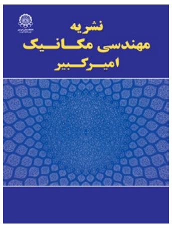

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Thermoeconomic Analysis of a Double Slope Basin Solar Still Equipped to Phase Change Material and Photovoltaic Thermal Collector

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ABSTRACT: In present study the thermoeconomic analysis of a double slope basin solar still equipped to phase change material and photovoltaic thermal collector is carried out. The governing equations of problem are obtained by writing energy balance for different components of the system. The goal of governing equations solution is the calculation of glass cover temperature, absorber temperature, saline water temperature, phase change material temperature, freshwater productivity and the useful heat gain of photovoltaic thermal collector. Also, the output electrical power of photovoltaic module is calculated by four parameters current-voltage model. Present study numerical results are in good agreement with experimental data. The system performance evaluation is carried out from the viewpoint of freshwater productivity and energy efficiency for the sample winter and summer day of Zahedan. Results show that the freshwater productivity increases to 10.6% by increasing of mass flow rate from 0.001 to 0.01 kg/s. Increase of saline water mass of basin from 20 to 30 kg decreases the freshwater productivity to 4.8% during the day. On the other hand, it increases the freshwater productivity to 7.43% during the night. The energy efficiency is 37.5% less on winter day than summer day. The freshwater production cost is obtained 0.0314 $/l.m2.

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1- Introduction

In recent years, the scarcity of fresh water has become one the main challenges faced for the continuation of human life. Drinking water resources constitute about three percent of the total volume of water on Earth, and ocean water cannot be utilized directly due to its salt content of about 3.5 percent [1]. Therefore, people need to find ways of providing drinking water to overcome this problem. In countries like Iran, use of solar energy for distillation of salty seawater can be a suitable method for producing fresh water. Al-harahsheh et al. [2] studied the experimental performance of a double slope basin solar still connected to a conventional solar energy collector. They used a series of cylindrical blocks containing a Phase Change Materials (PCM) for this solar still. Their system could produce about 4300 mL/m2.day. Forty percent of this fresh water was produced during the night by the phase change material.

The innovation in the present research was the concurrent use of phase change materials and PhotoVoltaic Thermal (PV/T) collector in a double slope basin solar still, something that was not carried in previous research [1-4]. The PV/T collector helped improve fresh water production during sunlight hours through preheating the salt water, and the PCM allowed fresh water production during the night. However, the thermo-economic analysis of the hybrid system was not carried out.

2- Governing Equations of the System

A hybrid system was employed in this study consisting of a double slope basin solar still together with PMC and a PV/T collector, and fresh water was produced day and night due to of the presence of the PMC. Fig. 1 presents a general view of the studied system. Energy balance equations were written for the various components of the system to analyze energy and the performance of the solar still together with the PMC and the PV/T collector. Analysis of these equations yielded a nonlinear system of ordinary differential equations to find the various temperatures of system components. Since the energy source for the system was solar energy during the day and the PCM at night, energy equations were written for the charge and discharge states. Energy balance for the western glass, the water in the basin, the absorber plate, and the PCM in the charge state are presented below, respectively [1-4]:

$$\alpha_g G_{sw} A_g + h_{W-gw} A_b (T_W - T_{gw}) = h_{c,gw-a} A_g (T_{gw} - T_a) + h_{r,gw-sky} A_g (T_{gw} - T_{sky}) + h_{r,gw-ge} A_g (T_{gw} - T_{ge}) + M_g c_g \frac{dT_{gw}}{dt} \quad (1)$$

$$\tau_g \alpha_W G_s A_b + h_{c,b-W} A_b (T_b - T_W) + \dot{Q}_c = h_{W-gw} A_b (T_W - T_{gw}) + h_{W-ge} A_b (T_W - T_{ge}) + M_W c_W \frac{dT_W}{dt} \quad (2)$$

