Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 54(5) (2022) 221-224
DOI: 10.22060/mej.2022.20404.7227

Analysis of an Auxiliary Household Underfloor Heating and Domestic Hot Water System Using Solar Energy in a Cold Area

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ABSTRACT: Nowadays, population growth and energy consumption, especially non-renewables, are growing significantly. It is expected that by increasing public awareness about the necessity of optimal energy consumption, the choice of methods and equipment that will lead to less energy consumption of the building, will be more welcomed. Among heating systems, the underfloor heating systems can reduce fuel consumption due to lower operating temperatures, despite creating uniform heat in all zones of the building. On the other hand, In Iran, which has a high potential for solar energy, it is possible that by combining underfloor heating and solar heating systems, despite the reduction of fossil fuel consumption, the desired heat in the building can be provided. In the present study, a combined floor heating system including a solar underfloor heating system and a hot water boiler is designed and simulated to heat a building in the cold climate of Iran to reduce fossil fuel consumption. The simulation results show that the solar heating system designed in this study can provide 98.5 % of the total energy required for domestic hot water and 17.3 % of the total energy required for underfloor heating. These results show that the heating system provided for building energy supply in the cold climate of Iran is very useful and can significantly reduce fossil fuel consumption.

Review History:

Received: Aug. 14, 2021
Revised: Jan. 07, 2022
Accepted: Feb. 04, 2022
Available Online: Feb. 09, 2022

Keywords:

Floor heating
Solar energy
Solar thermal systems
Solar water heaters
Solar collectors

1- Introduction

Energy plays a decisive role in the industry, economy, agriculture, and transportation of any country. Energy consumption has become a key indicator of a country's economic development due to its undeniable importance. Iran's residential share of energy consumption is about 27%, which is 6% higher than the rest of the world [1]. Renewable energy is recommended as a means of reducing non-renewable energy consumption in the household sector, based on the country's existing potential. Solar energy is one of the renewable energy sources with a high potential for production in the country; because 300 days of each year in the country are sunny [2]. Studies [3] show that, even with the best construction and insulation conditions, a building's energy consumption can be significantly reduced. In the present study, a solar floor heating system is designed to heat a building in the cold climate of Iran. The temperature of hot water in the floor pipes in an underfloor heating system is generally lower than the other heating methods and it results in a lot of energy savings [4]. In addition, due to the low temperature required by the underfloor heating system, clean energy sources such as solar energy can be used for underfloor heating. In this study, a combined floor heating system with water working fluid was designed and simulated to heat a sample 115-meter building and supply Domestic Hot Water (DHW) in the cold climate of Iran (Urmia).

2- Methodology

The heat flux and load of different rooms of the building were calculated using LoopCAD software. These calculations are based on the winter design temperature, which is the average minimum outside temperature in winter, and -8.6 $^{\circ}C$ is listed for the city of Urmia in the software library. The pipes layout is done using the values of heat flux in each room, as shown in Fig. 1. The software calculates the required properties of the feed water to the manifold.

The feed water properties obtained from the LoopCAD software were used as inputs to the T*SOL software for solar heating system design. The feed water temperature, flow rate, and pressure are obtained at 59 $^{\circ}C$, 5.12 $l.min^{-1}$, and 8.6 kPa, respectively. The solar heating system designed in this study is shown in Fig. 2. This system consists of two coiled tanks that are heated to 45 $^{\circ}C$ in a 650 l water tank and used to provide DHW. The 900-liter tank also serves as hot water required for heating. The hot water boiler is only used for heating when the required energy is higher than the energy provided by solar collectors. The performance of the proposed system was evaluated using meteorological data from the T*SOL software library, data from LoopCAD software, and the distribution of DHW consumption on a daily (holidays

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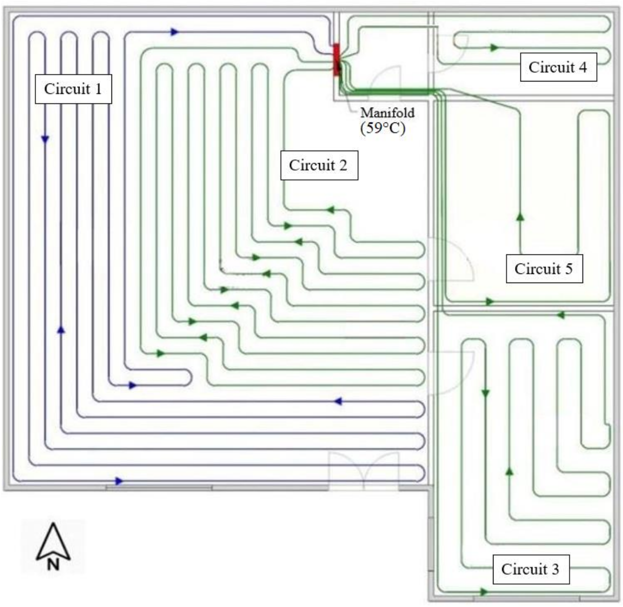

