DOR: 20.1001.1.24234931.1401.9.1.4.5

Original Article Volume 9, Issue 1, Spring & Summer, p. p. 13-15

Received: 08/31/20 **Journal of Renewable and New Energy**

Accepted: 02/14/21 **jrenew.ir**

Optimizing energy consumption in air conditioning system and refrigerator in residential buildings using ground energy

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Received: 31 October 2020 Accepted: 14 February 2021

Abstract

In order to reduce energy consumption in air conditioning and refrigeration systems, in this research, a system based on the vapor compression refrigeration cycle and ground energy use has been proposed. This system centrally supplies the energy needed for the air conditioning unit, refrigerator and freezer of a building. The condensing unit of this system is cooled separately and in series by two heat exchangers using outdoor air as well as ground energy. The energy consumption for a sample building is simulated by analytical calculations as well as the use of HYSSIS and TRANSYS softwares. The results of the calculations, which include the system performance coefficient, compressor power consumption, refrigerant quality and mass flow rate, have been compared with the values of the conventional system. The results show that using the water-cooled condenser unit, the inlet refrigerant temperature to the reducer valve is significantly lower than the outdoor air temperature. This significantly increases the performance of the proposed system and noticeably reduces the refrigerant mass flow rate. The effect of reducing the exit refrigerant temperature of the condensing unit on the exergy of the refrigerant has also been investigated.

Keywords: Air Conditioning, Refrigeration, Optimization, Ground Energy, Exergy

1. INTRODUCTION

One of the ways to increase the efficiency and coefficient of performance of a refrigeration cycle is to reduce the temperature in the distillation unit (condenser) as much as possible. In general, and in theory, using an air-cooled distillation unit, the refrigerant temperature can be reduced to the temperature of the air outside the building. However, by using methods such as water-cooled distillation unit or pouring water on the distillation unit, its temperature can be reduced to less than the outside air temperature.

In 2010, Hajidavaloo and Eghtedari [1] proposed a system to reduce the temperature of the distillation unit in a compression cycle using sprinkler nozzles. Their results showed that the performance coefficients increased by 50% and energy consumption could be saved up to 20%. Khalajzadeh et al. [2] used a ground heat exchanger to reduce the air conditioning temperature of the building before it was cooled by the refrigeration cycle. Omar [3] analyzed the performance of two different ground heat pump systems along with the main equipment of each, including compressor, distillation unit, evaporation unit, expansion valve and pumps.

The purpose of this study is to concentrate the various equipment of a building that need refrigeration and cooling load. By concentrating the equipment, the energy of the deep earth can be used optimally. By doing this research, the following can be achieved.

1- Reduce building energy consumption.
2- Using available renewable energies.
3- Providing the comfort temperature of the residents, during the peak heat.
4- Integrating all refrigeration equipment in a centralized cycle.

2. The proposed refrigeration cycle

The refrigeration cycle in hot seasons includes the refrigeration loads of air conditioner, refrigerator and freezer. In this cycle, the lowest temperature will be required in the freezer, then in the refrigerator, and finally in the air conditioning system. Figure 1 shows a schematic circuit of the equipment of this cycle.

The refrigerant will be compressed by three compressors in series. At point 4, the refrigerant enters the cooled-air distillation unit as superheated vapor with high temperature and pressure. During a constant pressure process, its temperature decreases to the temperature of the outside environment, which is predicted as the primary heat sink. The key and effective process in this cycle is the 5 to 6 process, which in addition to transferring refrigerant heat from the cycle to the ground, causes the temperature of the refrigerant entering the pressure reducer valve to be equal to the depth of the earth.

