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An Analytical Studyof Active Solar Still Incorporated Cpc Collector

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Abstract -The study's primary goal is probably to analyse the energy matrices, exergoeconomic parameters, enviroeconomic parameters, productivity, and efficiency of these distinct solar distillation systems. By examining these components, the researchers can gauge the general performance and cost-effectiveness of each system. The creation of more efficient and affordable solar distillation equipment to produce drinking water can then be accomplished using this information. The existence of partially covered PVT flat collector plates (FPC) and compound parabolic concentrators (CPC) suggests that the researchers are investigating the integration of thermal and solar technologies into the distillation process. The calculation of exergoeconomic parameters, enviroeconomic parameters, productivity, and various efficiencies was done after this. Exergoeconomic parameters are typically used in mechanical, thermal, and other systems, according to numerous studies.

Keywords: energy, photovoltaic, exergy, enviroeconomic, exergoeconomic

1. Introduction

It is true that water makes up the majority of the human body—roughly 75% of the body's mass. Seawater has a salinity of between 35,000 and 45,000 ppm, while the majority of readily accessible water on Earth has a salinity of up to 10,000 ppm. However, the World Health Organisation (WHO) claims that drinking water with salinities up to 1,000 ppm poses no appreciable health concerns to people.The empirical relations for the inner coefficients of heat transfer from the natural flow with a heat exchanger in a solar distiller unit were developed by Lawrence and Tiwari [1]. Popiel and Wojtkowiak [2] investigated the base fluid's thermo-physical characteristics. Numerous relationships were examined by Pak and Cho [3] for various attributes. G. N. Tiwari [4] researched the basic construction of a solar still. Al2O3 nanofluids' heat transfer coefficient was examined by Hwang et al. [5]. The heat transfer coefficients of the base fluid can also be enhanced, according to Barden [6]. Nanoparticles (1-100 nm) are easily suspended in base fluids (ethylene glycol, thermal oil, water, etc.) because of their superior thermo-physical properties. With the use of nanofluids, fluids with extraordinarily rapid heat transfer capabilities are being created. Customising the size and shape will also improve the properties of the base fluid. There aren't many advantages to solar distillers over other distillation technologies including filters, membranes, and batteries, and they require a relatively low initial expenditure. Nanofluids were numerically analysed by Ho et al. [8] for natural convection in a square enclosure: effects of viscosity and thermal conductivity uncertainty. Nanofluid was used in Otanicar and Golden's [9] analysis of the eco-economic impact of solar collectors, and they discovered that it neutralises 74 kg over the course of 15 years. Patel et al. [10] discovered that nanofluids had thermal conductivity. Entropy generation for nanofluids was theoretically investigated by Singh et al. [11]. Elzen et al. [12] examined carbon price, abatement costs, and emission reductions. This paper by Khanafer and Vafai [13] presented the thermophysical characteristics of nanofluids. For a solar heating device for nanofluids, Khullar and Tyagi [14] analysed and reported reduced emissions of 103 kg approximately/household/year. Based on the cost of flat plate collector (FPC) employing tin oxide, copper oxide, titanium oxide, and aluminium oxide) nanofluids, Faizel et al. [15] conducted an analysis. It is determined that the high density, low specific heat, and thermal conductivity of CuOnanofluid provide the best explanation for its performance. The integrated solar distiller unit of the evacuated tube's economic analysis has been reviewed by Liu et al. [16]. The only inclined solar distiller unit with vacuum was examined by Kabeel et al. [17] as a water-based nanofluid. Elango et al. [18] used several nanofluids to analyse the thermal energy, exergy, and productivity of a single slope solar distiller. Omara et al. [19] used nanofluids to analyse the effectiveness of a corrugated wick type and a straightforward solar distiller unit. Tiwari et al.'s [20] experimental analysis of the active solar distiller examined the exergoeconomic and environmental benefits of employing water-based nanofluid to meet daily demands for potable water. A $6.29 year estimate has been made for the environmental cost. Sahota et al.'s [21] analysis of the environmental and energy economics of a passive double slope solar distiller with water-loaded nanofluid (CuO, Al_2 O_3, TiO_2) indicated that the system's energy payback time is short and that the annual cost of environmental mitigation with nanofluid is higher. The improvement in energy matrices of the N-PVT-FPC partially double slope solar distiller was examined by Singh and Tiwari [22]. N-PVT-CPC, a single slope, Nth identical photovoltaic thermal compound parabolic concentrator collector, was examined by Joshi and Tiwari [23]. Desalination with nanofluids has been reviewed by Dharamveer et al. (24). [25] Using a compound parabolic concentrator, Kumar and Singh analysed the energy and exergy of active solar stills.[26] Shanker, et al. modified the injection timing and pressure to analyse the performance of a C.I. engine utilising biodiesel fuel. [27]Using FEA, Anup et al. examined the refrigerator compartment to maximise thermal efficiency. Optimised thermal behaviour of a compact heat exchanger by Kumar and Singh [28].Utilising green and clean technology is the main focus of Zhang et al.'s [29] presentation in the field of sustainable energies. Dhivagar et al. [30] examined the energy, exergy, and financial aspects of a single slope grate crude oil solar distiller machine. The effects of active and passive solar still behaviour on energy matrices and environmental economics were examined by Dharamveer and Samsher [31]. In order to generate water, Arora et al. [32] examined the double slope solar distiller N-PVT-CPC. [33] Dharamveer et al. used CuO Nanoparticles to conduct an analytical study on Nth identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) active double slope solar distiller.[34] Dharamveer, et al. used CuO nanoparticles to analyse an N-identical active single slope solar distiller with a helically coiled heat exchanger. [35]Comparative analysis of a single phase microchannel for heat flow using CFD by Kumar and Singh. [36] Thermal analysis of coal and waste cotton oil liquid produced by pyrolysis of diesel engine fuel was carried out by Subrit and Singh.

