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Application and Experiment on Solar-Ground Coupled Heat Pump with Heat Storage

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ABSTRACT

A demonstration project of Solar-Ground Coupled Heat Pump with Seasonal Storage (SGCHPSS) was set up and a data acquisition system was developed. In the SGCHPSS system, the abundant solar energy in summer was stored into the underground soil, in order to rise the soil temperature as the heat source for the Ground Coupled Heat Pump (GCHP), and to enhance its efficiency. That realized solar energy transfer utilization through the energy inter-seasonal storage. The phase change heat storage was designed to store and balance solar energy use in the short-term.

Primary experiment on the SGCHPSS system was obtained, including the solar collection temperature, solar collection power and storage power.

1. INTRODUCTION

Energy, environment and energy saving has been the urgent and important task faced by the whole world. It is necessary to strengthen the utilization of new energy and renewable energy, and reduce the consumption of conventional energy. The energy storage in short-term or long-term could realize energy complement and reuse, and increase energy efficiency and supplement. The solar energy storage and its inter-seasonal heat storage would enhance the solar energy utilization deeply and wildly, and to bring about the solar use controllable and mastered.

Central Solar Heating Plant with Seasonal Storage system (CSHPSS) mainly uses certain storage media, such as thermal water, gravel-water, buried pipe or aquifer heat storage style for solar energy storage, to compensate for solar radiation and seasonal changes of heat demand, and enhance solar energy utilization more efficiently[1~2]. In Europe, the proportion of solar energy to the total heat demand had reached to 40~60% in CSHPSS system. CSHPSS system has become more popular, with very high development potential and the first choice for large-scale use of solar energy system in the world, and a number of demonstration projects have been built [3~4].

Ground-Coupled Heat Pump (GCHP) has being widely used as energy saving technology with high efficiency. Some study on the energy storage through the underground heat exchanger and the heat transfer in soil in the GCHP system was carried out [5~8].

2. SOLAR-GROUND COUPLED HEAT PUMP WITH SEASONAL STORAGE (SGCHPSS) SYSTEM

2.1 SGCPSS System Introduction

In Tianjin, a demonstration project of Solar-Ground Coupled Heat Pump with Seasonal Storage (SGCHPSS) was set up with solar energy utilization, phase change heat storage, inter-seasonal energy storage and Ground-Coupled Heat Pump. The building has 3 floors with total building area of 5700m^2. It contained conventional air-conditioned areas, such as office, library, conference room, and leisure areas like basketball hall, table tennis room, and weight training area. Especially, there was an entertainment area with swimming pools, bathing room, which needed year-round hot water supply. The design heat load was 310kW in winter, hot water load was 180kW in winter, and cooling load was 460kW in summer respectively. Figure 1 was the schematic diagram of the SGCHPSS system.

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SGCHPSS system comprised solar heat collection system, Ground Coupled Heat Pump (GCHP) system, hot water and terminal system. In SGCHPSS system, the solar collector was 600 m^2 with flat plate, heat storage water tank 15m^3; GCHP system had 2 sets of water-water Water Source Heat Pump, which burdened large space heating & air-conditioning load, such as first floor hall, swimming pool, basketball hall; the heating & air-conditioning load for the 2, 3 floors were respectively burdened by small-scale water-air Water Source Heat Pump Units. Underground U-type heat exchanger consisted of 60 double U foundation piles with 20m depth and 48 double U boreholes with 120m depth, and 8 boreholes in it was for energy storage. As shown in Table 1.

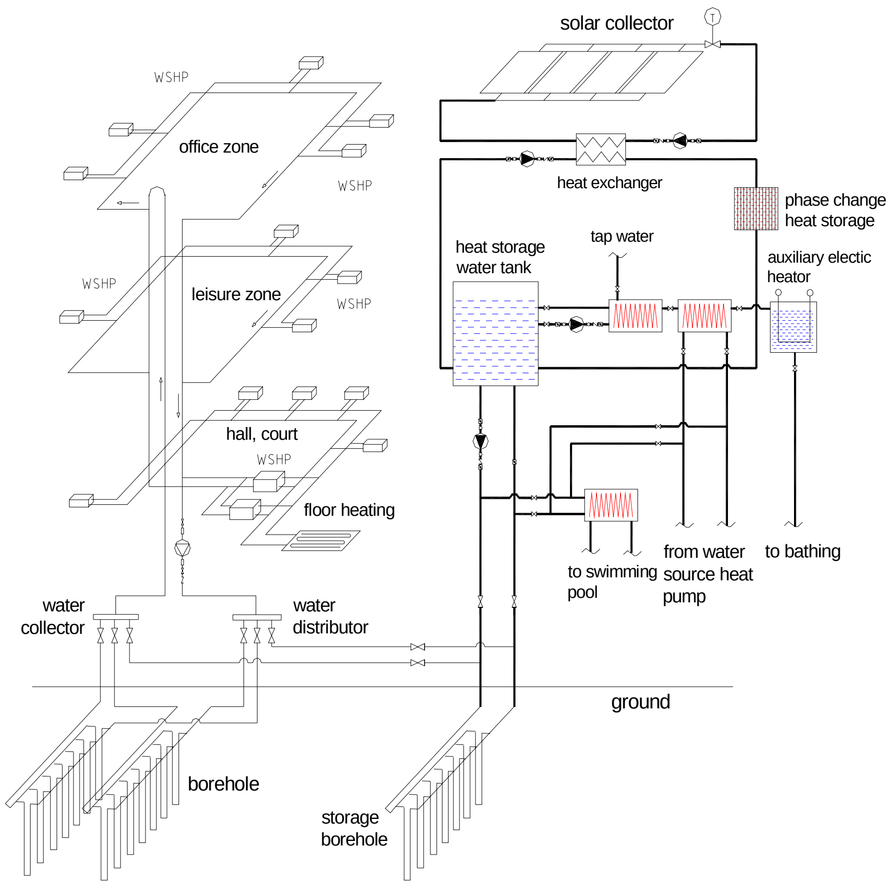

Figure 1: Scheme of Solar-Ground Coupled Heat Pump with Seasonal Storage (SGCHPSS).

