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Experimental investigation of thermal performance of a ground source heat pump system for spring season

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ABSTRACT

Limited fossil fuels for heating and cooling building as well as air pollution make people to use and utilize renewable energy, i.e., solar energy and ground heat energy. Ground source heat pump is regarded as the future and attractive energy-saving system using for the whole society. In this paper, a ground source heat pump system with the power of 16.6 kW has been established firstly, and then the soil temperatures of four buried depths have been experimentally tested, finally the values of COP in this system have been calculated by the testing parameters. The results show that the soil temperature changes slightly from 11:00 to 18:00 in the testing six days. The results also show that the values of COP in this system range from 1.56 to 2.01, which is lower than other system. The present paper contributes to the knowledge of the soil temperature distribution characteristics and COP value for a real system in a spring season, when the system has a small building load.

1. Introduction

Energy and environment are the main issue for all fields in the modern society. How to save energy and protect environment is the key project for the scientific scholars. Renewable energy, i.e., solar energy, wind energy, and ground heat energy, is very important for perfecting energy construction [1–4]. Ground source heat pump (GSHP) system has been widely utilized in Chinese and global building because of its energy-saving and green performance, also this system has been applied in every walk of life. GSHP can play an efficient role to cool and heat building [5,6]. In general, GSHP consists of three contributions as following: heat pump unit, buried pipe, and ground heat exchanger. It is obvious that each part has a direct effect on the system's performance and efficiency. Therefore, the higher efficiency of GSHP is the most mean to address problems resulting from fossil fuels in different areas. Coefficient of performance (COP) value of GSHP system is an important parameter reflecting the good and bad performance of the system, and is a new and emerging technology in the energy-industry field.

In the past decades, most studies have concentrated on improving the efficiency of the GSHP system. Dehghan [7] has investigated the thermal performance of vertical spiral ground heat exchangers by the experimental and computational methods. During this study, the different configurations of spiral exchangers have been tested for 150 h. Jonas et al. [8] have investigated simulated the characteristics combined parallel solar thermal and ground or air source heat pump systems. Li et al. [9] have introduced a nearly zero energy building with a general presentation of its energy system, then analyzed this system operation and soil temperature variation from November 2014 to September 2015 based on real operation data. Lucia et al. [10] have reviewed the thermodynamic approach of the GSHP system. Lu et al. [11] have finished the economic analysis of vertical ground source heat pump systems in Melbourne. The results show that Air Source Heat Pump (ASHP) is marginally more financially attractive than a GSHP system for a design life of 20 years, but GSHP system provides more savings than ASHP system for a design life of 40 years. Adamovsky et al. [12] have investigated the changes in energy and temperature in the ground mass with horizontal heat exchangers. Noorollahi et al. [13] have studied the economic analysis of a ground source heat pump for supplying energy for a greenhouse in Iran. Luo et al. [14,15] have studied the operation management of borehole heat exchangers for a large-scale hybrid ground source heat pump system in China. Also, some scholars have performed the experimental and simulated work for the GSHP system [16–19]. Ying et al. [20]. have studied the characterization of the effects of borehole configuration and interference with long term ground temperature modelling of ground source

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Fig. 1. Photo of the ground source heat pump located at Wuhan University of Science and Technology.

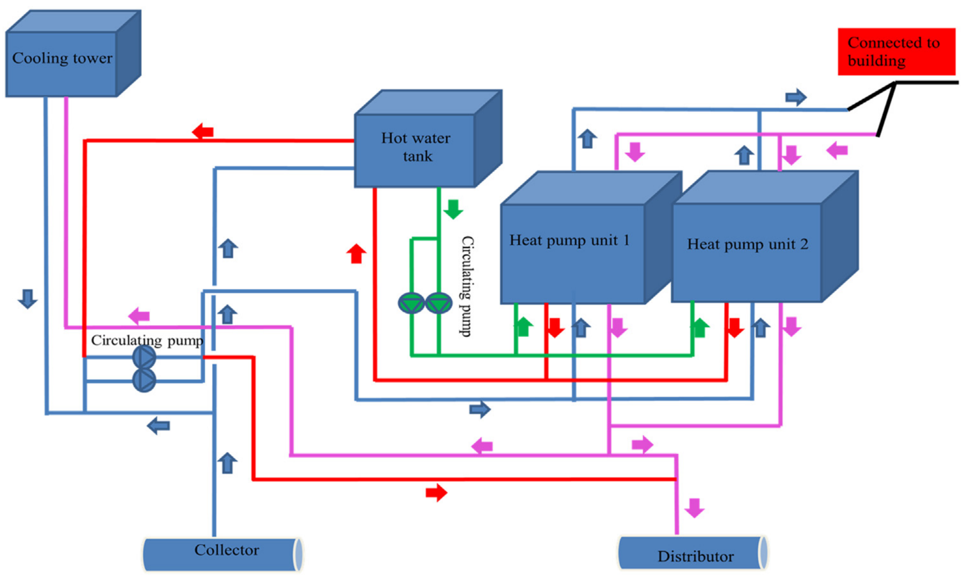

Fig. 2. The flowchart diagram of the GSHP system.

heat pumps. For building, the GSHP system has been used for the energy-saving and optimal control [21–23].

In this paper, experimental setup of a real GSHP system has been established and described firstly, and then the distribution characteristics of soil temperature in different buried depths have been tested. Also, the values of COP for this system in different conditions have been calculated by the testing parameters. All the experimental parameters are tested in following conditions: six days (April 11, 2017–April 16, 2017) and eight time ranges (11:00–18:00). The aim of this paper is to obtain the temperature distribution and the value of system's COP, and this study can provide a reference to improve and perfect the GSHP system's efficiency.

2. Experimental setup description

In order to test the efficiency of the system, GSHP setup has been established in Wuhan University of Science and Technology, China, and a photo of this system has been shown in Fig. 1. Fig. 2 shows the flowchart diagram of the whole GSHP system. It can be seen from this figure that there are nine contributions in the system, that are cooling tower, hot water tank, heat pump unit, circulating pump, pipelines, collector, distributor, building, and ground heat exchangers. Ground heat exchangers and the buried pipe have been shown in Fig. 3. In the summer season, the heat flux transfers from the indoor to the ground, and in the winter season, the heat flux transfers from the ground to the indoor. However, in the spring season, the heat flux for different days is free in the heat transfer direction.

It also can be seen from Fig. 3 that this GSHP system has two kinds of heat exchangers, which are two horizontally spiral and five vertical U-tubes exchangers. The arrow shown in this figure represented to the flow direction of the heat fluid in the spring season. Fig. 4 shows the location of temperature sensors in different buried depths. It can be seen from the figure that there are four temperature sensors located at the buried pipeline, that is 10 m, 20 m, 40 m, 100 m.

In this paper, the experimental work firstly has been finished. In the summer season, the cooling tower is open and the hot water tank also needs to open in the winter season because the building load is very big. The basic testing parameters in this paper are following: operation condition is in spring season of Wuhan city with the highest temperature of 301 K and the lowest temperature of 281 K. The heating power of the heat pump unit is 8.3 kW. The depth of the buried pipe is 100 m with a diameter of 100 mm. The flow mass of the fluid in the building is 8.0 m^3/h for the standard condition. Cooling tower and hot water tank are closed due to the