The current literature survey indicates that both passive and active solar stills have been the subject of several studies. The examination of active solar systems that are still filled with water-based nanofluids is, however, not well covered in the literature. Dharamveer et al. only examined Compound parabolic concentrator collector with double slope solar still incorporated based on energy and exergy. There hasn't been any research on the investigation of the effects of water, energy, exergy, energy matrices, exergoeconomics, and environeconomics on double slope solar still combined with compound parabolic collector containing different nanofluids.

Additionally, no research has been done on evacuated tube collectors or compound parabolic concentrator collectors using water-based nanofluids in basin-type solar stills.

2. Methods and Material

Analyze the energy and exergy of the N-identical photovoltaic thermal CPC's active solar distillers on the downward slope. For a comparative analysis of double slope active solar distillers N-PVT-CPC, the four yearly weather conditions types-a, type-b, type-c, and type-d for each month have also been taken into account. Energy, exergy, and electrical exergy have all been calculated, along with the temperature of the basin water and the collector outlet.

The methodology's aims are as follows, including calculating the energy and exergy of an N-identical hybrid double slope. In order to do that, the temperatures of the basin water, the east and west glass covers, the collector outlet temperature, the thermal energy, the thermal exergy, the electrical exergy, and the yield must be determined. The system has then been analysed based on the following parameters.

$$T_{\mathrm{gi}}=\frac{a_{gI_s(t)A_g+h_{1w}T_wA_b+U_{c,ga}T_aA_g}}{U_{c,ga}A_g+H_{1w}A_b}$$

$$T_{giE}=\frac{A_1+A_2T_w}{P}$$

$$T_{giW}=\frac{\frac{Kg}{Lg}T_{giE}+h_{1gE}T_a}{\frac{Kg}{Lg}+h_{1gE}}(2.1)$$

$$T_{giW} = \frac{\boldsymbol{B}_1 + B_2 T_w}{P}$$

$$T_{goW} = \frac{\frac{Kg}{Lg} T_{giW} + h_{1gW} T_a}{\frac{Kg}{Lg} + h_{1gW}} \qquad (2.2)$$

