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Study of The Utilization of Thermoelectric Generator and Thermocline for Improvement of Solar Still Performance

Dan Mugisidi[1, 3, a)], Berkah Fajar[2)], Syaiful Syaiful[2)], and Tony Suryo Utomo[2)]

[1]*Doctoral Programme Department of Mechanical Engineering, Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia.*
[2]*Department of Mechanical Engineering, Faculty of Engineering, Universitas Diponegoro, Semarang, Indonesia.*
[3]*Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Prof Dr. Hamka, South Jakarta, Indonesia.*

[a)]Corresponding author: dan.mugisidi@uhamka.ac.id

Abstract. Solar stills generally work because they are energized by solar energy, making them very economical. Unfortunately, solar still productivity is still low and lowers further when solar irradiance decreases. This is one of the reasons for the low efficiency of solar stills. This study uses a thermoelectric generator attached to the solar still to overcome this inefficiency. The heating temperature for the thermoelectric generator is obtained from the outer side of the solar still heat absorber, while the cold temperature is from the thermocline layer. The heat absorber of the solar still size is 400 mm x 300 mm using 3 mm of aluminium material. The thermoelectric generator uses 48 pieces of TEHP1-1263-1.5-1.3A type, and the thermocline is set at a temperature of 5 °C. The results show that the efficiency of the solar still increased by 129% with the addition of a thermoelectric generator and thermocline.

INTRODUCTION

The availability of clean water is a big problem faced by many countries [1] because its use is increasing along with the increase in population and industrial development [2], while the amount is limited. Therefore, an alternative source is needed for use as clean water, namely seawater. The earth's surface is 71% covered by the ocean [3], so seawater can be used to overcome the limited availability of clean water. Unfortunately, seawater cannot be used directly to meet daily needs [4] because it contains large amounts of minerals [5] and must be purified.

One method of purifying seawater as freshwater is solar distillation [6] using a solar still. A solar still is filled with seawater, which is then heated using the sun's heat to evaporate and condense into freshwater [7,8]. This process can be used for up to 200 m3/day [9]. Since the productivity and efficiency of solar stills are still low [10], many researchers are researching to improve them. Solar stills' low productivity and efficiency are due to the variation in solar radiation used as its energy source, especially during the hot afternoon sun [11]. If solar radiation decreases, solar still productivity also decreases [12-14].

To overcome the decrease in productivity due to reduced solar heat, another heat source is needed to replace it. One solution is to use an electric heater with a thermoelectric generator (TEG) source of electricity because it can utilize solar heat and convert it into electrical energy [15]. TEG is a tool for converting heat energy into electrical energy because there is a temperature difference on both sides [16,17]; the hot and cold sides, so to obtain a high amount of electrical energy, the temperature difference on the hot and cold sides needs to be as large as possible. The heat required by the TEG can come from the exhaust heat; [18] Therefore, several studies have made use of water vapor heat by placing the TEG's hot side in the condenser of the solar still [19-21] or placing the TEG in the heat plate absorber to increase the thermodynamic efficiency [22]. In contrast to previous studies that used airflow as a coolant, in this proposal, the TEG generates electricity utilizing the heat at the bottom of the heat absorber and seawater thermocline as a coolant. The thermocline of the thermal layer is a thin but distinct layer in a large body of fluid in which temperature changes more drastically with depth [23]. Therefore, the temperature at sea level ranges from 28–

30 °C, and the temperature gets lower as the depth increases. At a depth of 220 m, the water temperature is around 13 °C, and at a depth of 600 m, the water temperature is around 5 °C [24] with an average distance of 110.67 m [25], which is influenced by the circulation that occurs in the surface layer [26].

Therefore, this study proposes a solar still system whose performance is enhanced by utilizing the heat from the absorber using a TEG and, on the cold side, using water with a temperature of 5 °C. The electrical energy generated will be stored in the battery and used at night.

