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НАЦИОНАЛНО НАУЧНО ТЕХНИЧЕСКО ДРУЖЕСТВО (НАЦИОНАЛЕН КОМИТЕТ) ПО ТММ

ТОПЛОТЕХНИКА

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ИЗДАТЕЛСТВО НА ТЕХНИЧЕСКИ УНИВЕРСИТЕТ - ВАРНА

BUILD-UP OF HYBRID INSTALLATION WITH GROUND SOURCE HEAT PUMP AND SOLAR COLLECTORS

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Abstract

An experimental hybrid installation with ground-source heat pump and solar collectors was constructed at the Technical University of Sofia, branch Plovdiv. It has to be used for space heating and air conditioning. The main parts of a system are: three flat plate solar thermal collectors, two borehole heat exchangers, water-water heat pump, water tank, buffer vessel, brazed plate heat exchanger, circulating pumps, remote controlled valves, measuring sensors and devices. The installation can operate in different regimes to achieve optimal results. It has also the possibility to store heat into the ground in different seasons depending on the needs for heating and cooling.

Keywords

Ground source heat pumps, solar collectors, hybrid system

Introduction

Ground Source Heat Pump (GSHP) systems are one of the most long-lived heating and cooling systems. Using the ground like heat source or sink for heat pumps has many advantages –higher COP due to constant yearly ground temperature. Solar radiation can be collected by solar collectors and use for space heating and production of domestic hot water. Combining solar collectors with GSHP is promising and perspective way to save more energy and achieve better working conditions. Recently has appeared reports concerning creation of such hybrid system for air conditioning [Chen Xi et al. 2011], [Elisabeth Kjellsson et al. 2009], [Enyu Wang et al. 2012]. In these works are used solar collectors like additional heat source to increase COP of heat pump, to offset heat extraction and to store heat energy into the soil in summer months. That helps to keep constant ground temperature and avoid so called thermal depletion [Valentin Trillat-Berdal et al. 2007] when the system operates long time.

The aim of this work is to present a hybrid system in Bulgaria with solar-assisted ground-source heat pump, including three flat plate solar collectors, heat pump and two vertical ground heat exchangers. Such a system offers possibilities investigate the operation under different regimes of heating, cooling and energy storage into the ground.

Installation description

A hybrid installation with ground-source heat pump and solar collectors was constructed at the Technical University –Sofia, branch Plovdiv. The principal scheme of the experimental installation is presented in Fig.1. It consists of the following main parts:

<u>Solar collectors</u>: flat glazed type, PK Select-CL "Sunsystem" Ltd - Bulgaria, 3 pcs each with 2.15m^2 absorption surface of copper, coefficient of absorption/ reflection – 95%/5%, heat carrier – 20% water-propylene-glycol solution. The collectors are coupled in parallel scheme on the roof of the building and equipped with thermal regulator, pump station WILLO-SOLAR 20/6 (P1), expansion tank 12 l, power supply unit IN-100K and air remover. The produced heat power of about 600 kWh/m^2/year is supplied to the next element of the system - the plate heat exchanger.

<u>Brazed plate heat exchanger:</u> GEA type GBS-100M-20 with 20 plates 74x204 mm, overall heat exchange surface and power are 0,3 m^2 and 40 kW respectively (Fig. 2). The maximum flow rate is till 4 m^3/h, outputs and inputs have a size of 3/4 inch. The heat from the solar loop is transferred to water storage tank through plate exchanger by means of pump (P2).

