Investigation of the Usage of Ground Source Heat Pump System on Wall Heating

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Abstract

Wall heating systems are more preferable heating systems than other conventional systems due to their low temperature operating ranges. These systems are equipped with heating serpentines or panels where the water is circulated and the serpentines are mounted on the walls of rooms. Ground source heat pump systems are todays one of the useful renewable energy based heating systems.

In this study, daily analysis of a wall heating (radiant heating) system fed by a vertical type ground-coupled heat pump system is investigated and parameters of the system in a month (Feb. 2010) are recorded in 1 second intervals. As a result, temperatures of the wall heating system are investigated with inlet and outlet temperatures of the heat pump system. The mean heat transfer rate to the TEST room is found 1.017kW where 4.28 kW is the inlet energy rate and 3.26 kW is the outlet energy rate.

Keywords: *Analysis, Renewable Energy System, Ground Source, Heat Pump, Wall Heating*

Introduction

Wall heating systems are more preferable heating systems than other conventional systems because of its low temperature operating ranges. It is equipped with heating serpentines or panels where water is circulated and serpentines are mounted on the walls of rooms. Ground source heat pump systems are today's one of the useful renewable energy based heating system and renewable energy source based systems such as heat pump systems can be easily used in wall heating systems.

Ground-source heat pump (GSHP) systems are widely used because of their potential of energy-efficiency, environmental friendly behavior. Heat pumps are a kind of renewable energy source based energy systems which are powered with electricity. Especially usage of vertical type ground source heat pumps (V-GSHP) in heating and cooling purposes reduces energy consumption due to their high efficiency. In several studies, geothermal energy for heating and cooling systems was examined (1) (2). However, in the world, there exists large difference between climate conditions of countries. Also overall Coefficient of Performance (COP) changes due to the systems used in conjunction with the GSHP (3) (4) (5) (6). A good approach is to combine GSHP systems with the systems which work in low temperature values and ranges. This is an opportunity for energy saving.

Wall heating system is a kind of extremely simple installation which reduces investment and operating costs. It has significant advantage on increasing thermal comfort and wall heating system can be easily conjunct to a renewable energy source. In this system, heat transfer occurs from the radiant panels which are installed inside the wall to the room. Heat transfer mechanism can be classified into two sections such as radiation and natural convection. At least 60% of heat transfers by radiation with this system. Several studies in literature examined the amount of transferred heat from the radiant panels. Min et al. (7) identified natural convection coefficient of a room which is heated from walls. Schutrum and Vouris (8), represented the effect of the size of room is irrelevant except too large rooms like hangars and depots. Pamelee and Huebscher studied on the effect of forced convection coefficient on this system and suggested an increased convection coefficient for heat transfer calculations (9). Wall heating system can be used for cooling too. Some radiant panels can be mounted on ceiling if heat transfer surface area is insufficient. It will be practical and cheaper to install only one system for heating and cooling purposes. Imanari (10) compared radiant ceiling panel system with a conventional air handling unit in terms of thermal comfort, energy demand and total cost. He represented that radiant ceiling panel system provides comfort and energy saving. Vangtook (11) (12) made experimental and simulation studies on a radiant cooling system which is used with natural ventilation for very hot and humid climate. All studies in literature about radiant heating and cooling system emphasized that this system is comfortable and economical.

In the study of Kincay et.al.; wind, solar and geothermal energy sources are discussed and the study is focused on the Hybrid Renewable Energy Systems (13). Hepbasli and Ozgener are presented energy and exergy analysis of a GSHP system with a 50 m vertical 1.25 in. nominal diameter U-bend ground heat exchanger (14). In the previous study of Yoru et al. a DISS-An C++ code with Artificial Neural Network (ANN) library is developed by authors to obtain results of energy and exergy analysis of a real vertical ground source heat pump system (15).

In this study daily analysis of a wall heating system fed by a vertical type ground-coupled heat pump system is investigated and parameters of the system are recorded in 1 second intervals. In wall heating system radiant panels mounted in the walls and their surface areas are sufficient for both heating and cooling purposes. Besides a V-GSHP system is conjunct to this system as a renewable energy supply.