SYSTEM DESCRIPTION

This study combines experimental results with calculations to predict system efficiency. Water temperature, heat absorber plate temperature, solar radiation, and freshwater yield measurements were obtained on the day of the experiment results. Other than that, battery charging, basin water, inner side glass cover temperature, and freshwater yield at night were obtained using a calculation. The entire system configuration is shown in Figure 1.
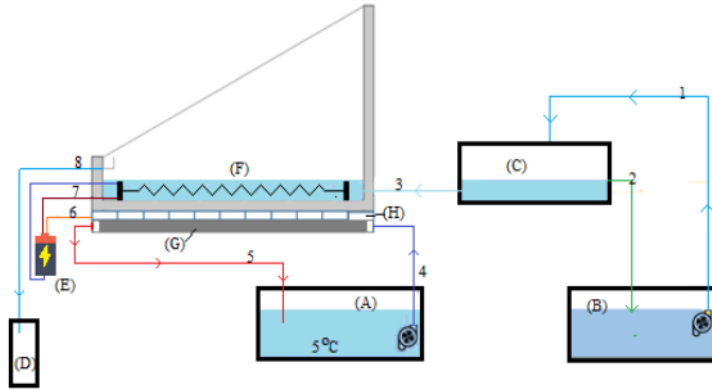
FIGURE 1. Proposed system diagram; (A)=Thermocline water box, (B)=Basin water tank, (C)= Level control tank, (D)=Fresh water collecting jar, (E)=Battery, (F)=Water heater, (G)=Colling water box, (H)=TEG, 1=Circulation line, 2=Overflow line, 3=Supply line, 4=Colling water inlet, 5=Colling water outlet, 6=Charge line, 7=Discharge line, 8=Fresh water line

Figure 1 shows seawater flows from the water tank basin to the level control tank. The water level at the control tank level is the same as in the solar still. Water level adjustment is made by adjusting the overflow. Water from the level control tank will flow into the solar still when the water evaporates and causes its level to decrease. The water vapor will condense in the solar still cover glass and flow to the freshwater collecting jar through the freshwater line. In this approach, the water used on the cold side of the TEG is kept at a temperature of 5 °C in the thermocline water box and circulated with a pump through the cooling water box. The TEG uses 48 pieces TEHP1-1263-1.5-1.3A.

Internal Heat Transfer and Charging

The evaporation process in the solar still starts with an increase in water pressure so that it has a difference in pressure with the cover glass. The energy balances in solar still are [27]:

$$M_w C_{p-w} \frac{dT_w}{dt} + h_{tw}(T_w - T_{gi}) = \alpha_w I_{(t)s} + h_{ba}(T_b - T_w) + q_u \tag{1}$$

T_w and T_{gi} are water and inner side cover glass temperature, respectively. T_b is basin temperature, and $I_{(t)s}$. The heat transfer that occurs includes convection, radiation, and evaporation [28].

$$qt = qc + qr + qe \tag{2}$$
$$ht = hc + hr + he \tag{3}$$

Convection, radiation, and evaporation heat transfer can be calculated using:

$$q_c = h_c(T_w - T_{gi}), \tag{4}$$

$$h_c = C(G_r P_r)^n \frac{k_f}{d_f}, \tag{5}$$

$$K_f = 0{,}0244 + 0{,}7673 \times 10^{-4} \times T_w, \tag{6}$$

$$q_r = h_r(T_w - T_{gi}), \tag{7}$$

$$h_r = \varepsilon_{eff}\sigma\left[(T_w + 273)^2 + (T_{gi} + 273)^2\right](T_w + T_{gi} + 546), \tag{8}$$

$$q_e = h_e(T_w - T_{gi}) \tag{9}$$

and

$$h_e = 16.273 \times 10^{-3} \times h_c \left[\frac{P_w - P_{gi}}{T_w - T_{gi}}\right] \tag{10}$$

Water temperature is predicted using equation [28]:

$$T_w = \frac{ft}{a}[1 - e^{-at}] + T_{w0} \cdot e^{-at} \tag{11}$$

The values of C and n were searched using the Nusselt and Rayleigh (Nu-Ra) power-law relation [29]. Battery capacity can be determined using:

$$C = \frac{E_k}{V \times Pf} \tag{12}$$

and

$$E_k = Q \times t_p \tag{13}$$

The power required to heat water over a period of time is:

$$Q = m \times C_p \times \frac{\Delta T}{t} \tag{14}$$

The equations can calculate the time required for filling:

$$t = \frac{C}{C_c} \tag{15}$$

Where t is charge time, C is battery capacity and C_c is battery charging capacity. Then:

$$C_c = I_o \times n \tag{16}$$

Io is the output current, and n is the number of TEG. The result of the evaporation of solar still per hour can be calculated by using the following equation [30]:

$$m_w = \frac{h_e \ (T_w - T_{gi})}{h_{fg}} \times 3600 \tag{17}$$

The efficiency calculation of the solar still is [31]:

$$\eta = \frac{m_d \times h_{fg}}{A \times I_{(t)s} \times 3600} \ x \ 100\% \tag{18}$$

Where h_e is the evaporation heat transfer coefficient. Efficiency (h) is provided by multiplying freshwater yield (md) and latent heat of evaporation divided by solar radiance ($I_{(t)s}$) in solar still area (A) for one hour in a second.