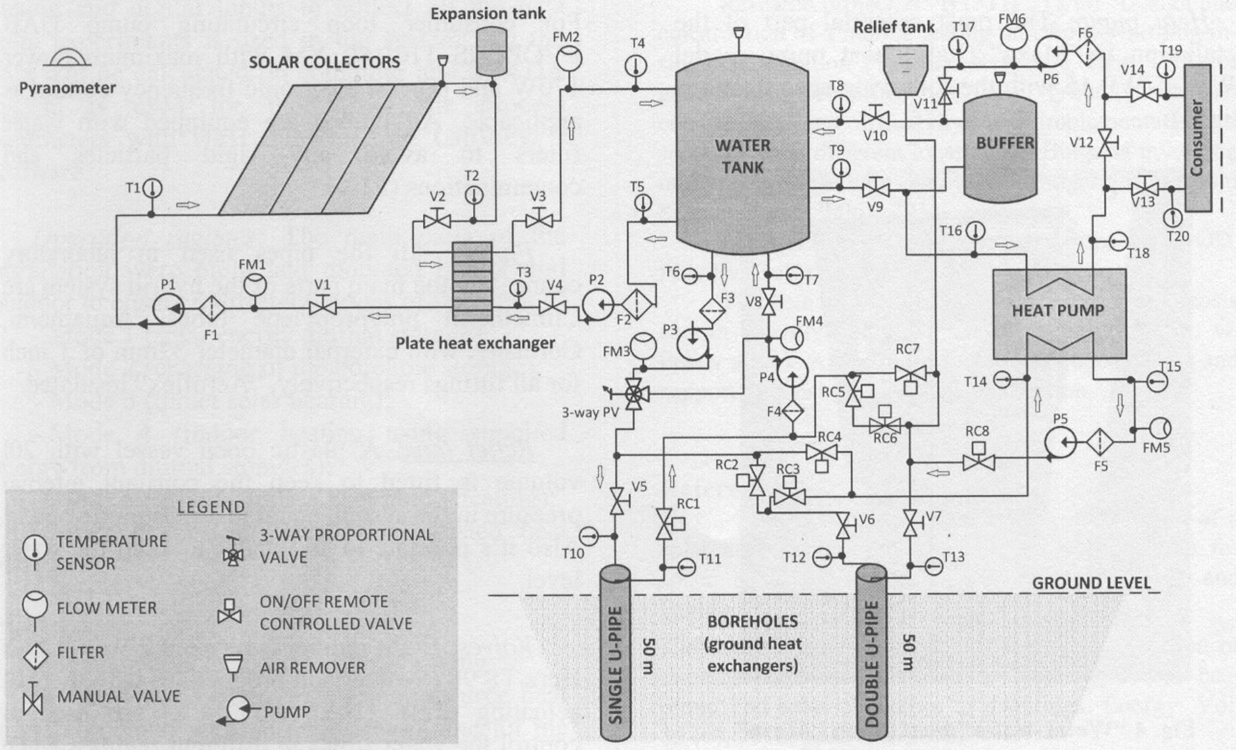


Fig. 1 Schematic diagram of the hybrid installation

Water tank: a 300 l volume stainless steel tank is used to store the hot water from solar collectors with temperature level till 70°C. It has thermal isolation and 3 outputs and inputs. The stored water in the tank supplies directly the consumer and the heat pump. Also it can be injected to boreholes.

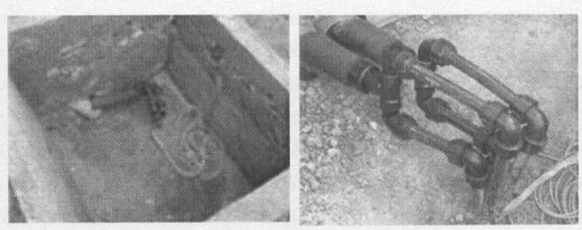
Fig. 2 Plate heat exchanger

Buffer vessel: a buffer is used to store cold water during cooling regime of heat pump. The vessel PS 150, "Sunsystem" - Ltd, Bulgaria, has a volume of 150 l and PU thermal insulation.

Borehole heat exchangers (BHE): two BHEs were constructed on the ground level in the vicinity of the laboratory with the aim to use the ground as heat source and energy storage for the heat pump. The perforations were drilled with the help of modern hydraulic drilling machine MDT Mc 200 B, Italy. The distance between the drilled holes is 13m, the length of 50 m and 165 mm in diameter. Two different piping types (single and double piping) of high density polythene (HDPE) PE 100 were inserted in the boreholes. They have an external diameter of 32 mm. A backfilled with grout material (mixture of cement and bentonite with factor 0,5) was used to enhance the thermal transfer between tubes and ground. Thus two different type of ground heat exchangers were designed (single and double U-pipe). Six three-wire thermoresistors Pt100 (production of Comeco, Bulgaria) were inserted in the two boreholes along the tubes on every 10 meters with the aim to measure the temperature distribution in depth.

The lithological structure of the area consists mainly of clay, sands with different size of grains and some gravel.

The so-called Thermal Response Test (TRT) was implemented to evaluate the ground thermal conductivity and the borehole thermal resistance of the BHEs. A device, earlier developed at the TU-Sofia, branch Plovdiv, was used during the test [Georgiev A. et al. 2010].



a) b)

Fig. 3 Borehole upper parts: a) single b) double

Heat pump: The most essential part of the installation is "Maxa" (Italy) heat pump model HWW-A/WP 15 with the following specifications (Fig. 4):

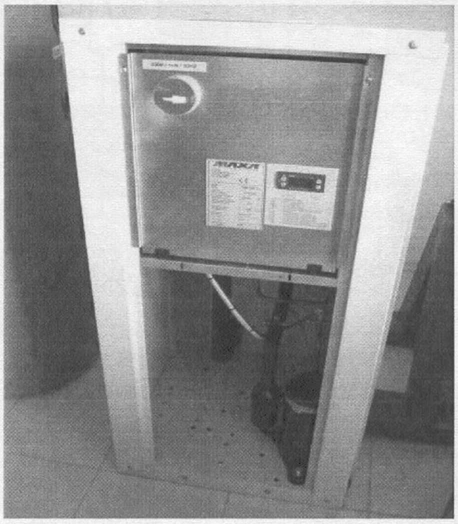


Fig. 4 "Water-water" heat pump "Maxa"

- type – water-water heat pump;
- inputs/ outputs – 1 inch diameter;
- heating capacity - 5.9 kW nominal;
- cooling capacity – 4.6 kW nominal;
- maximum absorbed power - 1.2 kW electrical;
- compressor type – one rotary Scroll;
- refrigerant – 0.5 kg R410A;
- oil charge – 0.4 kg;
- power supply – 230 V, 50 Hz, single phase;
- weight – 77 kg.