Table 1: Parameter of Boreholes and Storage Borehole

Borehole type	Heat exchanger type	Number	Depth (m)	Length (m)
Borehole	Double U	40	120	19200
Storage borehole	Double U	8	120	3840
Foundation pile	Double U	60	20	4800
Sum	/	108	/	27840

2.2 Solar Heat Collection and Inter-Seasonal Energy System

The SGCHPSS system combined solar hot water system, solar inter-seasonal heat storage and GCHP systematically. To make full use of solar energy and underground energy, the solar inter-seasonal heat storage in summer through underground heat exchanger was designed to be integrated with Ground-Coupled Heat Pump (GCHP). The abundant solar energy in summer could be stored into the underground soil, in order to rise the soil temperature as the heat source for the GCHP in winter, and to enhance its efficiency. That realized the solar energy transfer utilization.

The phase change heat storage was designed to store and balance solar energy use in the short-term.

2.3 Data Acquisition and Measurement

A PLC data acquisition system was developed for the SGCHPSS demonstration project, which acquired and measured the data of system temperature, flow-rate and electricity consumption. It included 20 temperature points, 4 flow-rate points and 3 power points. Computer data acquisition and monitor were compiled based on Industrial Control Configuration Software MCGS (Monitor and Control Generated System) run on Microsoft's platform. After a series of treatment specified by the user, MCGS system provided data acquired and measured though a variety of ways, such us animation display, alarm processing, process control, real-time curve, report output.

3. EXPERIMENT ON SOLAR COLLECTION TEMPERATURE, HEAT STORAGE AND POWER

The SGCHPSS demonstration project started operation in November 2007 after set up. The system run 10 hours from 7:30am to 17:30pm every day.

Figure 2 was the variation of solar collected power and inlet & outlet temperature of heat storage water tank from the heat exchange with solar collectors. On Sep. 12, 2008, the inlet temperature to the heat storage water tank increased to a peak at first, and then began to decrease in a day. And the solar collector achieved a maximum power of 78kW, which appeared at about 12:30.

From 11:30 am to 15:00 pm, the inlet temperature of heat storage water tank was higher than 50□, which was a design temperature switched to store the solar superabundant heat into underground soil. This showed there was 3.5 hours everyday in early September for storing solar superabundant energy into underground soil.

Figure 3 was the variation of hot water power and storage power to underground. Generally, the hot water load concentrated in the afternoon and evening, and the demand was dispersive and not fixed, and its average load power was about 7.0kW. For the discontinuity and dispersion of hot water demand, the heat storage will be a better way for energy-saving and solutions.

At the initial stage of heat storage, the storage power to underground reached more than 50kW. The heat storage power concentrated in 18~36kW, and the average power was about 22.9kW everyday. The time for heat storage to underground was 3~5 hours per day.

The relationship between hot water load and heat storage to underground could be commutative. During the day, the hot water load was small, and the majority of solar collection could be stored into the underground; while from 17:00pm, the temperature of heat storage water tank was below 50□ of the design temperature for storage, and hot water demand increased, solar collection was mainly to meet the hot water load, not the heat storage.

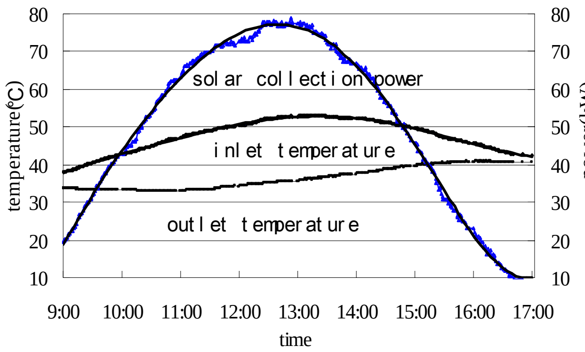

Figure 2: Inlet & outlet temperature of heat storage water tank and the solar collected power.

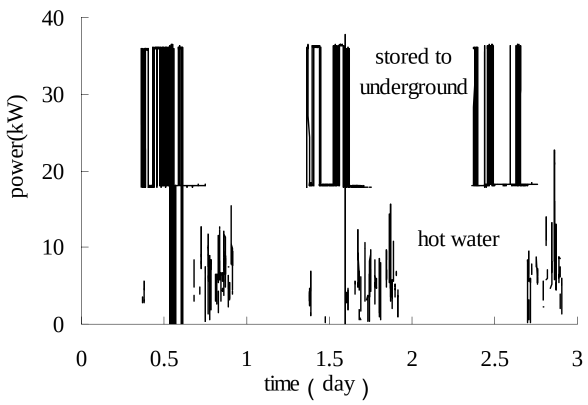

Figure 3: Power of hot water and heat stored to underground.

4. CONCLUSIONS

(1). In Tianjin, a project of SGCHPSS combination system was designed and set up, which comprised solar heat use, heat storage and Ground-Coupled Heat Pump. Solar energy met the conventional hot water supply, and also realized the solar inter-seasonal heat storage into underground in summer, which supplied higher temperature heat source for GCHP in winter.

(2). Experiments shown the solar collection power reached maximum 78kW in early September. The solar superabundant heat could be stored into underground, and the average heat storage power was 22.9 kW, which lasted 3~5hours per day.

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