The constants of equations (2.1) to (2.4a) are given in appendix. using equations (2.1), (2.2), (2.3) and (2.4) with the help of MATLAB.

$$Hourly\ exergy\ gain = \frac{A_b}{2} \times h_{ewgE} \times \left[\left(T_w - T_{giE}\right) - (T_a + 273) \times ln \frac{(T_w+273)}{(T_{giE}+273)}\right] + \frac{A_b}{2} \times h_{ewgW} \times \left[\left(T_w - T_{giW}\right) - (T_a + 273) \times ln \frac{(T_w+273)}{(T_{giW}+273)}\right] (2.12)$$

$$\eta_{hourly\ ,exergy} = \frac{A_b \times h_{ewg} \times [\left(T_w - T_{gi}\right) - (T_a+273) \times ln \frac{(T_w+273)}{(T_{gi}+273)}]}{0.933 \times \sum_{i=1}^{24} (A_b \times I_s(t))} \times 100 (2.13)$$

$$\eta_{daily\ ,exergy} = \frac{A_b \times h_{ewg} \times \sum_{i=1}^{24} [\left(T_w - T_{gi}\right) - (T_a+273) \times ln \frac{(T_w+273)}{(T_{gi}+273)}]}{0.933 \times \sum_{i=1}^{24} (A_b \times I_s(t))} \times 100 (2.14)$$

$$\eta_{hourly\ ,exergy} = \frac{\frac{A_b}{2} \times h_{ewgE} \times \left[\left(T_w - T_{giE}\right) - (T_a+273) \times ln \frac{(T_w+273)}{(T_{giE}+273)}\right] + \frac{A_b}{2} \times h_{ewgW} \times \left[\left(T_w - T_{giW}\right) - (T_a+273) \times ln \frac{(T_w+273)}{(T_{giW}+273)}\right]}{0.933 \times \left[\left(\frac{A_b}{2} \times I_{SE}(t)\right) + \left(\frac{A_b}{2} \times I_{SE}(t)\right)\right]} \times 100 \qquad (2.15)$$

$$\eta_{daily\ ,exergy} = \frac{A_b \times h_{ewg} \times \sum_{i=1}^{24} [\left(T_w - T_{gi}\right) - (T_a+273) \times ln \frac{(T_w+273)}{(T_{gi}+273)}] + A_b \times h_{ewgW} \times \sum_{i=1}^{24} [\left(T_w - T_{giW}\right) - (T_a+273) \times ln \frac{(T_w+273)}{(T_{giW}+273)}]}{0.933 \times \sum_{i=1}^{24} [\left(\frac{A_b}{2} \times I_{SE}(t)\right) + \left(\frac{A_b}{2} \times I_{SW}(t)\right)]} \times 100 (2.16)$$

.

$$\eta_{hourly\ ,thermal\ ,DS} = \frac{[\dot{m}_{ewE} + \dot{m}_{ewW}] \times L}{\left[\left(\frac{A_b}{2} \times I_{SE}(t)\right) + \left(\frac{A_b}{2} \times I_{SW}(t)\right)\right] 60 \times 60} \times 100 \qquad (2.19)$$

$$\eta_{daily\ ,thermal\ ,DS} = \frac{\sum_{t=1}^{24} [\dot{m}_{ewE} + \dot{m}_{ewW}] \times L}{\sum_{t=1}^{24} \left[\left(\frac{A_b}{2} \times I_{SE}(t)\right) + \left(\frac{A_b}{2} \times I_{SW}(t)\right)\right] 60 \times 60} \times 100 \qquad (2.20)$$

3. Methodology to be adopted

The following steps are included in the approach used to study the suggested system:

Step-I

The proposed systems for the annual are calculated using the Lui-Jordon formula for beam and global irradiation. Calculate daily solar radiation by multiplying the number of days in a month by the number of clear, hazy, hazy, cloudy, and cloudy days.

