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Performance Improvement Analysis on PV/T Solar Water Collectors Connected in Series and Parallel

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ABSTRACT

The solar panel is one of the most sought after methods to produce electrical energy for domestic purposes. Solar PV/T systems converts solar irradiation into thermal and electrical energy. Module is made of Poly c-Si material. This experiment aims at analysing the comparative performance of hybrid solar PV/T water collectors connected in series and parallel. It was conducted in Saranathan College of Engineering, Tiruchirapalli-12. It is located at latitude of 10.7560°N and longitude of 78.6513°E. The maximum temperature of water obtained was 42.8°C and 40.8°C respectively in series and parallel. Overall the parallel connected PV/T system's performance is 12.12% higher than the series connected PV/T system.

Keywords: *Solar, PV/T, Unglazed, Series, Parallel etc.*

I. INTRODUCTION

Solar is the best form of renewable energy which is widely used all around the world currently. Solar energy is used for many domestic purposes but it has its own snags. Current dollar technology only converts electricity with a maximum efficiency of about 25%. This is because of occurrence of thermal degradations like non uniform cooling, high operating temperature of the panel, dust accumulation on the panel. The performance made by forced circulation mode gives the output water temperature around 0.5–2.5°C from parallel configuration which is higher than the series[1].

In order to avoid dust accumulation the pitch angle should be set to zero early morning or late in the evening to drop slide off the dust[2]. The electrical efficiency is increased and cell degradation is reduced with time by proper cooling.

Without active cooling the temperature of module was high and with cooling the temperature dropped significantly [3-4]. Use of nano fluid is also experimented but it is economically costly and there is a change of thermal properties of a 3% nano fluid (SiC) on viscosity (1.8%);thermal conductivity (8.2%);density (0.0082%) and thermal conductivity of nano particles was increased up to 4.3% [5].

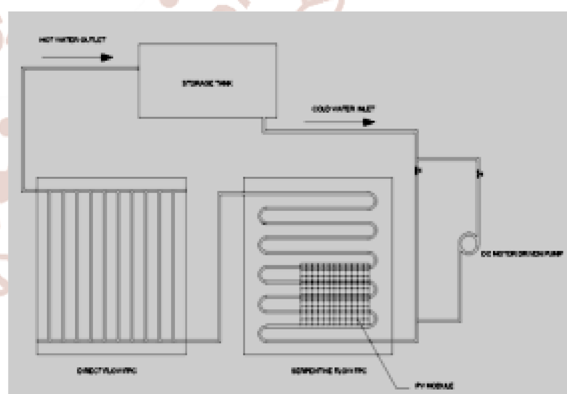


Fig 1. A schematic 2D diagram of series connected PV/T system

The module temperature is greatly reduced by using clay. The results have exhibited a maximum increase of 19.4% to the output voltage and 19.1% to the output power[6]. High resistance of PV/T system produce energy less than the energy consumption of pump. An account to overcome the problem, natural circulation is implemented various parameters. It is found that annual integrative efficiency is 60% [7].

II. EXPERIMENTAL SETUP

The setup consists of a storage tank which is connected to the PV module using UPVC pipes. The flow tubes fixed behind the module is made up of copper. The copper tubes are brazed in such a way that there is no leakage. Electrical components such as ammeter, voltmeter, rheostat and connecting wires are used for electrical connections.

The figure 1 depicts the schematic diagram of the PV/T module connected in series. The inlet is given from the storage tank which is capable of storing 100 L. The water enters into the first panel at T_{fi}(°C) temperature. The outlet of the first panel is the inlet for the second panel. The outlet temperature of first panel is T_{f01}(°C). The water passes from the top header of the first panel to the bottom header of the second panel.

The outlet of the second panel is T_{f02}(°C) and is passed into the storage tank again which contributes a closed system.

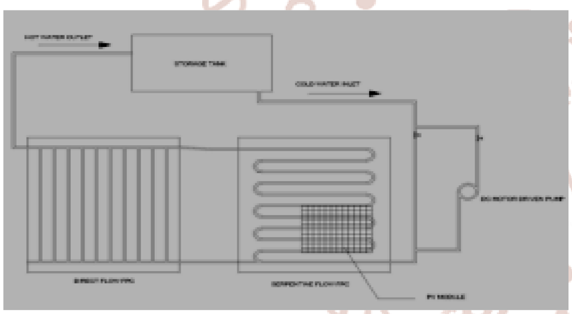


Fig 2. A schematic 2D diagram of parallel connected PV/T system

The figure 2 depicts the schematic diagram of the PV/T module connected in series. The inlet is given from the storage tank which is capable of storing 100 L. The water enters into the first panel at T_{fi}(°C) temperature. The outlet of the first panel is the inlet for the second panel. The outlet temperature of first panel is T_{f01} (°C). The water passes from the top header of the first panel to the top header and the bottom header of the first panel to the bottom header of the second panel.

The outlet of the second panel is T_{f02} (°C) and is passed into the storage tank again which also contributes a closed system.