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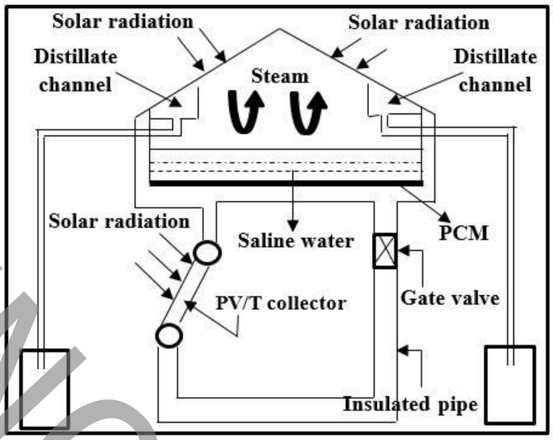

Fig. 1. Hybrid turbine model

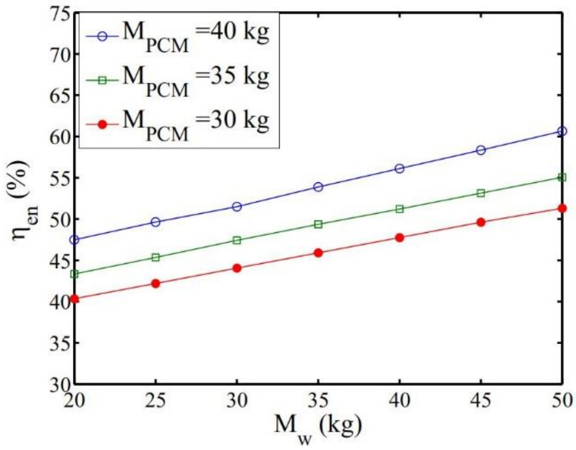

Fig. 2. The flow field and boundary conditions

Table 1. Turbine characteristics

Parameter	Error (%)
Temperature of the water in the basin	6.8
Temperature of the glass condenser	7.32
Temperature of the collector cell	3.8
Temperature of the outflow from the collector	3.1

$$\tau_g \tau_W \alpha_b G_s A_b = h_{c,b-W} A_b (T_b - T_W) + \frac{k_{PCM}}{X_{PCM}} A_b (T_b - T_{PCM}) + M_b c_b \frac{dT_b}{dt} \quad (3)$$

$$\frac{k_{PCM}}{X_{PCM}} A_b (T_b - T_{PCM}) = \frac{k_{ins}}{X_{ins}} A_b (T_{PCM} - T_a) + M_{equ} \frac{dT_{PCM}}{dt} \quad (4)$$

The rate of evaporation energy related to the solar still and the mass of fresh water produced by the system are obtained from the following equations.

$$\dot{q}_{ev} = h_{ev} A_b (T_w - T_g) \quad (5)$$

$$m_w = \frac{\dot{q}_{ev} \Delta t}{h_{fg}} \quad (6)$$

The energy efficiency the PV/T solar still is defined as the ratio of the desirable output energy to the net energy entering the system.

3- Validation

Since no comprehensive research was found to exactly match the present one, the validation process took place in the two stages shown in Table 1. The first stage was validation of the code written for the PV/T collector through comparison with data related to the testing setup of the PV/T collector located at the Mechanical Engineering Department of University of Sistan and Baluchestan. The second stage was validation of the code written for the double slope basin solar still employing the experimental data reported by Tiwari et al. [4].

Table 1 indicates the simulation results matched previous empirical data well.

4- Results

Fig. 2 shows the average daily energy efficiency based on changes in PCM and water masses.

As shown in Fig. 2, the average daily energy efficiency improved with increases in water mass and also improved with increases in PCM mass.

The present study used the economic analysis performed by Fath et al. [5]. The estimated cost of the machine (the price of dollar at Tomans 4200) was 337 dollars. According to the mentioned economic analysis, the production cost per unit area was 0.0314 dollar per liter of produced fresh water.

5- Conclusions

Main conclusions of the present study are as follows:

•Numerical simulation results in the present study for the double slope basin solar still, and for the PV/T collector connected to it, are in good agreement with those of previous experimental research.

•Increases in the mass of salt water inside the basin at first reduced but then increased the daily energy efficiency of the system. However, the daily energy efficiency improved on average.

•The performed economic analysis and its comparison with those of similar studies show that the suggested system is a cost-effective one and, in addition to producing water, generates electricity.

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