SOLAR ASSISTED GROUND SOURCE HEAT PUMP SYSTEM

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Abstract

The objective of the project was to find the most suitable solution for heating and cooling a conference room in an office building at Gödöllő, Hungary. Ground source heat pump system assisted by four solar photovoltaic cells for electric energy generation was installed in 2009. For a collector system two 100 m deep U-type-tubes were placed in separate boreholes. The system works in heating and cooling mode. The heat pump is not used for cooling. The excess heat is delivered to the soil by a heat exchanger situated in a depth of 15 m.

Keywords

ground source heating, heat pump, solar energy, heating, cooling

Introduction

The price of fossil fuel and the need for an independent and pollution free energy source motivates businesses and households looking for alternative energy sources in Hungary especially for heating and cooling [3]. Heat pumps are suitable for the weather in Hungary as it can provide heating in winter and cooling in summer and soil conditions in this geographical area are suitable for collecting heat from the relatively high temperature ground[6].. The disadvantage of heat pumps is that they require external power and as a solution it is possible to combine it with a solar system for electricity generation. A solar assisted ground source heat pump system is installed in one of the office buildings at Gödöllő. The purpose of this project was to find a cheaper, cleaner and more independent heat energy source.

Design and installation

A solar assisted ground source heat pump system is installed for heating and cooling a 100 m² conference room of an office building at Gödöllő in 2009. The heat pump requires electricity and to provide cheaper and more environmental friendly energy solar collectors are used for power generation. The system consists of a heat source - ground collector system, water-to-water heat pump which raises the temperature of the collected heat and transfers it in form of the water to a buffer tank and further to a heat distribution system – water is transferred from the buffer to fan-coil units[1].. The collector system consists of two 100 m deep boreholes. A location of boreholes and a floor plan of conference room are shown in Figure 1.

There are two different types of ground source heat pump systems – a direct expansion system where a refrigerant is circulated through the heat pump and the collector system; and an indirect system where a mix of water with antifreeze circulates through the collector system and the refrigerant circulates only in the heat pump. In this case it is an indirect system[4].. The distribution heat system of the conference room consists of four series connected fan-coil units, the heat exchangers in which water is circulated and heated or cooled air is transferred to the room by a fan[6]..

The system is assisted by four solar photovoltaic cells for electricity generation to run the circulation pump. System is shown in Figure 2.