Cooling conditions:

- temp. in/ out on evaporator – 12/7 °C;
- temp. in/ out on condenser – 15/ 35 °C.

Heating conditions:

- temp. in/ out on evaporator – 15/10 °C;
- temp. in/ out on condenser – 40/45 °C.

The heat pump is controlled using microprocessor based device Energy ST 500, Eliwell, Italy.

Consumer: The consumer (heat load) can be radiant heating floor or water-air convector on which the supplied heat power is measured.

Water pumps: For the loops with boreholes two centrifugal pumps DAB JET 82M, Italy are implemented (P4 and P5). The pumps are equipped with Active Driver 1.1M to keep given constant pressure and flow rate till 3m³/h and 47m head. For circulating loops from water tank to heat exchanger and to boreholes two wet rotor circulating pumps DAB VA 35/130 with maximum flow rate 2.5m³/h (P2 and P3) are used. For consumer loop circulating pump DAB EVOPLUS 110/180 XM with maximum power 170W and precise electronic frequency control is applicable. All pumps are equipped with water filters to avoid any rigid particles and contaminations (F1-6).

Piping: All the pipes used in laboratory connecting the main parts of the hybrid system are Climatherm polypropylene tubes, Aquatherm, Germany, with external diameter 32mm or 1 inch for all fittings respectively, "Aeroflex" insulated.

Relief tank: A plastic open vessel with 20l volume is fitted to keep the constant internal pressure in the system equal to atmospheric one. Also it`s possible to add water to keep the water level.

Valves: Eight remote controlled 2-way valves Herz TS 90 (Switzerland production) with thermal actuating drive 220V (RC1 – 8) are used to control the water flows in different regimes when operating system. 3-way mixing valve VMBT4 (Italy production) with proportional actuating drive MVT57 (Italy production) are used to inject hot water from the water tank to the boreholes.

Sensors: Temperature sensors Pt 100, class A in special copper closed tubes are fitted on every input and output of the constituent system parts (Fig. 6).

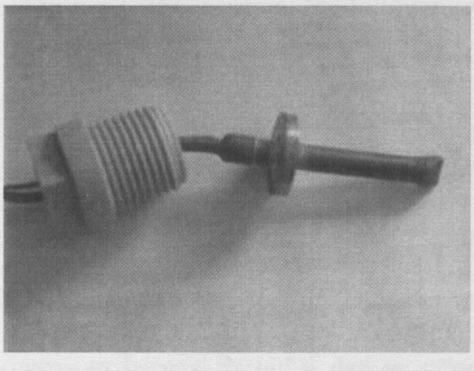


Fig. 5 Temperature sensor Pt 100

Every circulating loop is equipped with flow meters BEL 90 (Bulgaria production). They have maximal rate till 5 m³/h and digital output with sensitivity of 1l/h (FM1-6).

A pyranometer Kipp & Zonen CMP 6 (Holland production) is mounted on the roof to measure the global solar radiation, which incident in the area of the thermal.

Data system: Data logger system based on National Instruments LabJack™ LJ-U9 with analog and digital inputs to collect all the data from experiments is used in the system. All the data will be calculated on computer and SCADA system is used for monitoring the process parameters with HMI integrated in LabView^{TM} software.

Operation regimes: The main parts of the installation were build and mounted indoor and outdoor to ensure 6 different modes of operation:

- Mode 1 (solar energy diurnal storage);
- Mode 2 (charging of the borehole storage);
- Mode 3 (direct solar heating);
- Mode 4 (indoor heating using supplied energy from diurnal storages);
- Mode 5 (ground-source heat pump heating);
- Mode 6 (heating with solar assisted heat pump).

Conclusions

The main conclusions are the following:

(1) A hybrid system with ground-source heat pump combined with solar collectors and all the necessary measuring devices to perform experiments during all seasons of the year was constructed for the first time in Bulgaria;

(2) The installation can operate in different regimes to achieve optimal conditions for space heating and cooling, respectively high COP of the heat pump;

(3) The hybrid system also has the possibility to store heat into the boreholes ant to use it during the winter.

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ИЗГРАЖДАНЕ НА ХИБРИДНА ИНСТАЛАЦИЯ СЪС ЗЕМНО БАЗИРАНА ТЕРМОПОМПА И СЛЪНЧЕВИ КОЛЕКТОРИ

Е. Тошков

Резюме

Създадена е експериментална хибридна инсталация със земно базирана термопомпа и слънчеви колектори в ТУ-София, филиал Пловдив. Тя може да се използва за отопление и кондициониране на помещения. Главните части на системата са: три плоски водни слънчеви колектори, два земни вертикални топлообменници, термопомпа тип „вода-вода", водосъдържател, буферен съд, пластинчат топлообменник, циркулационни помпи, кранове с дистанционно управление, измервателни сензори и прибори. Инсталацията може да работи в различни режими с цел постигане на оптимални резултати. Възможно е също така да се използва и за съхраняване на топлина в земята през различните сезони според нуждите за отопление и охлаждане.