RESULTS AND DISCUSSION

Evaporation in a solar still occurs due to differences in the surface pressure of the water and the cover glass [32] caused by temperature differences. Therefore, when solar radiation has decreased, the heat source is diverted to a water heater that uses electrical energy. Electrical energy is obtained from batteries that are charged with electricity from a TEG. The amount of power generated by the TEG can be calculated using the open-circuit voltage equation [17].

$$Y = -7 \cdot E^{-05} \cdot x^2 + 0.064 \cdot x - 0.9553 \tag{19}$$

The power required to keep 2,738 kg of basin water at a temperature above 40 °C for 15 hours at night is 8025.08 Watts, so the required battery capacity is 572.2 A, and the charging time is estimated at 8 hours and 1 minute. Figure 2 shows the measurement of solar radiation (I), water temperature (Tw), and the inner glass cover temperature (Tgi). The values of C and n are 0.3919 and 0.4659, respectively, calculated from the experimental results. After time 17.00, the water temperature is predicted by equation (10), and the energy source is a battery regulated to keep the temperature above 40 °C. Tgi is approached using equation 0.8892.x + 2.2023, which is obtained using the linear fitting between Tw and the Tgi of the experimental results.

Freshwater obtained from the solar still during the day is 371.2 gr/m² and at night is 114.65 g/m², so the total accumulation of freshwater obtained is 485.68 gr/m². Because the main energy source is solar heat, the solar's

efficiency of the solar still at day time is 34%, increasing the efficiency to 44% for 24 hours' usage. The system efficiency increases by about 10% due to the low efficiency of TEG. This result is similar to the experiment of Rahbar which has an efficiency of 7% [33]. Since the source of solar energy is used to evaporate water in the solar still and, at the same time, it is converted into electrical energy using TEG, the efficiency increase.
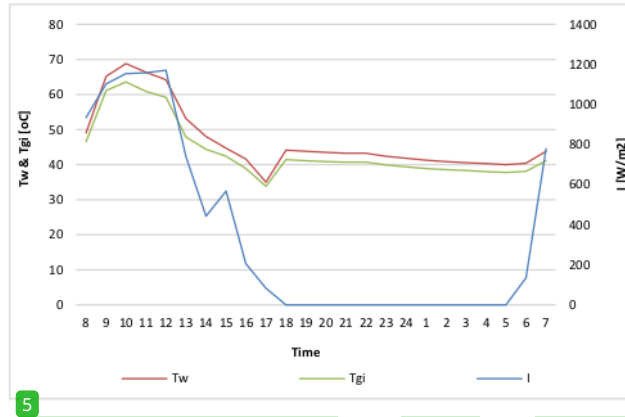

FIGURE 2. Solar irradiance (I), water temperature (Twi), and inner cover glass temperature (Tgi).
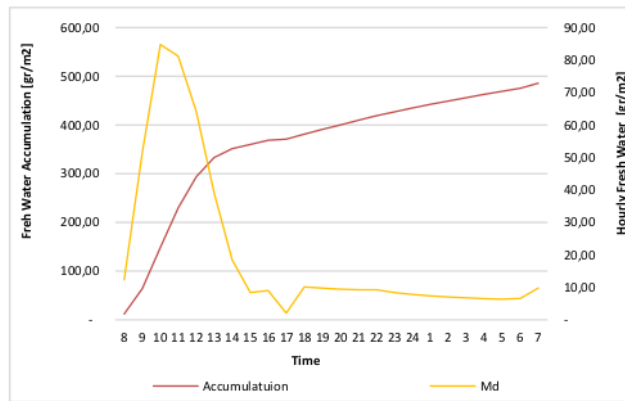
FIGURE 3. Hourly freshwater yield and daily accumulation.

CONCLUSION

The efficiency of the solar still with the addition of a TEG and thermocline is increased by 129% when compared to the same solar still without a TEG. This shows that the productivity of solar stills can still be improved. Electrical energy can be sourced, apart from using a TEG, from photovoltaics, wind energy, wave energy, or a combination of renewable energy sources. It can then be used at night or when the water temperature becomes low. Using energy from various sources, a solar can still operate 24 hours a day without depending on only one main energy source, the sun.

