Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 52(2) (2020) 89-92
DOI: 10.22060/mej.2018.13864.5733

Simulation of the Heating, Ventilation, and Air Conditioning System with Geothermal Energy and Solar Collector

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ABSTRACT: Future concerns for the limitation of fossil resources and the reduction of environmental pollutants will extend the use of renewable energies such as geothermal energy plus solar energy. The presence of this energy in the country makes it suitable for heating or cooling residential and commercial spaces. In this paper, the thermal load of a home built according to energy efficiency standards is simulated. The air conditioning system based on the geothermal heat pump and the solar collector is modeled on the house using the Transmission software, and the effect of using the heating element of energy recovery from wastewater in the system, the technical-economic system performance in different cities of the country in terms of climate and efficiency. The solar collector component is examined for the average storage temperature. The results show that the heating used by the recycling component leads to the 0.9% increase in the temperature of the heat pump inlet in a five-year period and an increase of 1.9 degrees Celsius on the average temperature of the hot water tank during one year. The system's performance in warm and dry climates is 25047 $ better than elsewhere in the country.

Review History:

Received: 24/12/2017
Revised: 01/06/2018
Accepted: 24/06/2018
Available Online: 27/06/2018

Keywords:

Geothermal energy
Solar energy
Geothermal heat pump
TRNSYS software

1. INTRODUCTION

The earth is plentiful with thermal energy waiting to be harnessed for human needs, assuming an average geothermal gradient of 25 ºC/km, only 0.1% of the earth has a temperature below 100 ºC [1].

Geothermal energy is supplied at a relatively constant rate from the interior of the lithosphere and is therefore recognized as a renewable source of energy. The independence of geothermal energy from meteorological conditions offers an important advantage over other types of renewable energies (e.g. solar, tidal, wind, etc.). From the period covering 1975 up until 2013, global installed geothermal capacity has increased from 1300 MWe to 11,765 MWe [2].

Different limits on the output power of renewable energy technology reduce the widespread use of it but by adopting an incremental combine to enhance renewable energy technology, it can play an important role in optimizing energy through reducing greenhouse gas emissions [3].

The idea of connecting a solar collector to spiral tubes buried in the ground was first introduced by Penrod, with the knowledge that the sun's energy could be stored on the ground. After several decades, Metz [4] proposed a solar geothermal heat pump system.

2. HOUSE MODEL

The house chosen for this model has been simulated and it was one of two energy efficient demonstration houses built by a local builder, Mattamy in Milton in 2005. To compare the cooling and heating demands of the simulated house with its original reference, the house was first modeled in the Milton City climate. In the following work, the weather conditions of each city under study in the Iran country were applied to the whole modeling and the house. It is assumed that this house conforms to the standards established inside the country. The house is a detached two-storey building with 498 square meters of heated area with basement, with the following characteristics [5]:

Construction

Light wood frame, 50 × 150 mm (2×6 in) exterior wall construction installed on 610 mm (24 in) centers.

Insulation

Spray foam insulation for walls with RSI 3.5, RSI 7 attic insulation.

Windows

Low E/Argon-filled with insulated spacers, Vinyl, RSI 0.35

Occupant

Two adults and two children for 50% of time

Basement Flooring

Concrete floor, hydronic slab under heating, RSI 2.11

Seasons that require heating considered from October 1st (6552 hours) to April 30th (2880 hours) and seasons requiring

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Table 1: The heating and cooling loads that simulated in this paper and the main reference [5]

Load	Simulated in this article	The main simulation
Heating Load (GJ)	93.9	95
Cooling Load (GJ)	20.9	19

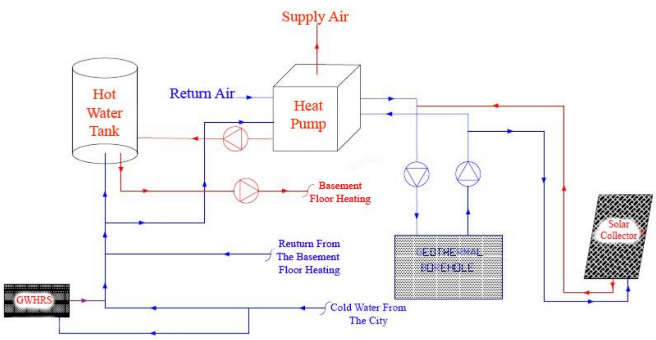

Fig. 1: Schematic diagram of the geothermal heat pump system with the solar collector

cooling considered from May 1st (2881 hours) to September 31st (6553 hours). Table 1 shows the simulated cooling and heating loads for the desired home in this paper and its main reference [5].