System Description

The investigated wall heating system (Fig.1a) and vertical ground source heat pump system (Fig1.b) are located in Renewable Yildiz Energy House at Davutpasa Campus of Yildiz Technical University, Istanbul.

Fig.1 : (a) Wall heating serpentines (b) The investigated heat pump system

Wall heating systems are built in 3 different rooms of Renewable Yildiz Energy House and a saloon of a hall for heating and cooling applications.

Heat pump system with a 1.7kW scroll type compressor feeds this system. Two vertical 65m pipes were used to supply ground source water heat to the water heat pump. On the wall heating 14 mm inner diameter and 16 mm outer diameter polyetilen pipes are used. Total pipe length mounted to walls is 441m and the detailed information are given in Table 1.

Table 1: Size of heating serpentines mounted to walls

ROOMS	**SIZE**	**QUANTITY**	**LENGTH (m)**	**TOTAL (m)**
ROOM I	150x200	3	25	75
	75x200	3	15	45
	50x130	1	7	7
ROOM II	150x200	2	30	60
	75x200	3	15	45
	50x130	1	7	7
	150x200	2	25	50
ROOM III	150x200	4	25	100
	75x200	3	15	45
	50x130	1	7	7
SALOON	190x70	20	17	340
	60x140	8	11	88
	60x70	2	5	10

The compressor was controlled by an inverter to meet the need of cooling load under actual GSHP operating conditions. The boreholes were drilled down to 65 m under the ground to obtain the stable temperature of circulating water in the ground heat exchanger. The parameters such as the outdoor air temperatures, inlet-outlet temperatures, mass flow rates of both ground heat exchanger and circulating water were monitored. The heating performance of the GSHP system was determined by measuring the input power and heating capacity.

Hybrid renewable energy system is designed for the energy requirement of 92 m^2 place. This system is original, because of different renewable energy sources as components of a conventional energy source and automatic control system.

Analysis

In the analysis of the system, the following assumptions were made for the Ground-source heat pump system;

- The system is steady state in 1 second intervals
- The efficiency of the evaporator and condenser assumed constant $(\eta_{cond} = \eta_{eva} = 0.85)$
- 3 pumps in the system are equivalent and have same power. *(W_p1=W_p2=W_p3=0.132 kW)*
- R410a flow rate is calculated and assumed constant during a second

In the energy analysis of the heat pump system mass balance equation and first law of thermodynamics law were used. Thereby COP of the heat pump system and all its components can be derived. Basically general mass and energy balance equations for a steady-state and steady-flow process are given as follows, respectively,

$$\dot{m}_{in} - \dot{m}_{out} = 0 \tag{1}$$

and

$$\dot{E}_{in} - \dot{E}_{out} = 0 \tag{2}$$

The investigated vertical gorund source heat pump system has 3 different flow cycles; ground source water (gsw) cycle , R410a refrigerant cycle and heating water cycle. The heat transfer rate in the evaporator is

$$Q_L = \dot{m}_{gsw} C_p (h_6 - h_7) \tag{3}$$

where Cp is the specific heat of the water–antifreeze solution, $\dot{m}$ is the mass flow rate of the water/antifreeze solution. The heat rejection rate in the condenser is calculated

$$Q_H = \dot{m}_{hw} C_p (h_{11} - h_{10}) \tag{4}$$

Efficiency of compressor is found from

$$\eta_{comp} = \dot{m}_{r410a} (h_2 - h1) / \dot{W}_{comp} \tag{5}$$

and for the analysis of a cubic TEST room, simply inlet and outlet energies of wall heating system are calculated from the obtained data. Therefore heat transfer to the TEST room can be found

$$\dot{Q} = \dot{E}_{out} - \dot{E}_{in} \tag{4}$$

where E is calculated by means of inlet and outlet temperatures of heating water.

Results

After modeling the system and analysis of given data, energy results are found by using thermodynamic equations in DISS-An application. Results are shown by both graphics and tables. In general 2,230,856 data lines (25 parameters per line) were obtained from the heat pump system and 2,418,000 data lines (5 parameters per line) were obtained from the wall heating system.

All energy calculations of both heat pump system and wall heating system are made by a DISS-An C++ code generated by authors (15). Daily data obtained from the heat pump and wall heating systems are shown in Figure 2.