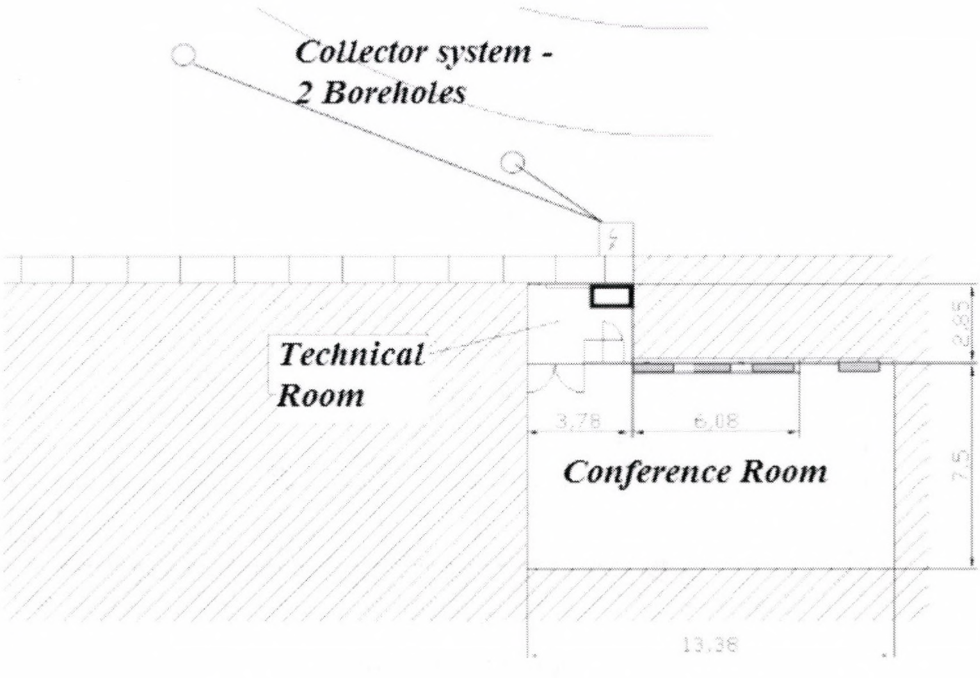

Figure 1. Floor Plan of a Conference room and borehole locations

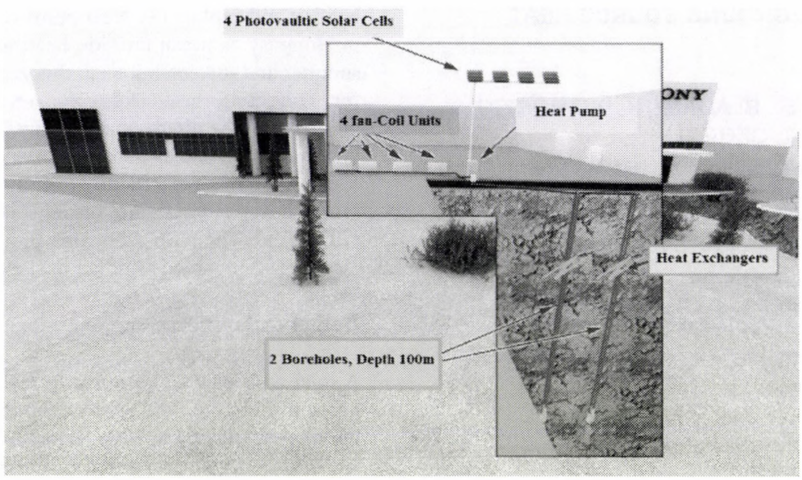

Figure 2. Solar assisted heat pump system

The components of the heat pump system

The system consists of two parts – primary and secondary side which are separated by the heat pump[7]. The primary side consists of a vertical ground collector system with the heat exchanger and the secondary part consists of a heat distribution system with four fan-coils. A compressor of the heat pump works periodically by turning on and off. To maintain a correct and constant flow a buffer tank is used. In summer in cooling mode the heat exchanger is used without using heat pump. Figure 3 and Figure 4 shows a schematic and components of the installed heat pump system.

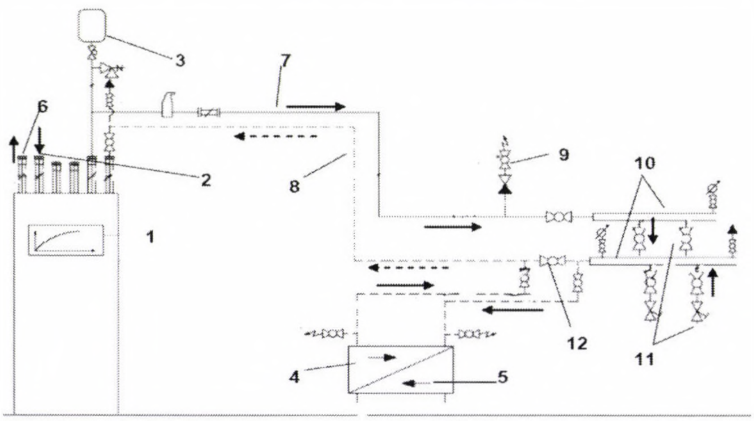

Figure 3. Primary side

1. Heat pump 2. The secondary side (return pipe) 3. Compensator container 4. The primary side of the refrigeration heat exchanger 5. The secondary side of the refrigeration heat exchanger 6. The secondary side (outgoing pipe) 7. The branch of the primer side (outgoing pipe) 8. The secondary side (return pipe) 9. Recharging tap 10. Boreholes return pipes 11. The boreholes outgoing pipes 12. Relay tap in case of refrigeration in summer

