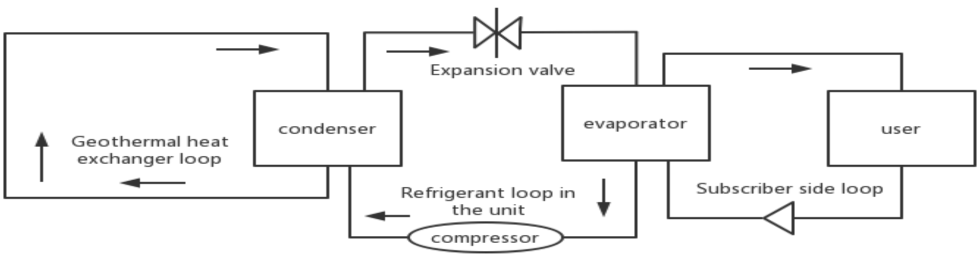

Figure 1. Schematic diagram of GSHPS

Outdoor buried pipe heat exchanger system. The loop of buried pipe heat exchanger refers to the outdoor buried pipe part. The function of this part of the loop is to realize the heat exchange between the unit and the soil. The cooling capacity or heat of the indoor air conditioning area passes through the indoor loop and refrigerant loop, and is finally transmitted to the earth through this loop. The energy transmission medium in the loop is water, which usually includes an appropriate amount of antifreeze. The pipe is generally high-density compressed plastic pipe, The whole heat exchange process uses the equipped circulating pump to supply power [15-16].

Indoor loop. The purpose is to provide the necessary cooling capacity or heat to the room, and realize the control of indoor temperature and humidity through the indoor end. The loop energy transmission medium is generally water, and the circular flow of the medium and energy distribution are realized through the circulating water pump. The principle of this part is the same as that of the indoor loop of the chiller air conditioning system.

3. NS and Control of Thermal Equipment Process

3.1. Energy Calculation Simulation Method

Because there is no operating data, a standard must be established to compare the resource consumption of ground source heat pump devices with it before implementing the energy-saving plan. Now the following regulations are made: in summer, the EC of electric refrigeration chillers is taken as the basis of air conditioning EC in summer; In winter, the coal consumption of coal-fired boilers is taken as the EC basis for heating in winter [17].

3.2. EC Calculation Model of GSHPS

Due to the lack of scalable operating system data, energy saving can be simulated by simulating relevant data in the design concept. Under the same use conditions, the house uses electric air conditioning as the basic energy source and ground source heat pump for heating in summer / winter. Cold air, heat source and other settings to calculate heating power and compare it with heating power to calculate energy saving [18].

The EC of GSHPS mainly includes three parts, and its total EC is:

$$G_r = \frac{Q}{EERS} = \sum G_i = G_1 + G_2 + G_3 \tag{1}$$

GR is the power consumption of air conditioning; Q is the total cooling capacity; Eers is the performance coefficient of GSHPS. Of which:

$$G_1 = Q \times GL_1 \tag{2}$$

The energy savings of the GSHPS include the sum of the energy savings in the cooling season and the heating season, namely:

$$\Delta G = \Delta G_r + \Delta G_L \tag{3}$$

$$\delta_L = 1 - 1.75824 \times (GH_1 + GH_2 + COP^{-1}) \tag{4}$$

The energy saving rate of GSHPS in summer is:

$$\delta_R = 1 - EERS^1 \times (GH_1 + GH_2 + COP^{-1}) \tag{5}$$

Δ L refers to the energy saving rate in winter; Cop is the coefficient of performance. δ R refers to the energy saving rate of the system in summer; That is, the comprehensive performance coefficient of the cooling device of eers-1.

4. Energy Saving Measurement and Verification Analysis of GSHPS based on Thermal Equipment Process NS

The project data is the comprehensive data of the whole system, which is not divided into classified data such as pump EC and unit EC in detail. Therefore, in the calculation, the whole system is taken as the boundary, and the comprehensive data of the system is used for analysis. The data selection takes the power consumption of the system as the dependent variable, and the factors affecting the dependent variable take the outdoor daily average temperature and indoor daily average temperature as independent variables to screen the data provided by the owner and retain the required data, The data statistics period is from November 15 to December 4, and the data statistics results are shown in Table 1 and Figure 2.

Table 1. Statistical table of data

Time	11.15	11.16	11.17	11.18	11.25	11.26	11.27	11.28	12.03	12.04
Outdoor dry bulb temperature (℃)	-2.5	-1	-1	-0.5	3	1.5	2	4.5	1	0.5
Indoor daily average temperature (℃)	21	20.5	20.6	21.2	21.8	22	21.4	20.8	20.9	21.6
Daily power consumption (KWH)	5460	5105	5085	4875	4325	4565	4480	4160	4620	4645

