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Application analyze of a ground source heat pump system in a nearly zero energy building in China

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ABSTRACT

Ground source heat pump system has been widely utilized in office buildings in China. Its application in nearly zero energy office building pioneers an innovation in China. This paper focuses on real operation introduction and performance analysis of a Ground Source Heat Pump (GSHP) system in a nearly zero energy building (NZEB) with different HVAC terminal for the first time. The paper introduces the nearly zero energy building with a general presentation of its energy system, then analyzes GSHP system operation and soil temperature variation from November 2014 to September 2015 based on real operation data. The analyses manifests that the HP2# worked under an average COP of about 5.4 and 5.0 in summer and winter, respectively and HP1# worked under an average COP of 3.9 and 3.0 in winter and summer respectively. In the winter season floor and ceiling radiation system has a relatively higher performance than radiator system due to low supply water temperature going into the room. Room temperature keeps above 20 °C in the winter season and fluctuated around 26 °C in the summer season. Good room temperature and COP proves the GSHP system functions excellently. Soil temperature could recover in one year operation.

1. Introduction

Reducing energy consumption in the building sector is one of the most important measures for global energy reduction and climate adaptation. Nearly/net zero energy building is one promising path leading to further building energy conservation. Research regarding design methodologies, technologies, monitoring method or evaluation process et al. of nearly zero energy building has been carried out either by researchers or constructors.

Zhihua Zhou et al. [1] published articles regarding operation performance of a "net zero energy building" in China, in which they manifested challenges of nearly zero energy building development, and gave suggestions for nearly zero energy building to realize design target in China. Muhammad Waseem Ahmad et al. [2] focused on available technologies for building energy metering and environment monitoring in nearly zero energy building by analyzing their advantages and disadvantages. Limei Shen, Xiwang Pu et al. [3] presented the first study on thermoelectric technology applications in NZEB, which shows the system could satisfy cooling and heating requirement outstandingly, and improves annual solar generation 767 kWh (34%). It provides a progress way to apply thermoelectric technology in NZEB. ShengZhang [4] proposed a multi-criterion renewable energy system design optimization method for NZEB under un-certainties, Shicong Zhang [5] introduced the operation performance of ground source heat pump in CABRNZEB, and analyzed its good performance in summer season.

China has the biggest GSHP market, and the fastest GSHP yearly application in the world. Due to high performance and environmental friendly properties, GSHP system has been recognized as the best choice of energy system of buildings. Researches on ground source heat pump(GSHP) system goes to two directions, one is numerical simulation work [6–10], for purposes of proper GSHP design guidance, optimizing system operation especially for a combined system, longer term system operation observation, evaluation of special types of heat exchanger simulation. The others focus on system application effects, in different application environments, control strategies or climate zones [11–20].

A large borehole ground source heat pump system was adopted in a Nearly Zero Energy Building (NZEB) in Beijing, China. It is a 4-floor office building, with a floor area of about 4000 m^2 and occupancy of approximately 180 full-time employees (see Fig. 1). Adhering to the design principle of "passive building, proactive

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Fig. 1. Front view of the nearly zero energy building.

optimization, economic and pragmatic", the project integrated cutting-edge building technologies and set up the ambitious annual energy consumption cap of 25 kWh/(m^2.a) (including heating, cooling and lighting energy) with an acceptable indoor environment.

This article focuses on performance analysis of a GSHP system in a nearly zero energy building with different HVAC terminal through a whole year (2014.11–2015.9) based on real operational data, including a heating period and a cooling period. Important parameters such as inlet and outlet water temperatures in the primary and secondary side, coefficients of performance in summer and winter season, as well as typical days that are presented to help understanding system performance with different terminal in a low heating and cooling load building. Suggestions are provided to help optimize GSHP system operation after real operation data analysis.