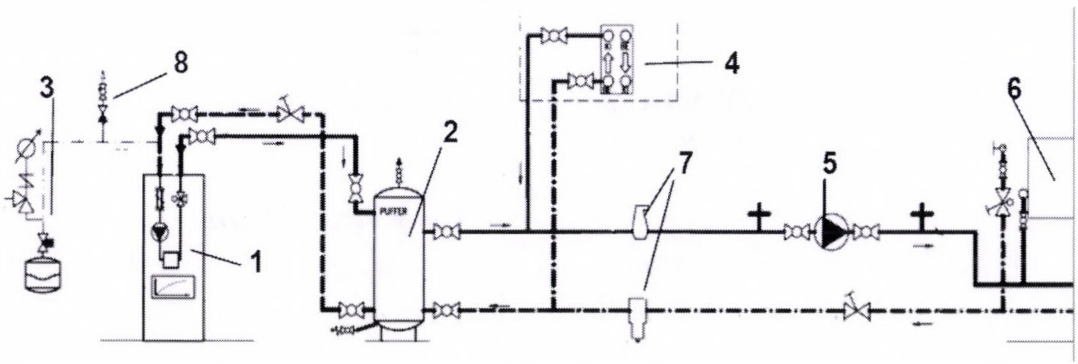

Figure 4. Secondary side

1. Heat pump 2. Puffer 3. Compensator container 4. Heat exchanger for refrigeration in summer 5. Circulation pump 6. Fan-coil units 7. Cleaning units

In heating mode heat is collected from the soil by a special liquid – mix of water and glycol running through U-type tubes situated in boreholes. In heat pump the heat is transferred to a refrigerant by heat exchanger and the temperature of it is increased by a compressor and the heat is transferred to the secondary loop by the heat exchanger and is delivered to a buffer tank where the heated water is stored. It equalizes the temperature of the water because the compressor works periodically. The water flow is circulated by a pump and transferred to four fan-coils. In cooling mode the process is reversed but a ground heat exchanger is used for giving the heat to the soil directly. The heat exchanger is in the 100 m deep boreholes. By using cooling heat exchanger the power requirement is lower.

Results

To analyse the performance of the system monitoring was carried out. Measurements were made for a period of 20 days starting from 30th October 2010 to 18th November 2010. Temperatures in 16 different points were measured. Most significant results of minimal, maximal and average temperatures of 24 hour measurement in 6th November are shown in Table 1.

Table 1. Measured temperatures

	Max T °C	Min T °C	Average T °C
Temperature of the soil (16m deep)	13,4	11,7	12,6
From the heat pump (out)	37,5	24,9	27,7
Back to the heat pump (in)	30,1	24,9	27,1
Air temperature in the room	25,0	23,4	24,3

Temperature parameters are closed to design ones. The difference between the heat pump minimal and maximal temperature is because the compressing process of the heat pump doesn't happen constantly. The temperature sampling time was 10 minutes. Figure 5. shows 24 hour (144 × 10 min) temperature diagram of outgoing and returning water of the buffer.

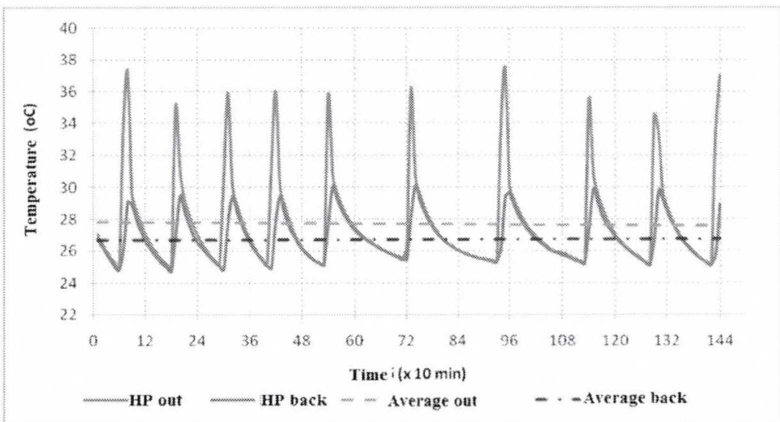

Figure 5. Outgoing and returning water temperatures of the Buffer

24 hours period of temperatures of borehole exchangers and the soil in 16 m depth are shown in Figure 6. The green line shows the soil temperature in 16 m depth which is between 11,8 and 13,4°C.