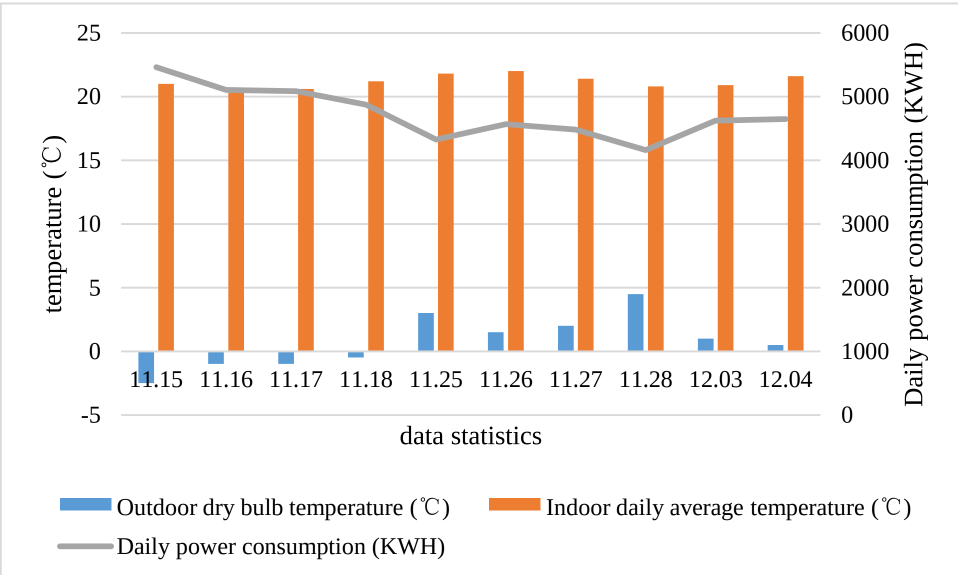

Figure 2. Statistical chart of temperature and daily power consumption data

In the collected data, outdoor dry bulb temperature and indoor daily average temperature are the influencing factors of the GSHPS, and the obvious bad points have been eliminated from the statistical data. Input the data in Table 1 into excel as SPSS reading file, and input the outdoor dry bulb temperature, power consumption and indoor temperature, power consumption into excel as SPSS reading file.

Research on energy-saving measurement and verification method of GSHPS based on NS and control of thermal equipment process; during the performance evaluation of buildings, the EC data of buildings is the basic basis for investigating and judging the energy-saving effect of buildings. This paper mainly discusses the EC of HVAC system energy equipment in Datong project when choosing different schemes, and compares and analyzes the final conversion results based on the consumption of electric energy. Table 2 and figure 3 show the EC measurement results of ground source heat pump units in summer.

Table 2. EC calculation table of ground source heat pump unit in summer

Outdoor temperature	24	25	26	27	28	29
Power ratio (%)	0.43	0.45	0.46	0.48	0.49	0.50
Shaft power (kw)	235	245	251	262	267	273
Frequency number n (H)	69.00	54.00	59.00	46.00	47.00	36.00
Power consumption (kW ·h)	16182	13253	14802	12042	12561	9817

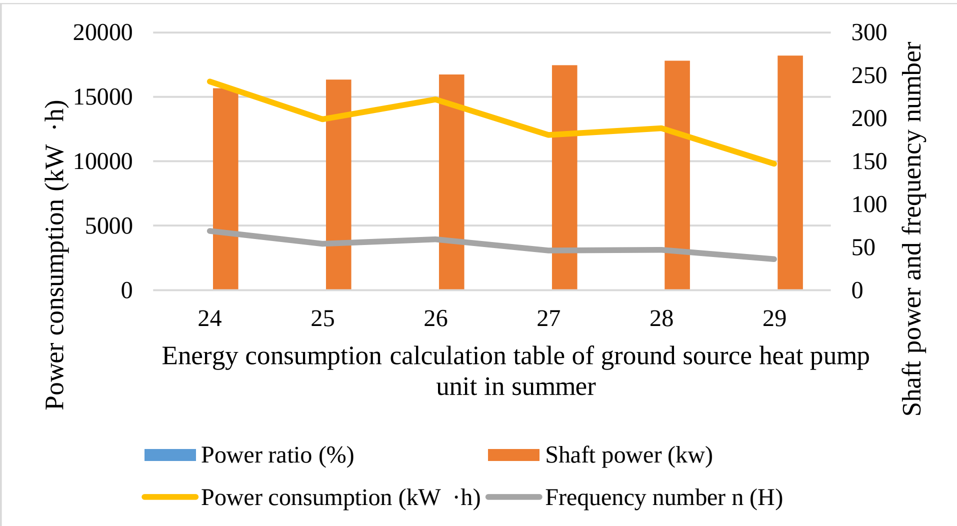

Figure 3. EC analysis of ground source heat pump unit in summer

From the above statistical results, it can be seen that in summer, without paying attention to the wind power of the wind turbine and the power of the water pump, the ground source heat pump saves 27% energy than the air source heat pump, and the energy-saving effect is not significant. However, considering the power consumption of fans and pumps, ground source heat pumps save

12.9% energy than air heat pumps respectively.

As the outdoor calculated temperature in winter in Datong is -18.9 ℃, the efficiency of air source heat pump is greatly reduced at this temperature, so it is not suitable to be used as the building heat source of this project. According to local conditions, there are municipal heating and self built boiler houses that can be accessed. Obviously, compared with municipal heating, self built boiler houses not only occupy the use area of buildings, but also have a boiler gas efficiency of less than 1.

5. Conclusion

Based on the NS and control of thermal equipment process, this paper studies and analyzes the energy-saving measurement and verification of the GSHPS, and has achieved good results, but there are also shortcomings. The analysis data of the ground source heat pump application projects that can be collected is not sufficient. Multiple project data should be selected for analysis to obtain universal influencing factors, making the energy-saving measurement method more instructive and accurate; The source of data may be inaccurate. When conditions are met, a special unit with monitoring qualification can carry out measurement and statistics, and introduce and record in detail the methods and instruments used in the statistical process, so as to make the whole data acquisition process more objective and accurate; For the ground source heat pump project in the design stage, due to the lack of actual data, the accuracy of the energy savings calculated by the theoretical model cannot be verified. It is suggested that the accuracy of the model should be verified by the measured data for different types of energy systems in the future.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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