Step-II

The basin water temperature is determined based on hourly, monthly, and yearly data, and all parameters are tuned to maximise the collector's output temperature.

Step III

Energy, electrical exergy, and yield have all been assessed in.

Step-IV

In proposed systems are contrasted with the prior system using numerically computed values.

Table 1: Annual solar energy (E_{sol})

Month	(type a)				(type b)			(type c)			(type d)			Monthly solar

													energy
Jan	9.78	3	29.34	9.52	8	76.15	6.66	11	73.24	4.66	9	41.93	220.66
Feb	10.90	3	32.69	11.30	4	45.22	7.59	12	91.03	5.23	9	47.08	216.02
Mar	12.45	5	62.27	13.53	6	81.20	9.43	12	113.11	8.63	8	69.03	325.62
Apr	14.18	4	56.73	14.75	7	103.23	10.79	14	151.02	11.06	5	55.28	366.26
May	14.50	4	57.99	14.36	9	129.27	13.27	12	159.22	11.15	6	66.89	413.37
Jun	14.84	3	44.52	15.25	4	61.00	13.13	14	183.78	9.89	9	89.00	378.29
Jul	13.74	2	27.48	13.90	3	41.70	11.88	10	118.77	9.20	17	156.40	344.34
Aug	12.58	2	25.15	13.22	3	39.65	10.89	7	76.24	8.74	19	166.10	307.14
Sep	12.52	7	87.65	12.45	3	37.35	11.09	10	110.93	8.35	10	83.47	319.39
Oct	10.36	5	51.78	9.92	10	99.19	8.27	13	107.45	6.87	3	20.62	279.04
Nov	9.00	6	54.02	8.14	10	81.38	5.86	12	70.33	5.80	2	11.60	217.33
Dec	8.66	3	25.99	8.29	7	58.00	6.93	13	90.07	5.01	8	40.10	214.16
Annual solar energy (kwh)													3601.63
$UAC = P_s \times F_{CR,i,n} + M \times F_{CR,i,n} - S_s \times F_{SR,i,n}$													(2.28)

Table 2Table for Rex

N	I	P_s	M	S	$F_{CR,i,n}$	$F_{SR,i,n}$	UAC	$G_{ex,annual}$	$R_{g,ex}$
Yr.	%	₹	@ 10%	₹	Fraction	Fraction	(₹)	(kWh)	(kWh/₹)
				Single slope passive solar still					
50	2	27143	2714.3	16447	0.032	0.012	755.69	108.48	0.144
50	5	27143	2714.3	16447	0.055	0.005	1556.92	108.48	0.070
50	10	27143	2714.3	16447	0.101	0.001	2997.25	108.48	0.036
				Double slope passive solar still					
50	2	23183	2318.3	13633	0.032	0.012	650.347	89.240	0.137
50	5	23183	2318.3	13633	0.055	0.005	1331.757	89.240	0.067
50	10	23183	2318.3	13633	0.101	0.001	2560.327	89.240	0.035

Table 3: Uniform end-of-yearannual

N	i	P_s	M	S	$F_{CR,i,n}$	$F_{SR,i,n}$	UAC	$G_{ex,annual}$	$R_{g,ex}$
Yr.	%	₹	@ 10%	₹	Fraction	Fraction	₹	kWh	/₹
				Single slope passive solar still					
30	2	27143	2714.3	7506	0.045	0.025	1148.10	108.48	0.094
30	5	27143	2714.3	7506	0.065	0.015	1829.28	108.48	0.059
30	10	27143	2714.3	7506	0.106	0.006	3121.60	108.48	0.035
				Double slope passive solar still					
30	2	23183	2318.3	6221	0.045	0.025	985.284	89.240	0.091
30	5	23183	2318.3	6221	0.065	0.015	1565.26	89.240	0.057
30	10	23183	2318.3	6221	0.106	0.006	2667.34	89.240	0.033

$$R_{(g,ex)} = G_{(ex,annual)}/UAC$$

3.1 Enviroeconomic analysis

The enviroeconomic parameter based on energy andenviroeconomic parameter based on exergy for single and double slope passive solar stills can be written as

