Desalination 420 (2017) 106–113

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Exergy and economic analysis for a double slope solar still equipped by thermoelectric heating modules - an experimental investigation

N. Rahbar[a,b,*], A. Gharaiian[c], S. Rashidi[a]

[a] Young Researchers and Elite Club, Semnan Branch, Islamic Azad University, Semnan, P.O. Box: 35196-97951, Iran
[b] Energy and Sustainable Development Research Center, Semnan Branch, Islamic Azad University, Semnan, P.O. Box: 35196-97951, Iran
[c] Department of Mechanical Engineering, Semnan Branch, Islamic Azad University, Semnan, P.O. Box: 35196-97951, Iran

ARTICLE INFO

Keywords:
Exergy analysis
Double slope solar still
Thermoelectric heating
Cost analysis

ABSTRACT

In this paper, an exergy analysis is performed for a double slope solar still equipped by thermoelectric heating modules to achieve a better thermodynamic performance. Thermoelectric modules were used as a water heater to increase the temperature of water and accordingly improve the performance of the solar still. The results are obtained by performing a series of experiments during ten days and nights under the climate conditions of Semnan (35° 33′ N, 53° 23′ E), Iran. Finally, an economic analysis has been performed to determine the production cost of water per liter. The obtained results showed that the heatsink temperature and heating created by thermoelectric cause an increase in the water temperature. This prevents reduction in production when the solar intensity decreases at afternoon. Moreover, it is observed that the exergy efficiency increases during the times of experiments. The maximum exergy efficiency of the system is about 25% and occurred at 3 p.m. Life cycle analysis also showed that the cost of distilled water for the day and night are 0.1422 and 0.237 $/L/m^2$, respectively.

1. Introduction

Access to drinking water is decreasing day by day, while the demand of it is increasing quickly. Only about 0.014% of available water in earth can be applied directly for human and industrial consumptions and the rest are impure and salty. This storage shows the importance of desalination techniques. Solar energy can be applied for desalination especially in remote areas. Solar stills are devices that used this energy to purify the impure water. The poor efficiency of such devices is major drawback of them. Accordingly, researchers have focused on various active and passive techniques to improve the efficiency of these devices [1–5].

In passive techniques, the modifications are not based on the external sources. Srivastava and Agrawal [6] floated experimentally and theoretically multiple low thermal inertia porous absorbers in the basin water of single slope solar still. They observed 68% more output for modified still incorporated by porous absorbers in comparison with the conventional one for clear days. This value was about 35% for cloudy days. El-Sebaii et al. [7] evaluated experimentally the effects of fin configuration on the performance of a single basin solar still. They showed that the productivity of the modified still enhances as the fin height increases, while it reduces as the fin thickness or fin number increases. Rashidi et al. [8] improved numerically the performance of a single slope solar still by incorporating the partition inside the still. Their results showed that incorporate of partition creates a higher number of vortices with smaller sizes that provides an adequate time to heat exchange and enhance the still efficiency. Sahota and Tiwari [9] evaluated the effect of Al_2O_3 nanoparticles on the performance of a double slope solar still. They achieved to 12.2% and 8.4% enhancements of yield, respectively for 35 kg and 80 kg basefluid by using Al_2O_3 nanoparticles with 0.12% concentration in comparison with the pure fluid case. Sarhaddi et al. [10] evaluated the potential of PCM as storage material in a weir type cascade solar still by using energy and exergy analysis. They concluded that the maximum energy and exergy efficiencies of the modified solar still with PCM are 74.35% and 8.59%, respectively. These values were 76.69% and 6.53%, respectively for conventional still.

Aside from passive technique, some active techniques are utilized by researchers to improve the performance of solar stills. In active techniques, the modifications are based on the external sources. Yadav and Kumar [11] used water flow in the basin of a single basin solar still. They found that the temperature of water enhances and accordingly the productivity and efficiency of the system improve as the mass flow rate decreases. Badran et al. [12] coupled a solar still with a conventional

* Corresponding author at: Young Researchers and Elite Club, Semnan Branch, Islamic Azad University, Semnan, P.O. Box: 35196-97951, Iran.
E-mail address: Rahbar@semnaniau.ac.ir (N. Rahbar).

http://dx.doi.org/10.1016/j.desal.2017.07.005
Received 1 April 2017; Received in revised form 22 May 2017; Accepted 6 July 2017
0011-9164/

Nomenclature

a	accuracy of the instrument
A	area (m^2)
AC	annual cost ($)
AMC	annual maintenance operational cost ($)
ASV	annual salvage value ($)
CPL	cost per liter ($ L^{-1})
CRF	capital recovery factor
FAC	fixed annual cost ($)
I(t)	solar radiation fall on the still (W m^{-2})
i	Interest rate (%)
I	Electrical current (A)
L	latent heat of the water (J kg^{-1})
L	length of basin (m)
$\dot{m}_{ev}$	fresh water production rate (Kg s^{-1})
M	average annual productivity (L)
n	life of the still (years)
P	capital cost ($)
S	salvage value ($)
SSF	sinking fund factor
T	temperature (K)
u	standard uncertainty
V	Electric potential difference (V)
w	power (W)
W	width of basin (m)