To analyse the performance of the hall system it is significant to analyse the consumption of the electricity. The system provides electrical energy for compressor, fan-coil units and the circulation pump. Performance of the system in a cold winter day when average outdoor temperature is -3 °C is shown in Fig. 7.

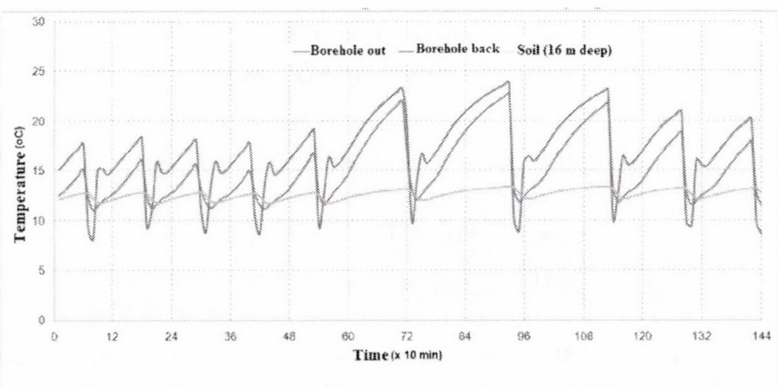

Figure 6. Temperature of U-tube-type borehole exchanger and the soil [2]

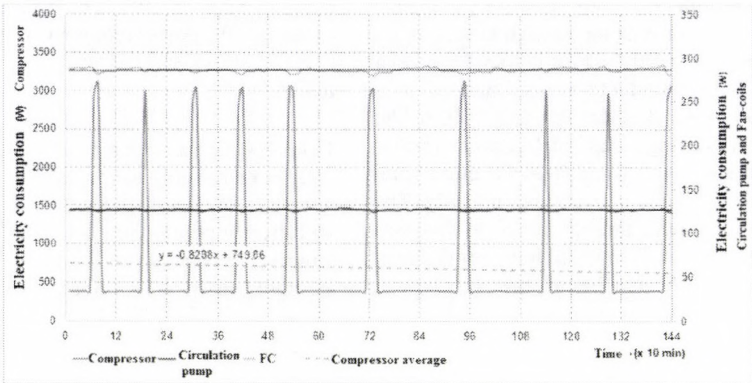

Figure 7. Electric consumption of the system

During a 24 hour period the compressor of the heat pump works with interval 17 – 25 min. The electric power consumption of the compressor unit during compressor turn-off only about 380 W, in turn-on state the electric consumption increases up to 3100 W. Electric consumption of fan-coils varies from 279,7 W to 292,2 W and the circulation pump's consumption is between126,5 and 129,9 W.

A variation of the supplied water temperature to fan-coils and the supplied air temperature to the room is shown in Figure 8. The supplied water temperature varies from 24,5 °C to 31,5 °C. And the supplied air temperature varies from 21,0 °C to 23,8 °C.