$C_{co_2,en} = c_{co_2 \times (E_{out} \times n - E_{in}) \times 2 \times 10^{-3}}$(2.30)

$C_{co_2,ex} = c_{co_2 \times (G_{ex,annual} \times n - E_{in}) \times 2 \times 10^{-3}}$(2.31)

The power to be produced in the power plant corresponding to one unit used by the consumer comes out to be 2.08 units taking into account the losses for domestic appliances as 20 and transmission and distribution losses as 40 %. The amount of CO_2 released corresponding to the production of 1 kWh electrical energy at source is 0.96 kg as per Sovacool (2008). If one utilizes 1 kWh of electrical energy, then the amount of CO_2 release comes out to be 2 kg.

The enviroeconomic parameter based on energy as well as exergy of single slope and double slope passive solar stills have been calculated using equations (2.30) and (2.31) for 50 year life span. They have been presented in Table 2.15.

Results and Discussion

Based on the available data, the yearly exergy and energy values of single slope and double slope passive solar stills have been computed. The yearly exergy of the single slope system is reported to be 108.48 kWh, while the annual exergy of the double slope system is reported to be 89.24 kWh. The single slope system's annual energy consumption is indicated as 1159.43 kWh, whereas the double slope system's annual energy consumption is 1037.19 kWh.

4.1 Conclusions

i. Single slope passive solar stills have superior annual exergy gain, annual energy output, thermal efficiency, and exergy efficiency than double slope passive solar stills for the same geometrical parameter and environment.

ii. Single slope passive solar stills outperform double slope passive solar stills in terms of energy and efficiency with LCCE. EPBT and EPF based on exergy are both better for single slope passive solar than double slope passive solar for the same geometrical parameter and environment. However, double slope passive solar is still preferred to single slope passive solar in terms of EPBT and EPF based on energy for the same geometrical parameter and equivalent climatic situation.

iii. Double slope passive solar stills have a better annual productivity than single slope passive solar stills for the same geometrical parameter and environmental condition. Additionally, both single slope and double slope passive solar stills have annual productivity values that are higher than 100%, demonstrating the practicality of both systems.

References

[1] S. A. Lawrence, G. N. Tiwari, Theoretical evaluation of solar distillation under natural circulation with heat exchanger, Energy Convers. Manage., 30 (1990) 205–13.

[2] C. Popiel, and J. Wojtkowiak, Simple formulas for thermo-physical properties of liquid water for heat transfer calculations (from ° C to 150 °C). Heat Transfer Eng, 19 (1998) 87-101.

[3] B. C. Pak, Y. I. Cho., hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles. Exp Heat Transfer: A J Therm. Energy Generation, Transport, Storage, Convers 11 (1998) 151–70.

[4] G. N. Tiwari, Solar energy: fundamentals, design, modelling and applications. New Delhi/NewYork: CRC Publication/Narosa Publishing House; 2002

[5] K. S. Hwang, J. H. Lee, S. P. Jang , buoyancy-driven heat transfer of water-based Al2O3 nanofluids in a rectangular cavity, Int. J. Heat Mass Transfer, 50 (2007) 4003-10.

[6] O. O. Barden, Experimental study of the enhancement parameters on a single slope solar still productivity, Desalination, 209 (2007) 136-43.

[7] G.N. Tiwari, A. K. Tiwari Solar distillation practice for water desalination systems, New Delhi, Anamaya Publishers, 2008.