2. Building introduction

The NZEB integrated cutting-edge building technologies and strived to lay a foundation for China's NZEB standard. The building adopted prominent thermal insulation to reduce the cooling and heating energy demands. It uses vacuum insulation board with a thermal conductivity of 0.006 W/(m^2 K) as insulation. The window has a K value of 1.0 W/(m^2 K) which uses vacuum glass and internal electrical shading design. EPS with a thermal conductivity of 0.03 W/(m^2 K) is used in the ceiling. Careful attention has been paid to the detailed design to avoid the thermal bridge and to maintain good air tightness.

There are different function rooms distributed on each floor. Four floors have almost the same structures, including office room and meeting rooms, whereas the difference is the scale of the meeting rooms. The meeting room on the first floor could maintain almost 50 people, and the one on the fourth floor is capable of 150 people.

3. Energy system description

3.1. Energy system

The building serves as an experimental building in several sections, such as renewable energy application, building envelop, indoor environmental comfort, HAVC terminals and others.

Solar thermal combined with ground source heat Pump system works as the main energy system of this building. As described previously, each floor has office room and meeting rooms respectively, and considering the demonstration purpose, different heating and cooling terminal are adopted. Water source variable refrigerant volume (WS-VRV) system and radiator system are utilized for the first and fourth floor in summer and winter respectively, whereas the second and third floor employs floor and ceiling radiation systems respectively.

3.2. Operation strategy

One absorption chiller and two GSHP units are involved in this energy system that are shown in Fig. 2. In summer season when the solar radiation is sufficient, the absorption chiller, driven by hot water (≥70 °C) which was produced by two types of solar collection systems, processes the ventilation load of the 1st and 4th floor, otherwise (hot water temperature < 70 °C), a 50 kW HP (GSHP1#) will serve the function of absorption chiller instead, when the switching operation of the two machine unit is controlled by BAS (building automation system). On the other side, room cooling load of the first floor is provided by (WS-VRV) system, the fourth floor is served by (WS-VRV) and water loop heat pump (WLHP) system respectively. On the other side, GSHP with 100 kW provides ventilation and cooling load of the 2nd and the3rd floor. In the winter season, GSHP1# provides heating and ventilation load of the 1st and 4th floor except for the meeting room which was supported by WLHP if meeting room is in use. The other 100 kW GSHP (GSHP 2#) unit is in place to meet heating and ventilation demands from the radiant terminals for the 2nd and the3rd floor. Performance parameter of the two heat pump is shown in Table 1.

4. Borehole system

Borehole tube is adopted as heat source or heat sink for the system in winter and summer, and cooling tower is set as an auxiliary cooling system of borehole in summer. Borehole distribution is illustrated in Fig. 3. Seventy boreholes are placed in open space of the demo building boundary, with 20 for double U-tube and 100 m-depth to the south, and 50 for single U-tube with depth of 60 m to the north and west. These boreholes are grouped in 7 sub-loops, where ground water join in a header before entering the building, and water inside the boreholes exchanges heat with the ground. Since very high temperature and humidity weather and relatively good U-tube water temperature in summer, cooling tower is out of use in this system now.

Water in the U-tube has few ways entering the building due to different season and operation modes, in the summer season, water

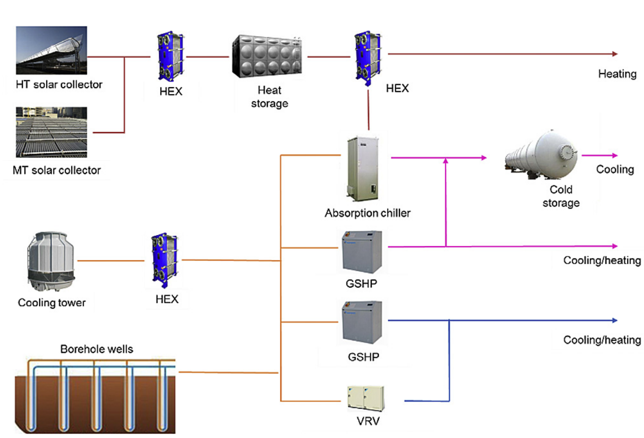

Fig. 2. Heating and cooling system of the NZEB building.