IMPROVEMENT OF EFFICIENCY ON PV/T COLLECTOR USING NANOFLUIDS

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ABSTRACT
Photovoltaic system converts 5-15 % of incoming solar radiation into electricity and remaining part has stored in the form of heat. This heat is accumulated in a PV module and raises the cell temperature, reduces the efficiency, voltage and life of the PV module. This unfavorable heat can be removed and increases the power output by using suitable heat extraction techniques. A thermal collector fabricated as spiral flow closed loop arrangement and attached underneath of PV panel. The nanoparticle Al_2O_3 mixed with double distilled water and filled with various concentrations of nanofluids such as 0.1%, 0.3% and 0.5% in the closed loop. The outlet of nanofluid loop connected indirect contact counter flow heat exchanger for extraction of heat from the nanofluid. The experiments have been carried out in the month of May 2017 from 10:00 to 15:00 hrs. The result indicated that the cell temperature has reduced and improved the power output in 0.5% volume concentration of nanofluids compared to other volume concentrations. The reduced cell temperature due to the heat is absorbed by nanofluids. The presents of fewer nanoparticles reduce the heat transfer rate and increase the cell temperature. In general, higher volume concentration of nanofluids gives better performance (higher thermal conductivity). However higher volume concentration leads to settle at the heat transfer surface and reduce the heat transfer rate. The present work the optimized volume concentration 0.5% gives better thermal performance and increase the power output due to the reduction of cell temperature. The efficiency of PV panel is in the order of 12%, 14% and 17% corresponding volume concentration of nanofluids such as 0.1%, 0.3% and 0.5%

Index Terms: PV/T system, spiral flow, heat exchanger and nanofluids.

I. INTRODUCTION

Fossil fuel power generation is the one of the most discussed in the past few decades. About 88.16% of world total energy consumption was supplied by burning of oil, natural gas and coal [1,2,3]. Harvesting solar energy is an efficient way in producing thermal, electrical energy, reducing greenhouse gases emission and decreases the importing of fossil fuel. Solar radiations can be converted directly to electricity by photovoltaic the effect. Covering only 1% of earth land area with 10% efficient solar photovoltaic PV module would produce twice the current need of energy worldwide [1,3]. Photovoltaic (PV) panel convert 5-15% of the incoming solar radiation into electricity and remaining greater percentage of heat is stored in the module. PV module temperature is one of the important factors that affect how much electricity produced within module/array. The solar radiations increase the temperature of PV module resulting in their electrical efficiency. Increasing cell temperature it acts as internal heat generation. The raising cell temperature can also causes a permanent structural damage of PV panel with the thermal stresses remains for a prolonged period. The internal heat generation is a highly nonlinear function of voltage and current of the PV array [4,5,6,7]. Overheating of PV module decreases the performance output power by 0.4–0.5% for 1°C [8]. Cooling of PV has become important for electricity production. To reduce this unwanted heat a cooling medium has attached to back side of the PV modules.

Therefore interesting alternative to PV panel is hybrid photovoltaic system. Hybrid PV/T reduces the temperature in the PV panel through heat extraction with a proper natural or forced circulation of fluid behind the PV panel. The heat extracted can be utilized for low temperature thermal energy needs [7]. Solar thermal collector is used to cool the surface temperature of the PV panel. The hybrid PV/T system which can provide simultaneously electricity and hot water it can be used for domestic applications. To improving the efficiency of the photovoltaic thermal collector working fluid play important role for conversion efficiency. The conventional fluid have used such as water, air, ethylene glycol, in the existing PV/T system, it has lower thermal conductivity [5, 9]. In order to improve the performance of PV/T system nanofluids have used. The applications of nanofluids in solar PV/T collector view a homogeneous temperature distribution inside the collector. In addition the greater light absorption at visible wavelength and low affectivity at infrared wavelength can be achieved and sunlight can be directly converted into useful heat. Most of the previous studies stated that nanofluids have higher thermal conductivity. Most of the research has demonstrated nanofluid consists of Al_2O_3 nanofluids in water exhibits enhanced thermal conductivity [5,10,11]. The main objective of the present work is to compare the thermal performance of PV/T system with varying volume concentration of nanofluids such as 0.1, 0.3 and 0.5%. The thermal performances of PV/T system have explained in this paper.