ACKNOWLEDGMENTS

REFERENCES

1. Y. A. F. El-Samadony and A. E. Kabeel, **68**, 744 (2014).
2. M. S. S. Abujazae, S. Fatihah, A. R. Rakmi, and M. Z. Shahrom, 385 178 (2016).
3. H. Genda, J **50**, 27 (2016).
4. N. M. I. Kurnia, 1 (2015).
5. D. Mugisidi and O. Heriyani, **31 02005**, (2018).
6. F. F. Tabrizi, M. Dashtban, and H. Moghaddam, **260**, 248 (2010).
7. D. Mugisidi, J. Adv. Res. Fluid Mech. Therm. Sci **70**, 125 (2020).
8. S. A. Kalogirou, Energy Combust. Sci **30**, 231 (2004).
9. L. García-Rodríguez, **143**, 103 (2002).
10. A. Agrawal, R. S. Rana, and P. K. Srivastava, Technol **0**, 1 (2017).
11. A. Agrawal and R. S. Rana, 1525 (2019).
12. K. K. Murugavel, S. Sivakumar, J. R. Ahamed, K. K. S. K. Chockalingam, and K. Srithar, Energy **87**, 514 (2010).
13. T. Elango and K. M. Kalidasa, 359 82 (2015).
14. E. Rubio, J. L. Fernández-Zayas, and M. A. Porta-Gándara, J. Mar. Sci. Eng **8**, (2020).
15. S. Nazari, H. Safarzadeh, and M. Bahiraei, J. Clean. Prod 208 1041 (2019).
16. S. Wango and K. Prashantha, J. Mech. Prod. Eng. Spec. Issue,-Sep 45 (2016).
17. A. Montecucco, J. Siviter, and A. R. Knox, Energy **123**, 47 (2014).
18. J. T. Jarman, E. E. Khalil, and E. Khalaf, in *Energy Anal. Thermoelectr. Renew. Energy Sources 2013* (2013), pp. 143–53.
19. S. M. Parsa, A. Rahbar, M. H. Koleini, S. Aberoumand, M. Afrand, and M. Amidpour, 114354 (2020).
20. S. Nazari, H. Safarzadeh, and M. Bahiraei, Energy 135 729 (2019).
21. M. A. Al-Numr and K. S. Qananba, Energy **171**, 92 (2017).
22. N. Rahbar, A. Gharaiian, and S. Rashidi, 106 (2017).
23. S. K. Wang, *Air Conditioning Systems: System Classification, Selection, and Individual Systems* (2001).
24. K. C. Ng and M. W. Shahzad, Sustain. Energy Rev **82**, 240 (2018).
25. R. Yuliarinda, Muslim, and W. Atmodjo, 33 (2012).
26. H. C. Sidabutar, A. Rifai, and E. Indrayanti, Oseanografi **3**, 135 (2014).
27. G. N. Tiwari and L. Sahota, 401 151 (2017).
28. C. Elango, N. Gunasekaran, and K. Sampathkumar, Sustain. Energy Rev 47 856 (2015).
29. A. F. Mohamed, A. A. Hegazi, G. I. Sultan, and E. M. S. El-Said, Therm. Eng **150**, 1206 (2019).
30. U. R. Soni, D. P. K. Brahmatt, and H. B. Patel, J. Recent Innov. Trends Comput. Commun **1**, 843 (2013).
31. A. D. Jhon and W. A. Beckman, *Solar Energineering of Thermal Process* (Wiley, Canada, 2013).
32. D. Mugisidi, R. S. Cahyani, O. Heriyani, D. Agusman, and Rifky, Ser. Earth Environ. Sci 268 1 (2019).
33. E. H. K. T. Zorbas and K. M. Paraskevopoulus, Power and efficiency calculation in commercial TEG and application in wasted heat recovery in automobile **i**, (2011).

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and moth-flame optimizer", Case Studies in Thermal Engineering, 2021
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11 "Advances in Solar Power Generation and Energy Harvesting", Springer Science and Business Media LLC, 2020
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tubular solar water desalting system", Applied Energy, 2013.
Publication

13 Y. D. Deng, S. J. Zheng, C. Q. Su, X. H. Yuan, C. G. Yu, Y. P. Wang. "Effect of Thermoelectric Modules' Topological Connection on Automotive Exhaust Heat Recovery System", Journal of Electronic Materials, 2015
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