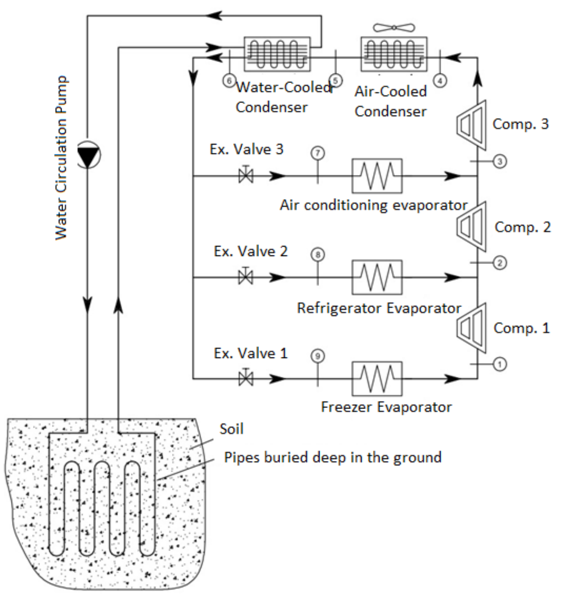

Figure 1. Proposed refrigeration cycle

Table 1. Comparison of two common and proposed systems

	CIRCUIT	Refrigeration load (kJ/hr)	Refrigerant mass flow, kJ/hr	Compressor work, kJ/hr
Common	Air conditioning	69000	496.2	21120
	Refrigerator and freezer	395	2.75	169.6
Proposed	Air conditioning	69000	386.7	16400
	Refrigerator	185	1.05	19.2
	freezer	210	1.36	17.2

2.1. Governing Equations

The equations needed to solve the problem include the relations for calculating the ground temperature, the mass flow rate of each circuit, and the work for the compressors which are listed below.

Earth temperature [15]

$$T = T_{mean} - T_{amp}\exp\left[-depth * \left(\frac{\pi\alpha}{365}\right)^{0.5}\right]\cos\left\{\left(\frac{2\pi}{365}\right)\left[t_{now} - t_{shift} - \frac{depth}{2}\left(\frac{365\alpha}{\pi}\right)^{0.5}\right]\right\} \quad (1)$$

Refrigerant mass flow rate

$$\dot{m} = \frac{\dot{Q}}{\Delta h} \quad (2)$$

Compressor work

$$\dot{W} = \dot{m}\Delta h \quad (3)$$

The calculations are performed using equation solving as well as HYSIS and TRANSIS softwares.

3. Results and Discussion

According to the output information of HYSIS software, which is shown in Table 1, the performance coefficient of the conventional system is 3.26, while the performance coefficient of the proposed system is 4.22, which is a 29% increase.

Figure 14 shows the simulation results of a landfill heat exchanger in TRANSIS software. In this simulation, a 50-meter-deep burial heat exchanger consisting of 500 U-shaped pipes is simulated.

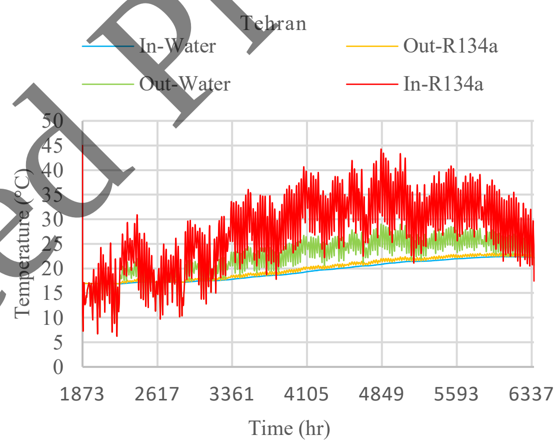

Figure 2. Burial heat exchanger simulation results for hot seasons

Weather information as well as soil conditions for the city of Tehran have been entered into the software as input. The simulation in TRANSIS software is transient and is performed for the first six months of the Shamci year. The refrigerant temperature at the outlet of the air-cooled distillation unit is also floating and is equal to 3 °C higher than the outside air temperature and therefore fluctuates. As shown in Figure 2, reducing the refrigerant temperature to 22 °C is possible by landfill heat exchanger, and the temperature of the water leaving the exchanger is initially upward and then downward.

4. Conclusions

In this study, the energy calculations required for a refrigeration cycle in the warm seasons of the year for a sample building in Tehran with analytical calculations and the use of engineering software and the results are compared with conventional systems. The most important results of this research are the following:

1- The use of water-cooled condenser unit due to ground energy makes it possible to reduce the inlet temperature to the pressure reducer valve from 42 to 22 ° C. As a result, the performance coefficient of the proposed system in the building refrigeration system in hot seasons was 29% higher than the performance coefficient of conventional systems under the same conditions.

2- Using water-cooled distillation unit reduces the refrigerant mass flow by 20.3% and reduces the power consumption of compressors by 25%.

5. References

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