II. NANOFLUID PREPARATION

The preparation of nanofluids were involves two processes such as single step preparation and two step preparation. In this work two step processes has used to prepare the nanofluid. Nanoparticle >50nm sized Alumina (Al_2O_3) particles has purchased from Sigma Aldrich Chemicals Pvt., Ltd., at Bangalore, India and properties of nanoparticles were shown in Table 1.

Table 1 Properties of nanoparticles.

Particulars	Specifications
Particle size	>50 nm
Particle shape	Spherical
pH value	6.8
Special heat of particle	880 J/kg-K
Thermal conductivity of particle	36-40 W/m-K
Density	3890 kg/m^3

The volume concentration of nanoparticle had calculated using Equation 1. The volume concentration of (0.1%, 0.3%, 0.5% and 1%) Alumina (Al_2O_3) nanoparticles directly mixed with 380 ml of double distilled water. This fluid is known as nanofluid. This mixture kept in a conical flask and stirred by using magnetic stirrer up to 2 hours to obtained homogeneous mixture, proper dispersion and uniform suspension and reduces particle agglomeration [11-14]. The prepared nanofluid stability was absorbed upto 24 hours. It clearly indicated that the particle could not settle at the bottom in 0.5% volume concentration. However the settlement rate higher in the case of 1% volume concentration and presented in the Fig 1.

$$\varphi = \left[\frac{\left(\frac{W_n}{\rho_n} \right)}{\left(\frac{W_n}{\rho_n} \right) + \left(\frac{W_b}{\rho_b} \right)} \right] \times 100 \qquad (1)$$

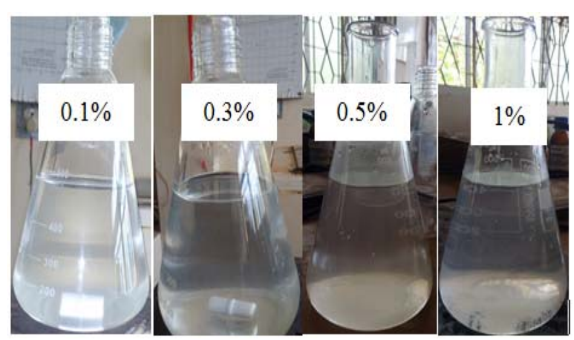


Fig 1. Prepared nanofluid (Al_2O_3+Water) and % of volume 0.1, 0.3, 0.5 and 1

III. EXPERIMENTAL SETUP

Thermal collector consists of copper tube, absorber plate and insulation**.** The black paint coated on the absorber plate to improve the absorption of more heat and copper tube used for higher thermal conductivity. The copper tube fabricated in the form of spiral coil. The spiral coil jointed by gas welding with inlet valve. The nanofluid filled inside the spiral coil through the inlet valve and sealed it. This known as nanofluid closed loop. This loop integrated with indirect type counter flow heat exchanger as shown in Figs 2-4. The nanofluid loop have attached underneath of PV module and followed by insulation materials to minimize the heat loss to atmosphere.

The fabricated PV/T have installed terrace in department of mechanical engineering, Pondicherry engineering college, Pondicherry at an angle of 12 degree in the north-south directions. The PV panel connected with charge controller (CML 05A) to measure the open circuit voltage and four thermocouples (K-type) were used to measure the cell temperature, absorber plate temperature, outlet water temperature and atmospheric temperature. A pyrometer (Kipp & Zonen) and anemometer (AM-4222) also attached on the corner of the PV/T system to measure the solar intensity and wind velocity during the experiments. The experimental setup specifications of PV/T collector are shown in the Table 2.

Water comes from storage tank under thermosyphon principle and enters into the heat exchanger. The heat is absorbed by nanofluids from the PV cell and it is utilized for heating of water in the heat exchanger. The experiments have been carried out entire month of May 2017 and four days measured values were considered for the present work to compare the performance of PV/T with different volume concentration of nanofluids. The experimental values are presented in the Tables 3-4.

Table 2 Specifications of PV/T system.