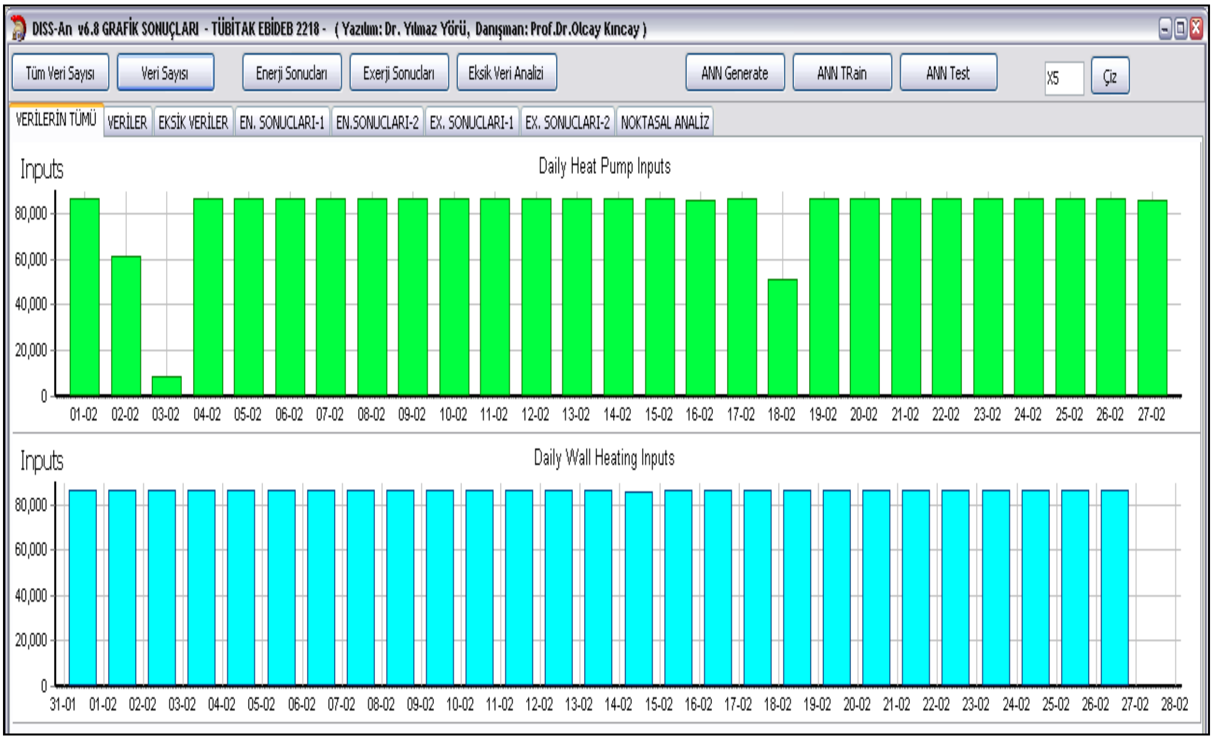

Figure 2 : Daily data obtained from the heat pump system and wall heating system (Feb. 2010)

DISS-An application is good at both displaying inputs and results beside its energy and exergy analysis. An example daily screen shot for the inputs of the heat pump system were shown in Fig. 3. It is easy to see when the heat pump started to operate and when stopped.