Fig. 1. The floor heating pipe layout obtained from LoopCAD software

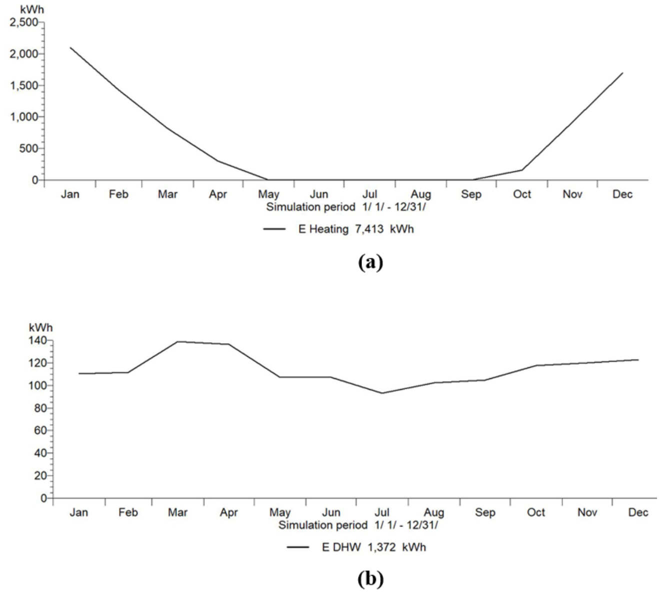

Fig. 3. a. The energy requirement for underfloor heating (7413 kWh per year). b. The energy requirement for DHW (1372 kWh per year)

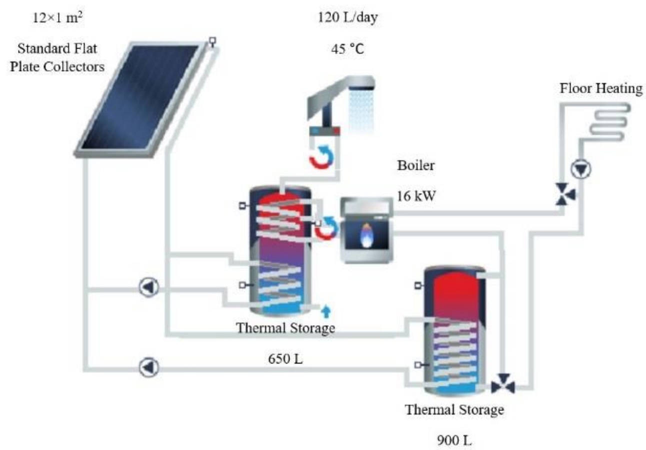

Fig. 2. The designed system in T*SOL software

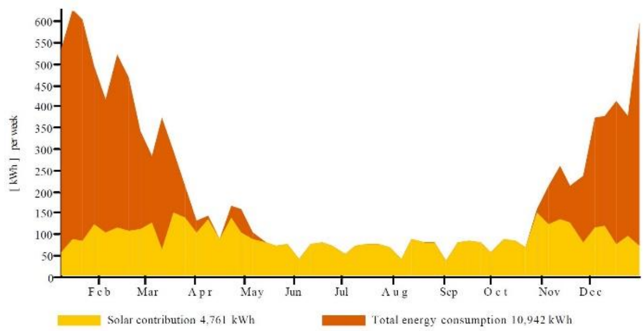

Fig. 4. The total energy consumption for heating and DHW (10943 kWh per week) and solar contribution (4761 kWh per week)

and working days), weekly, and annual basis.

3- Results and Discussion

The amount of energy required to provide heating and DHW during the year is calculated and plotted in Fig. 3. Fig. 4 depicts the amount of energy consumed versus the amount of energy produced by the sun over a year. The solar fraction denotes the proportion of energy obtained from the sun to the energy required for the desired purpose [5]. The solar fraction for underfloor heating and DHW is shown in Fig. 4. For DHW, this quantity is 0.985, indicating that the supply of DHW with this designed system is reliable throughout the year. Unlike DHW, the designed system does not meet the heating energy needs and natural gas consumption is used to meet the majority of the heating needs. As a result, the solar fraction for year-round underfloor heating and year-round underfloor heating and DHW is 0.173 and 0.440, respectively. Finally, Fig. 6 shows the efficiency of the system during the year, which is the ratio of energy output from the solar system to solar radiation energy.