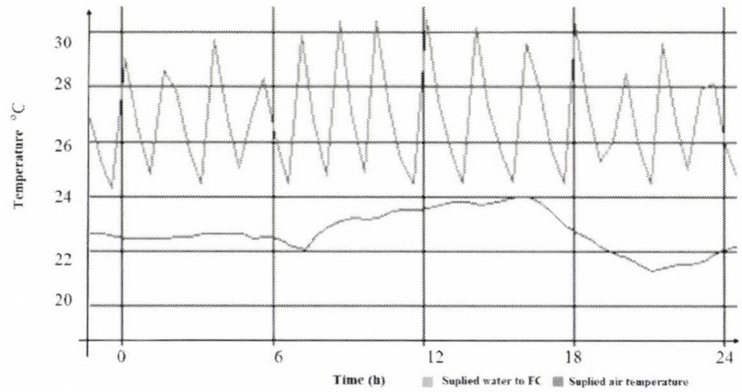

Figure 8. Fan-coil performance

Measured data proves that the project system meets the requirements. The operation was satisfactory and there was no trouble during a long period. Measured temperatures are close to designed temperatures and a comfort temperature +22 °C (± 2°C) was provided in the conference room even in the coldest months of the year.

Energy consumption of the running system – heat pump, circulation pump and fan-coils is shown in Table 2. It is compared with energy consumption of a natural gas boiler heating system combined with a separate climate control which would be required to heat and cool the same room. Savings of energy and carbon emissions of one year are shown in the table.

Table 2. Energy consumption of the heat pump system compared to the energy consumption of a traditional system

	kWh/year	MJ/year		kWh/ year	MJ/ year
Natural gas burner	11550	51975	Heat pump	2880	10368
Split clime	1650	5940	Circulation pump	480	1728
			Fan-Coils	162	583
Together	**13200**	**57915**	**Together**	**3522**	**12679**

Saving	**45236**	MJ/year
CO_2 Saving	**3871**	kg/year

One year energy consumption was 12679,2 MJ (Heat pump 10368 MJ, circulation pump 1728 MJ, fan-coil units 583,2). By using a traditional heating system with boiler and climate control this number could be 4,6 times bigger and saves about 45236 kg carbon emission and € 135 708 with it during one year. Energy consumed by a circulation pump is provided by solar panels on the roof.

Parameters and the performance of solar panel such as size, collected energy of one m^2 and a factor of a performance, working hours of a year and produced energy in one year are shown in Table 3.

Table 3. Performance of solar panels

m^2	kW/m^2	η	h/year	kWh/year
1,8	1000	0,16	2100	604,8

As shown in table solar panels provide 604 kWh/year but the circulation pump requires only 480 kWh/year. Cost of the heat pump system was € 13 868 (1 drilling of 100 m deep borehole in Hungary costs € 2190).

Conclusions

By installing a ground source heat pump system the energy consumption and CO_2 emissions are reduced. This solution for heating and cooling provides comfort for users as temperatures are easy to regulate and the system does not require maintenance. The system works error free and provides heating and cooling just by changing a position of a switch. The consumed energy is reduced by 4,6 times which makes up to € 135 708 savings in one year (according to the electricity and natural gas tariff in 2011) making the system environmental friendly and cost effective for the business. The results of measured data shows that system works without any disorders and appropriate to designed parameters.

References

1. Ochsner K.: Geothermal heat pumps: a guide for planning and installing, London, 2007.
2. Sarbu I., Bura H.: Thermal tests on borehole heat exchangers for ground–coupled heat pump systems, International Journal of Energy and Environment, Iraq, 2011.
3. Komlós F.: Épület - Energia - Élettér - Ember: hőszivattyús technika. Magyar Épületgépészet, XLVI. évf. (1997) 12. szám, p. 5 – 7
4. Steimle, F.: Wärmepumpentechnik - Einführung. Gas Wärmepumpen Praxis - Wärmepumpentechnologie, Band IV.
5. Büki G.: Magyar energetika a századfordulón számokban. Magyar Energetika, 2001/1. szám, p. 3– 11
6. Tóth.L, Fogarasi L, Bihercz G, Ménesi A: (2008): Utilization of Geothermal Heat for Air-Conditioning of Different Small Buildings. Journal of Agricultural Machinery Science. Volume 4, Number 3. 241-246. p. ISSN: 1306-0007
[7] http://www.hidro-geodrilling.hu/index.php