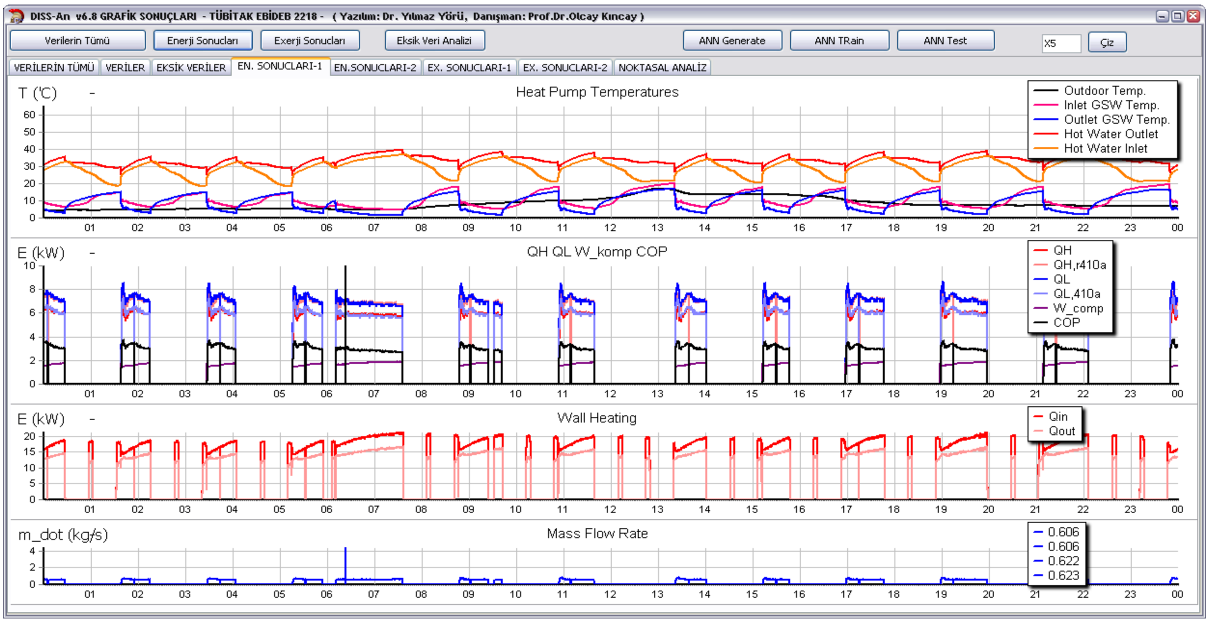

Figure 3: An example daily screen shot for the inputs of the heat pump system (16 Feb. 2010)

According to input data of wall heating system (Fig. 4), average inlet and outlet temperatures of heating water are found 30.9 °C and 25.54 °C, respectively. Average temperature of Test room is measured as 20 °C while average temperature of outdoor temperature is 7.8 °C.

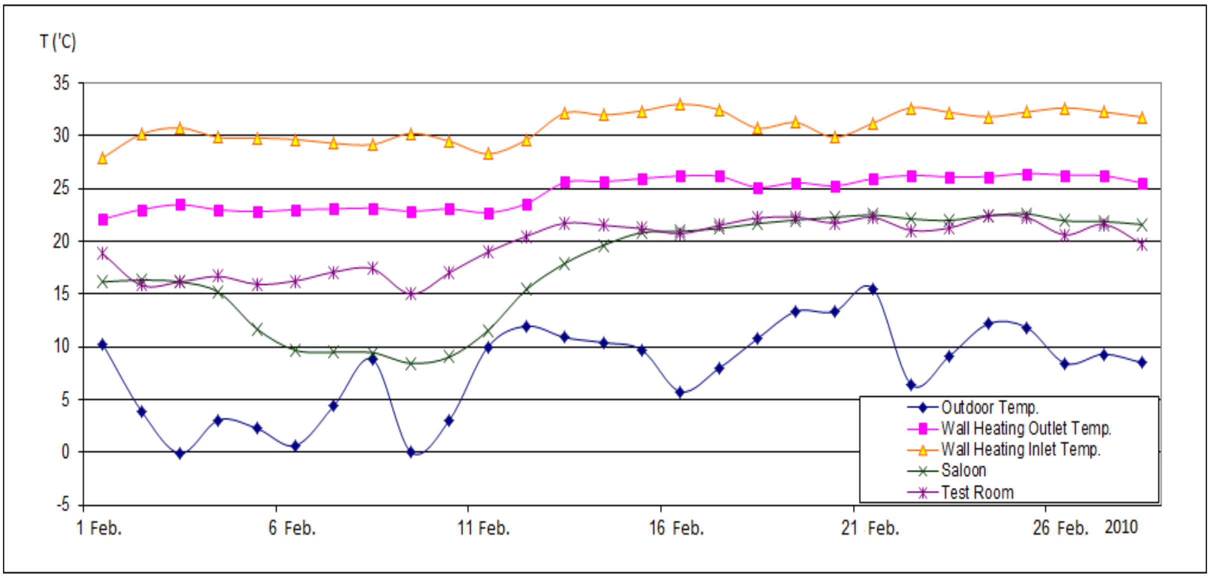

Figure 4: Average results of monthly data of wall heating system (Feb. 2010)

As a result from the obtained data of Feb. 2010, the mean heat transfer rate to the TEST room is found 1.02kW where 4.28 kW is the inlet energy rate and 3.26 kW is the outlet energy rate and hourly graph is shown in Fig. 4.