4- Conclusions

In this study, a combined floor heating system for heating a building in a cold climate was designed, simulated, and

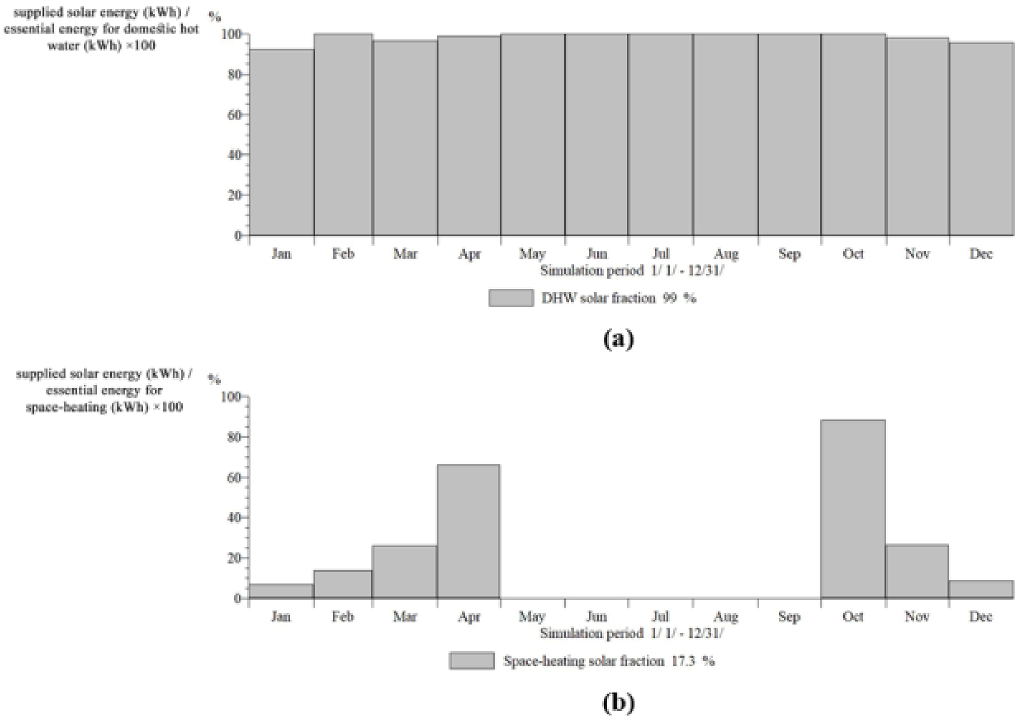

Fig. 5. a. The DHW solar fraction (average 99%). b. The underfloor heating solar fraction (average 17.3%)

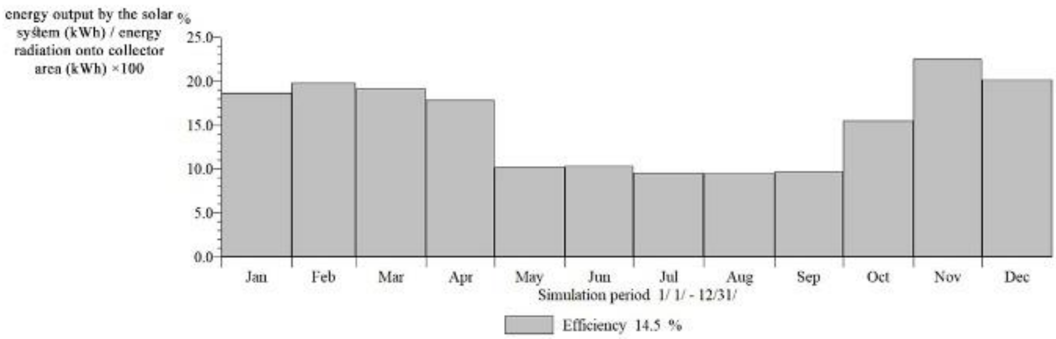

Fig. 6. The system efficiency (average 14.5%)

analyzed. The thermal load of the building was calculated using LoopCAD software. To supply the building load, the feed water properties are entered into the Valentin T*SOL software, and the proposed system for the solar floor heating section is simulated using this software. The simulation results show that in a sample building, the solar heating system designed in this study can provide 98.5 percent of the total energy required for domestic hot water and 17.3 percent of the total energy required for underfloor heating on its own. To make available.

References

[1] F. Amini, L. Saber Fattahi, P. Soleymanpour, N. Golghahremani, M. Shafizadeh, M. Tavanpour, M. Farmad, Iran Energy Balance Sheets: 1397, Iran Ministry of Energy, Deputy of planning and economic, (2019) (in Persian).

[2] G. Najafi, B. Ghobadian, R. Mamat, T. Yusaf, W.H. Azmi, Solar energy in Iran: Current state and outlook, Renewable and Sustainable Energy Reviews, 49 (2015) 931-942.

[3] A. Ebrahimpour, Y. Karimi Wahed, The best methods to optimize energy consumption for an educational building in Tabriz, Modares Mechanical Engineering, 12(4) (2012) (in Persian).

[4] M.S. Karimi, F. Fazelpour, M.A. Rosen, M. Shams, Comparative study of solar-powered underfloor heating system performance in distinctive climates, Renewable Energy, 130 (2019) 524-535.

[5] W.T. Grondzik, A.G. Kwok, Mechanical and Electrical Equipment for Buildings, John Wiley & Sons, Portland, (2014).

HOW TO CITE THIS ARTICLE

M. Asadi, A. M. Abazari, A. Hassanvand, Analysis of an Auxiliary Household Underfloor Heating and Domestic Hot Water System Using Solar Energy in a Cold Area, Amirkabir J. Mech Eng., 54(5) (2022) 221-224.

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