Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(6) (2018) 439-442
DOI: 10.22060/mej.2017.11728.5168

Performance Investigation of a Single Effect (LiBr-H_2O) Absorption Cooling System connected to Photovoltaic Thermal Collectors

O. Shahryari Zanganeh, F. Sarhaddi*

Department of Mechanical Engineering, University of Sistan and Baluchestan, Zahedan, Iran

ABSTRACT: In present research, the performance evaluation of a single effect (LiBr-H2O) absorption cooling system connected to photovoltaic thermal collectors is carried out. The main components of the system include generator, evaporator, condenser, absorber, heat exchanger, pump, expansion valves and photovoltaic thermal collectors. The governing equations of the problem are obtained by writing the mass balance, concentration balance and the first law of thermodynamics for the components of the system and it is solved numerically. The validation of simulation results has been carried out with the experimental data of the previous studies. The results show that there is a desired number for photovoltaic thermal collectors which is 50 number with total area 38.5 m2. It can supply a 5 kW cooling load. Finally, the effect of various operating parameters on the daily coefficient of performance of the system has been investigated. The increase of temperature of generator, condenser and absorber increases the daily coefficient of performance of the system, while the increase of evaporator temperature decreases the daily coefficient of performance of the system. The usage of PV/T collectors besides the supply of inlet heat of generator can provide the consumed pumping power through the system and additional electrical power for other applications.

Review History:

Received: 16 June 2016
Revised: 24 January 2017
Accepted: 5 March 2017
Available Online: 13 March 2017

Keywords:

Solar absorption cooling system
Single effect (LiBr-H_2O) cycle
Energy analysis
Photovoltaic thermal collector
Coefficient of performance

1- Introduction

As humans spend a major part of their time indoors (home and workplace), providing thermal comfort conditions is of great importance. The absorption chiller is one of the cooling and ventilation systems. Theory of Absorption Refrigeration System (ARS) was introduced in 1824 by Michael Faraday. Inlet thermal energy for ARS can be provided by solar energy and photovoltaic thermal collectors (PV/T collectors). The PV/T collector is a combination of conventional solar collectors and photovoltaic modules and simultaneously produces heat and electricity. Florides et al. [1] simulated a solar absorption cooling system for residential scale buildings. This cooling cycle is a single effect (LiBr-H_2O) absorption cooling system with a cooling capacity of 11 kW. They calculated the required amount of inlet heat in the heat generator to provide 11 kW evaporator cooling load and then, on this basis, they obtained an optimum surface of solar collectors as 45 square meters.

A number of studies have been carried out on the solar absorption cooling systems [1-4], this study aimed to investigate the usage of the PV/T collectors as a source of inlet heat of the single effect (LiBr-H_2O) absorption cooling system.

2- Governing Equations

Single effect (LiBr-H_2O) absorption cooling system connected to the PV/T collectors and the corresponding control volume are shown in Fig. 1. Correlations required obtaining temperature, mass flow rate, enthalpy, concentrations in different parts of the cycle can be achieved from the mass balance, concentration balance and the first law of thermodynamics for various components of the cooling cycle [5]:

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

$$\sum (\dot{m}x)_{in} = \sum (\dot{m}x)_{out} \tag{2}$$

$$\sum \dot{Q} - \sum \dot{W} = \sum (\dot{m}h)_{out} - \sum (\dot{m}h)_{in} \tag{3}$$

In this study, the rate of the inlet heat to the heat generator ($\dot{Q}_{gen}$) is provided by PV/T collectors [6].

$$\dot{Q}_{gen} = NA_c F_R \left[\frac{1-(1-K_K)^N}{NK_K}\right] \times [h_{p1} h_{p2} (\alpha\tau)_{eff} G - U_L (T_{13} - T_a)] \tag{4}$$

Electrical power output from a PV/T collector is calculated as follows [7]:

$$\dot{W}_{el} = \sum_{i=1}^{N} \left(\eta_{el,ref} G A_c \left[1 - 0.0045\left(T_{c,i} - T_{a,ref}\right)\right]\right) \tag{5}$$

The cooling cycle performance coefficient is defined as the desired energy ratio in the cycle by the rate of net inlet energy of the cycle.

$$COP = \frac{\dot{Q}_{eva}}{\dot{Q}_{gen}} \tag{6}$$

PV/T collectors' electrical efficiency is defined as the ratio of the rate of net electrical output power of photovoltaic

Corresponding author, E-mail: fsarhaddi@eng.usb.ac.ir

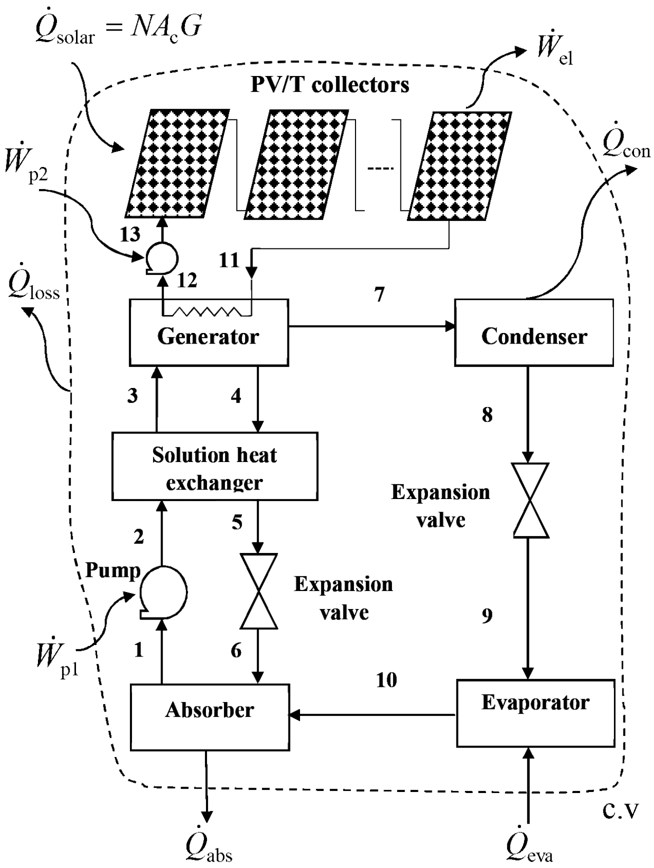

Figure 1. Single effect (LiBr-H_2O) absorption cooling system connected to the PV/T collectors and the corresponding control volume

modules to their solar energy absorption rate.