Totally, the wall heating system with heat pump is delivered 683 kWh energy to the test room in the investigated month.

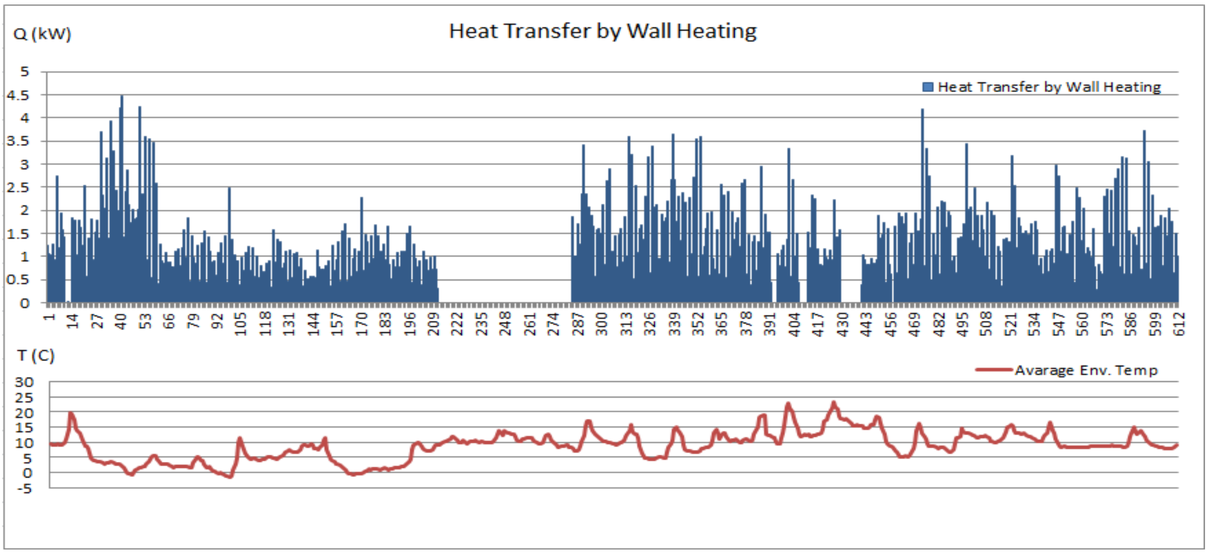

Figure 5 : Hourly heat transfer rate (Feb. 2010)

Conclusion

According to analysis, wall heating system is beneficial when used with a heat pump system and it may be developed by using hybrid renewable energy sources (solar, wind, geothermal) etc. Alternative solutions are recommended to reduce greenhouse effect due to CO_2 emissions and unhealthy combustion products of fossil fuels (CO, SO_X , NO_X , PbO_X) with this project. Besides reducing the usage of fossil fuels and effective usage of renewable energy sources of country will provide economical and environmental benefits in terms of the sustainable energy usage concept.

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Nomenclature

$\dot{E}$	energy rate (kW)	*Abbreviations*	
h	specific enthalpy ($kJkg^{-1}$)	COP	Coefficient of Performance
$\dot{Q}$	*heat transfer rate* (kW)	GSHP	ground source heat pumps
s	specific entropy ($kJkg^{-1}K^{-1}$)	V-GSHP	vertical type ground source heat pumps
$\dot{m}$	*mass flow rate*		
T	temperature (K or ˚C)		
t	target value (-)		
ψ	specific exergy ($kJkg^{-1}$)		
ε	exergetic efficiency		
Indices			
hw	heating water		
in	inlet		
gsw	ground source water		
out	outlet, output		
r410a	refrigerant R410a		

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