3. MODELING THE GROUND SOURCE HEAT PUMP SYSTEM BY USING A SOLAR COLLECTOR

Fig. 1 shows the detailed system layout. TRNSYS Studio is the main visual interface from which the ground source heat pump system with the solar collector is being created. The main components of the system are described as below:

Gray water heat recovery system

Gray water is used to recycle water or household wastewater from daily routine activities. This wastewater has a temperature above the urban cold water temperature and can be used in a heat exchanger to preheat cold water before entering and stored in a hot water tank. Type 91, a heat exchanger with constant effectiveness is a simple choice from the TRNSYS modules to simulate grey water heat recovery component.

Hot water tank

Preheated water from the recovery model is stored in the hot water tank for further uses. A Type 4, Stratified Storage Tank with variable inlets and uniform losses was selected for this model. The selected water tank is the Rheem 620T with a capacity of 220 liters, which has two Auxiliary heaters with a power of 4.5 kW.

Ground source heat pump

The 5-ton Daikin Mcquay 064 Geothermal Heat Pumps series with two auxiliary heating stages has been chosen. The water source heat pump is modeled as Type 505. This component models a single-stage liquid source heat pump with desuperheater for hot water heating.

Solar collector

The TRNSYS solar collector used for this study is Type 1. This component models the thermal performance of a flat-plate solar collector. The Enerworks solar collector has three solar panels that are connected in series and have an area of 6.18 square meters. The installed angle of the solar collector is determined for each city according to its latitude since the best angle of the solar collector is according to the latitude of that city [6].

Geothermal borehole

The geothermal borehole in the base state consists of four boreholes to a depth of 55 meters, each borehole having a radius of 100 mm and is used in the actual installation of the system. Type 557 models the vertical GHX that interacts thermally with the ground. The header depth of the boreholes is 1.8 m, the boreholes are 3.6 meters apart with each other's and the storage volume is equivalent to 2470 cubic meters.

4. RESULTS AND DISCUSSION

In order to determine the effect of gray water heat recovery system and solar collector components on the auxiliary heating of the heat pump, the geothermal heat pump system should be run once with solar collector component, and in the next step, the system should be run just with gray water heat recovery component. So, the economic benefits of each component find out. In Fig. 2, mode 1 shows the average amount of auxiliary heating operation (in heating season) in the presence of both recovery and collector components, mode 2 shows the average value of the auxiliary heating operation only if there is a recovery component and mode 3 shows This function only in the face of the presence of a collector. As a result, the difference between mode 2 and 1, shows the amount of savings achieved by the collector and the difference between mode 3 and 1 indicates the amount of savings from the recovery system. Table 2 depicts the increase in auxiliary heating power amount for these modes.

Table 3 shows the average inlet temperature to the heat pump and the system startup cost in the studied cities.

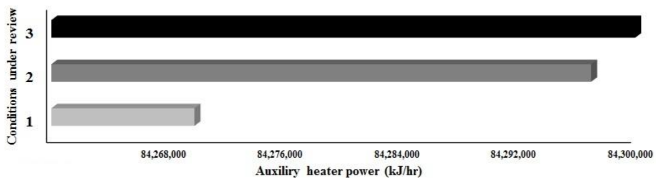

Fig. 2: Average auxiliary heating power performance for the conditions under investigation in one year

Table 2: The average increase in the use of auxiliary heating power in the absence of an intended component within a year

component	Increased use rate (kJ/h)
GWHR	30838.94
Solar Collector	27173.61

Table 3: The average inlet temperature to the heat pump in one year and the system startup cost for the cities under investigation

City	The average inlet temperature to the heat pump over a year (℃)	The total cost of the system (USD)
Ardabil	24.8	28572
Amol	26.4	25647
Tehran	27	25047
Bushehr	26.1	29547

5. CONCLUSIONS

According to the results, it is concluded that the gray heat recovery system and solar collector components have a positive effect on the economic performance of the system during one year. Also, the installation of the system in hot and dry climates such as Tehran has a lower cost and it is more economical to other cities under study.

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