[8] C. J. Ho, M. W. Chen, Z. W. Li, numerical simulation of natural convection of nanofluid in a square enclosure: effects due to uncertainties of viscosity and thermal conductivity, Int. J. HeatMass Transfer, 51 (2008) 4506-16.

[9] T. P. Otanicar, J. Golden, Comparative environmental and economic analysis of conventional and nanofluid solar hot water technologies, Environ Sci. Technol., 43 (2009) 6082-7.

[10] H. E. Patel, T. Sundararajan, S. K. Das, An experimental investigation into the thermal conductivity enhancement in oxide and metallic nanofluids. J. Nanoparticle Res. 12 (2010) 1015-31.

[11] P. K. Singh, K. B. Anoop, T. Sundararajan, K. D. Sarit, entropy generation due to flow and heat transfer in nanofluids, Int. J. Heat Mass Transfer, 53 (2010) 4757-67.

[12] M. G. J. D. Elzen, A. D Hof, A. M. Beltran, G. Grassi, M. Roelfsema, B. V. Ruijven, The Copenhagen accord: abatement costs and carbon prices resulting from the submissions, Environ. Sci. Policy, 14 (2011) 28-39.

[13] K. Khanafer and K. Vafai, A critical synthesis of thermo-physical characteristics of nanofluids, Int. J. Heat Mass Transfer, 54 (2011) 4410-28

[14] V. Khullar, H. Tyagi, A study on environmental impact of nanofluid based concentrating solar water heating system, Int J. Environ. Studies, 69 (2012) 220-32

[15] M. Faizal, R. Saidur, S. Mekhilef, M. A. Alim, Energy, economic and environmental analysis of metal oxides nanofluid for flat-plate solar collector, Energy Convers. Manage., 76 (2013)162-8.

[16] X. Liu, W. Chen, M. Gu, S. Shen, G. Cao, Thermal and economic analyses of solar desalination system with evacuated tubular collectors, Solar Energy, 93 (2013) 144-50.

[17] A. E. Kabeel, Z. M. Omara, F. A. Essa, Enhancement of modified solar still integrated with external condenser using nanofluids, an experimental approach. Energy Convers.Manage., 78(2014) 493-8.

[18] T. Elango, A. Kannan, K. K. Murugavel, Performance study on single basin single slope solar still with different water nanofluids, Desalination, 360 (2015) 45–51.

[19] Z. M. Omara, A. E. Kabeel, F. A. Essa, Effect of using nanofluids and providing vacuum on the yield of corrugated wick solar still. Energy Convers.Manage., 103 (2015) 965-72.

[20] G. N. Tiwari, J. K. Yadav, D. B. Singh, I. M. Al-Helal, A. M. Abdel-Ghaney, Exergoeconomic and enviroeconomic analyses of partially covered photovoltaic flat plate collector active solar distillation system, Desalination,367(2015) 186-96.

[24] Dharamveer, Samsher, D. B. Singh, A. K. Singh, N. Kumar, Solar Distiller Unit Loaded withNanofluid- A Short Review. Lecture Notes in Mechanical Engineering, Springer, Singapore, (2019) 241-247, https://doi.org/10.1007/978-981-13-6577-5_24.

[25] S Kumar and D. Singh, Energy and exergy analysis of active solar stills using compound parabolic concentrator, International Research Journal of Engineering and Technology (IRJET), 6 (2019) 12.

[26] R. Shanker, D. Singh, D. B. Singh “Performance analysis of C.I. engine using biodiesel fuel by modifying injection timing and injection pressure” International Research Journal of Engineering and Technology (IRJET) 6 (2019) 12.

[28] S Kumar and D. Singh, Optimizing thermal behavior of compact heat exchanger, International Journal of Mechanical and Production Engineering Research and Development, 10 (2020) 3, 8113-8130.

[28] A.K. Singh, Samsher, Material conscious energy matrix and enviro-economic analysis of passive ETC solar still, Materials Today: Proceedings (2020). https://doi.org/10.1016/j.matpr.2020.05.117