Subscripts/superscripts

a	ambient
b	basin
Ex	exergy
s	sun

Greek symbols

η	efficiency

flat-plate collector to improve the efficiency. They observed about 231% and 52% augmentations in distilled water production for the cases of tap water as a feed and salt water as a feed, respectively by using this coupling. Ahmed et al. [13] investigated the effects of integrating water sprinklers and cooling fan on the efficiency of a solar still. They reported that the productivity enhances about 8% and 15.5% as the average wind speed increases from 1.2 m/s to 3 m/s and 4.5 m/s, respectively. Moreover, the productivity was enhanced about 15.7% and 31.8% by applying water sprinklers at preset intervals of 20 min and 10 min, respectively. Heydari and Rahbar [14] applied a periodic injection on enclosure walls of a basin type solar still. They improved the efficiency and the fresh water production rate about 7% and 75%, respectively by using this technique. Application of thermoelectric modules in solar still to decrease the glass temperature and increase condense vapor was investigated by some researchers. Esfahani et al. [15] applied thermoelectric cooling in a portable solar still to enhance the productivity. They reported that the cost per liter of produced water is comparable with other types of conventional solar stills. Rahbar and

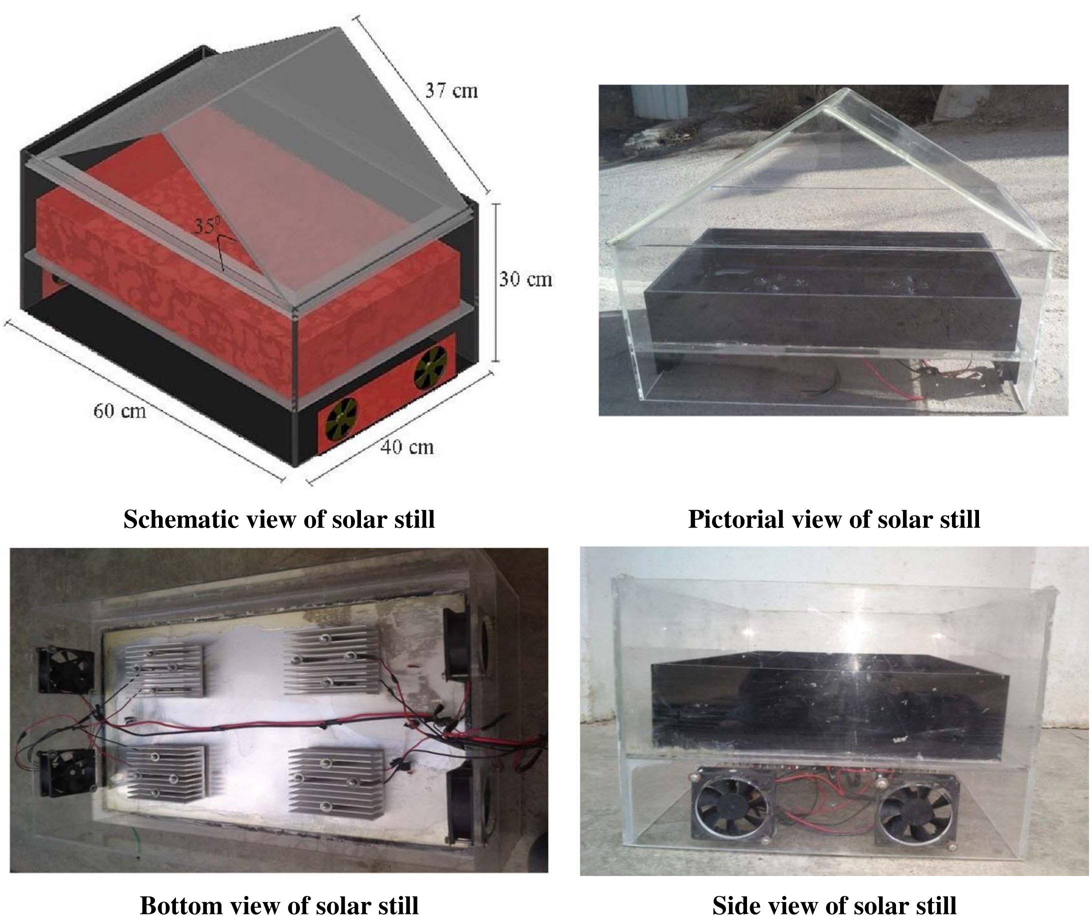

Fig. 1. Schematic and pictorial views of fabricated solar still.