$$\eta_{el}=\frac{\dot{W}_{el}-\dot{W}_{p1}-\dot{W}_{p2}}{A_{PV}\,(\alpha\tau)_{eff}\,NG} \tag{7}$$

3- Validation

The results of single effect (LiBr-H_2O) absorption cooling system simulation in this study have been validated with the results of theoretical research of Florides et al. [1] and the comparison of the results is presented in Table 1.

Table 1. Validation results of absorption cooling cycle

Parameter	Present study (kW)	Reference [1] (kW)	Error percent (%)
Heat rate in the absorber ($\dot{Q}_{abs}$)	13.89	14.1	1.48
Heat rate in the condenser ($\dot{Q}_{con}$)	11.6	11.8	1.69
Heat rate in heat generators ($\dot{Q}_{gen}$)	14.43	14.9	3.15

4- Results

Fig. 2 shows the coefficient of performance of solar absorption cooling cycle based on time (day) for different numbers of PV/T collectors.

According to Fig. 2, as the number of PV/T collectors increases, performance coefficient reduces, and changes are negligible after N=50. Therefore, the optimal number of PV/T collectors is considered to be 50 in this study.

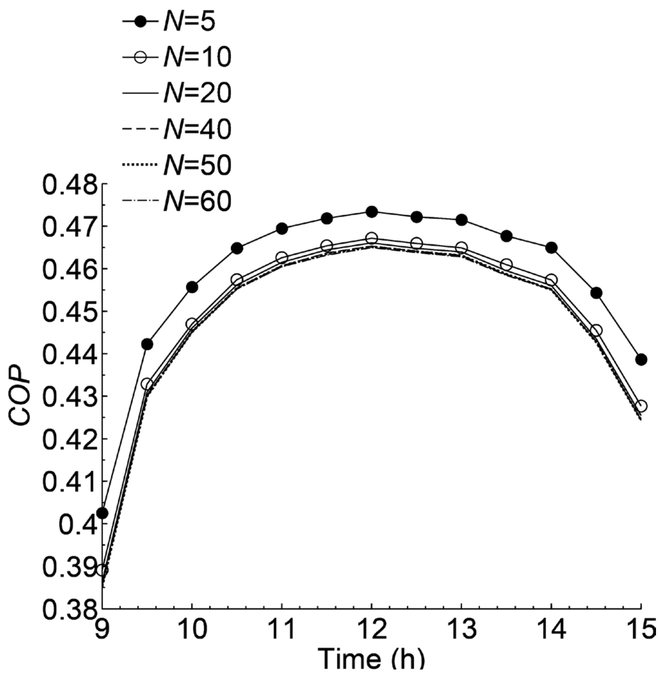

Figure 2. The coefficient of performance of solar absorption cooling cycle based on time (day) for different number of PV/T collectors

5- Conclusions

Main conclusions of the present study are as follows:

- simulation results for the absorption cooling system are in a good agreement with the theoretical data presented in the previous studies;
- There are optimal number for PV/T collectors in a hybrid system as N=50. This number of collectors having a good performance coefficient could provide a cooling capacity of about 5 kW.

References

[1] G.A. Florides, S.A. Kalogirou, S.A. Tassou, L.C. Wrobel, Modelling, simulation and warming impact assessment of a domestic-size absorption solar cooling system, *Applied Thermal Engineering*, 22 (2002) 1313-1325.

[2] S.C. Kaushik, A. Arora, Energy and exergy analysis of single effect and series flowdouble effect water–lithium bromide absorption refrigeration systems, *International Journal of Refrigeration*, 32 (2009) 1247-1258.

[3] O. Kaynakli, K. Saka, F. Kaynakli, Energy and exergy analysis of a double effect absorption refrigeration system based on different heat sources, *Energy Conversion and Management*, 106 (2015) 21-30.

[4] A. Shirazi, R.A. Taylor, S.D. White, G.L. Morrison, A systematic parametric study and feasibility assessment of solar-assisted single-effect, double-effect, and triple-effect absorption chillers for heating and cooling applications, *Energy Conversion and Management*, 114 (2016) 258-277.

[5] R.E. Sonntag, G.J. Van Wylen, C. Borgnakke, *Fundamentals of Thermodynamics*, 7th Edition, John Wiley & Sons, Inc. 2009.

[6] S. Dubey, G.N. Tiwari, Analysis of different configurations of flat plate water collectors connected in series, *International Journal of Energy Research*, 32 (2008) 1362-1372.

[7] A. Tiwari, M.S. Sodha, Performance evaluation of solar PV/T system: An experimental validation, *Solar Energy*, 80 (2006) 751-759.

Please cite this article using:

O. Shahryari Zanganeh and F. Sarhaddi, Performance Investigation of a Single Effect (LiBr-H_2O) Absorption Cooling System connected to Photovoltaic Thermal Collectors, *Amirkabir J. Mech. Eng.*, 50(6) (2018) 1375-1388.

DOI: 10.22060/mej.2017.11728.5168