Details	PV/T system specifics
Solar cell material	Polycrystalline
PV Module Area	0.3318 m^2
Spiral tube dimensions	0.001m x 0.7 m (Copper)
Absorber plate material and thickness	Aluminum sheet and: 0.0005 m thickness
Insulation	Thermocool and Wooden board
Spacing between tubes	0.002 m
Number of water tubes	Single tube
Number of spiral	15 x 15 turns
Thermal conductivity of absorber plate	205 W/m°C
Thermal conductivity of copper tube	401 W/m°C
Hot fluid	Nanofluid
Cold fluid	Water
Heat exchanger type	Counter flow

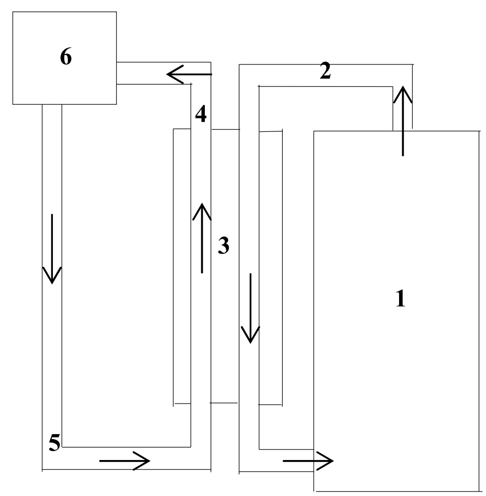
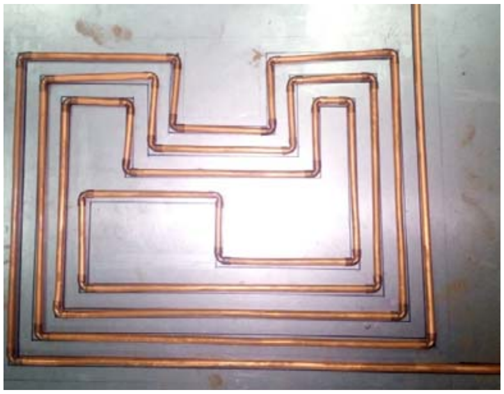
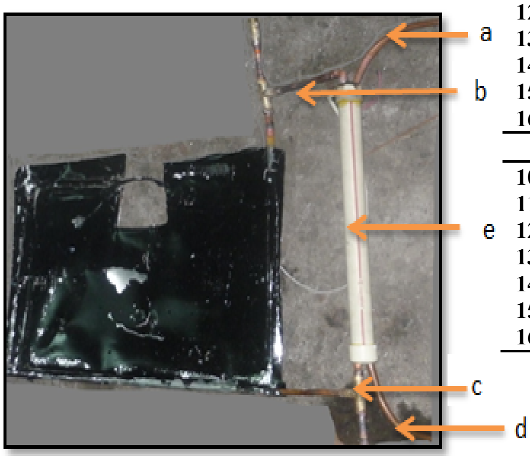


Fig 2**.** Line sketch of PV/T system with closed loop spiral flow arrangement and counter flow heat exchanger. (1) PV/T system, (2) nanofluid loop, (3) counter flow heat exchanger, (4) hot water outlet, 5) water inlet and 6) storage tank.



(a)



(b)

Fig 3. (a) Fabrication stage and (b) Fabricated counter flow heat exchanger a) hot water outlet, b) nanofluid inlet, d) water inlet and e) counter flow heat exchanger.

Table 3 Experimentally measured values of PV/T system with water-water.

Water-Water (24/05/2017)							
Time (hr)	S (W)	T_a(°C)	T_c(°C)	T_{ni}(°C)	T_{no}(°C)	T_{wo}(°C)	V(V)
10:00	846	45	62	52	50	42	19.51
11:00	894	45	65	46.5	40	42.6	19.54
12:00	930	48	67	48	41	47	19.65
13:00	924	46	69	55	44	51.3	19.44
14:00	936	47	65	47.2	41	44	19.3
15:00	864	45	58	45.4	38.8	43.5	19.3
16:00	840	45	58	44.9	38.6	40	19.26

Table 4 Experimentally measured values of PV/T system with Al_2O_3-water.

Time (hr)	S(W)	T_a(°C)	T_c(°C)	T_{ni}(°C)	T_{no}(°C)	T_{wo}(°C)	V(V)
0.1% (29/05/2017)							
10:00	970	42	52	52	47	45.6	19.81
11:00	990	41	60	58	49.7	50	19.86
12:00	1020	46	64	60	50	58	19.94
13:00	1100	48	64	61.5	50.4	56.8	19.93
14:00	960	48.5	59	61	50.5	56.4	19.91
15:00	869	49	57	57.9	53	54.9	19.9
16:00	860	48.5	56	57.5	51	54.3	19.87
0.3% (31/05/2017)							
10:00	570	38	49	48.5	40.5	40.5	19.9
11:00	900	40	52	52.2	42.7	40.2	19.86
12:00	1020	39.9	61	64.3	53	55	19.83
13:00	870	37.8	60	57.4	50	53	19.91
14:00	900	40	56	51.3	49.7	51	19.9
15:00	840	34.9	57	50	48	49	19.87
16:00	828	34.5	53	47.7	47.7	45	19.67
0.5% (02/06/2017)							
10:00	978	37	45	44	35	40	19.76
11:00	990	37.9	48	49	37	46	19.71
12:00	1010	41	58	57	43	52	19.93
13:00	1120	41	59	59	50	57	19.91
14:00	978	40	52	59	49	48	19.81
15:00	960	38	51	58	48	45	19.69
16:00	942	39	48	54	45	42	19.67

IV. THEORETICAL ANALYSIS

Useful heat gain obtained by the nanofluids and water can be expressed using equations 2 and 3[5, 8, 11]. The experimental values were substituted and calculated using equations 1-6 [14]. The calculated values were shown in Table 5.

$$Q_{u-nf} = m_{npf} C_{p-np}(T_o - T_i) \quad (2)$$

$$Q_{u-w} = m_{wf} C_{p-w}(T_o - T_i) \quad (3)$$

The heat capacity of nanofluid is calculated with the help of equation 4 [11].

$$C_{p-nf} = C_{p-n}(\varphi) + (C_{p-bf})(1-\varphi) \quad (4)$$

Fig 4. Experimental setup of PV/T systems with counter flow heat exchanger: (1) PV/T system, (2) nanofluid inlet, (3) nanofluid outlet, (4) water in, (5) hot water out, (6) counter flow heat exchanger and (7) instruments.

Table 5 Calculated values of heat gained, thermal efficiency and electrical efficiency.

Time(hr)	Heat gained Q_u(W)				Thermal efficiency η_{th} (%)				Electrical efficiency η_e (%)			
	Water	0.1%	0.3%	0.5%	Water	0.1%	0.3%	0.5%	Water	0.1%	0.3%	0.5%
10:00	506	759	362	828	57	77	74	81	10	10.5	14	17
11:00	513	761	739	784	60	78	80	84	9.5	10	12	13
12:00	636	806	819	936	68	79	82	81	10	11.5	13	15.5
13:00	618	856	629	782	67	77	79	80	10	12	14	16
14:00	578	701	712	765	62	73	77	78	10	11	13.5	16
15:00	524	622	651	742	61	71	75	77	9.5	10.5	13	15

The electrical and thermal efficiency were calculated using following equations 5 and 6 [5]:

$$\eta_e = \frac{(V \times I)}{(A \times S)} \qquad (5)$$

$$\eta_{th} = \frac{Q_u}{A \times S} \qquad (6)$$

V. RESULTS AND DISCUSSIONS

The graph plotted between cell surface temperature and time as shown in Fig 5. The results show that the same type of trend absorbed from 10:00 to 16:00 hrs for the all cases. When the surface temperature has reduced and increases the volume concentration of nanofluid in the order of 0.1% (64°C), 0.3% (61°C), 0.5% (59°C) and water (69°C). In the case of water surface temperature shows higher it because of thermal conductivity value is very low (0.613W/mK) and heat gained also low refer Table 5.

The variation of surface temperature is directly proportional to the thermal conductivity of the nanofluid. The heat gain is more in the nanofluids loop and this heat can be utilized in the heat exchanger. The heat exchanger absorbs the heat and raises the water temperature around 58°C. Whenever increasing the volume concentration of nanofluid more than 1% it settled at the heat transfer surface and acts as an insulator which gives less heat transfer rate. The order of surface temperature is water >0.1%>0.3%>0.5%. The reduction of surface temperatures obtained around 5% and 10% by using nanofluids and water.

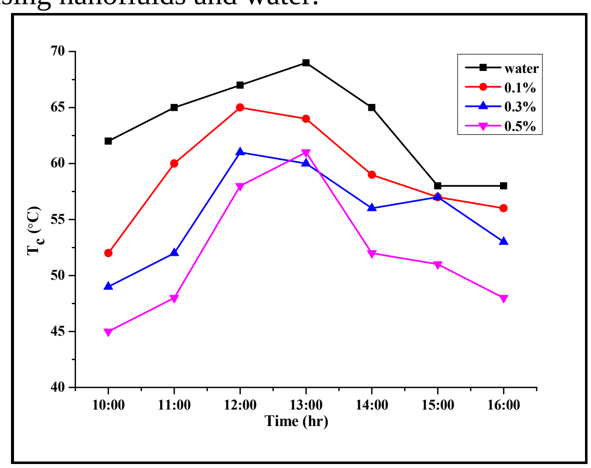


Fig 5. Cell surface temperature vs time

The thermal efficiency has improved around 5% compared to 0.1%, 0.3% and water. In general increase of nanoparticle concentration have higher heat transfer rate. Because of higher thermal conductivity, uniform distribution and properly suspended in the water. From the Fig 6 clearly indicated that the consistently improve the thermal efficiency in the case of 0.5% volume concentration. The electrical efficiency of PV/T system much more better using 0.5% volume concentration of nanofluids it means the maximum heat absorbed by nanofluids and maintain the surface temperature minimum compared to other working fluids such as 0.1%, 0.3% (nanofluids) and water. The variation of electrical efficiency depends with working fluids and represents in the Fig 7.

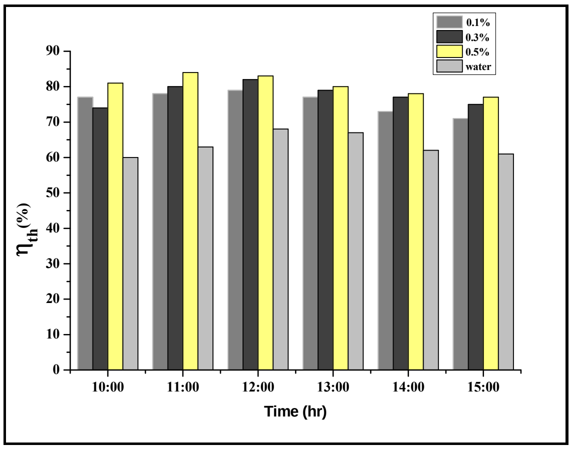


Fig 6. Thermal efficiency vs time

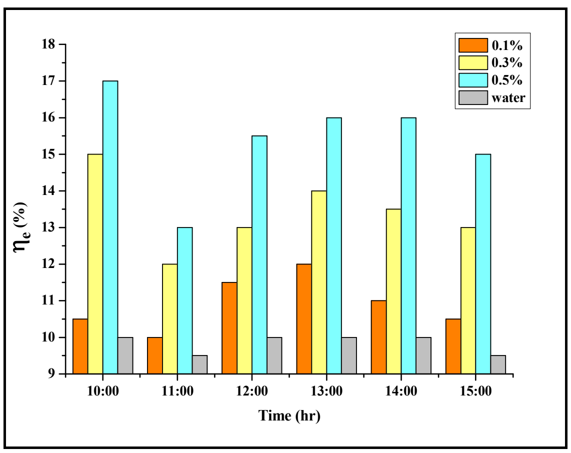


Fig 7. Electrical efficiency vs time

VI. CONCLUSIONS

The present investigation the following results were obtained.

1. The performance of nano loop gives better performance compared with water loop.
2. The 0.5% volume concentration of nanofluid gives better thermal and electrical efficiency of PV/T system.
3. Water has used as the working fluid in the PV/T system, temperature increase upto 69C due to the low thermal conductivity of water.
4. Electrical efficiency of the PV/T system enhanced by 10%, 12%, 14% and 17% respectively with water and 0.1, 0.3, 0.5 % of volume concentration of Al_2O_3 nanofluids and
5. Thermal efficiency of the PV/T system enhanced by 68%, 79%, 82% and 84% respectively with water and 0.1, 0.3, 0.5 of volume concentration of Al_2O_3 nanofluids.

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