IV. TECHNICAL SPECIFICATION

COMPONENTS	SPECIFICATION
ELECTRICAL	
Ammeter	(0-10) A
Voltmeter	(0-60) V
Rheostat	250Ω, 1.8 A
Optimum Voltage	18.2 V
Optimum Current	2.2 A
Power	40 W
THERMAL	
Thermocouple	K - Type
RTD	PT – 100
Storage Tank	100 litres capacity
Working Liquid	Water
Mass flow rate	0.009 kg/s
PV/T MODULE	
Company name	INNOVA
Module weight	4.9 kg
PV Module	Poly c – Si
Optimum Circuit Current	2.20 A
Optimum Operating Voltage	18.2 V
Module Area	610*670 mm^2
Open Circuit Voltage	22.2 V
Short Circuit Current	2.37 A
Shunt Resistance	236.99 Ω
Fill Factor	76.11%
Tube Inner Diameter	12.75 mm
Tube Outer Diameter	16 mm
Tube Material	Copper
Pipe Material	CPVC

V. FORMULA USED

The fill factor of the module for various time is calculated by the following formula

$$F.F = \frac{I_L * V_L}{I_{SC} * V_{OC}} \quad (1)$$

The electrical power is determined by the formula

$$P = I_{SC} * V_{OC} \quad (2)$$

The heat generated can be found by using

$$Q = m*C_p*(T_{in} - T_{f02}) \quad (3)$$

The electrical efficiency for the system can be determined by

$$\eta_{e\ per\ panel} = \frac{I_{SC}*V_{OC}*F.F}{N_m*A_m*I_t} \quad (4)$$

The thermal efficiency for the system can be found by

$$\eta_{t\ per\ panel} = \frac{m*C_p*}{N_m*A_m*I_t}*(T_{in} - T_{f02}) \quad (5)$$

The overall efficiency of the system is obtained using

$$\eta = \eta_e + \eta_t \quad (6)$$

VI. READINGS AND TABULATIONS

Table 2. Electrical and thermal readings taken on 28.02.2018 of the PV/T system connected in series.

TIME	T_a	I_L	V_L	I_{SC}	V_{OC}	I_r	F.F	T_{fi}	T_{f01}	T_{f02}	$\eta_{t\ per\ panel}$	$\eta_{e\ per\ panel}$
hours	°C	A	V	A	V	W/m^2	no unit	°C	°C	°C	%	%
10:00	24.5	1.5	15	2.1	40	772	0.26786	30	30.2	32.3	14.3144	3.5656
11:00	28	2	30	2.4	38	920	0.65789	30.7	31.8	34.3	18.8008	7.9786
12:00	30.5	2	30	2.3	37	1083	0.70505	33.7	34.4	37.1	15.0838	6.7778
13:00	29	1.8	30	2.2	38	1110	0.64593	36.7	37.5	40	14.2841	5.9516
14:00	30	1.5	30	1.8	36	980	0.69444	39.2	39.5	41.5	11.2762	5.6176
15:00	29.5	1	30	1.2	36	720	0.69444	40.9	41.4	42.8	12.6789	5.0975
16:00	31	0.6	25	0.7	36	610	0.59524	39.9	40.1	40.8	7.0888	3.0083
										AVERAGE	13.3610	5.4282

The above table infers the Electrical and thermal readings taken on 28.02.2018 of the PV/T system connected in series.

Table 3. Electrical and thermal readings taken on 27.02.2018 of the PV/T system connected in parallel

TIME	T_a	I_L	V_L	I_{SC}	V_{OC}	I_R	F.F	T_{fi}	T_{f01}	T_{f02}	$\eta_{t\ per\ panel}$	$\eta_{e\ per\ panel}$
hours	°C	A	V	A	V	W/m^2	no unit	°C	°C	°C	%	%
10:00	26	0.9	15	1.1	20	780	0.61364	30	30.5	32.4	14.7835	2.1174
11:00	28.5	4.9	15	5.5	18	944	0.74242	31.8	32.8	35.5	18.8318	9.5253
12:00	28	4.4	15	5	18	1072	0.73333	32.8	33.8	36.9	18.3760	7.5321
13:00	29	3.9	15	4.7	18	1115	0.69149	36.4	36.7	39.9	15.0819	6.4187
14:00	30.5	3.4	15	3.8	17.5	980	0.76692	37.9	38.8	40.8	14.2178	6.3666
15:00	30	2.6	15	3	18.5	700	0.70270	38.1	38.4	40	13.0412	6.8160
16:00	29	2	15	2.3	18.5	560	0.71351	38.4	38.6	39.3	7.7218	6.6325
										AVERAGE	14.5791	6.4870

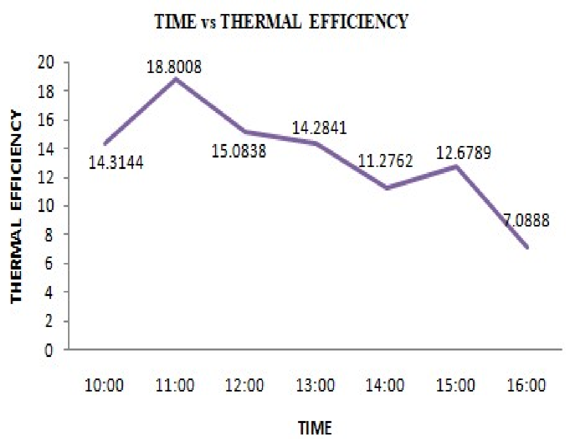
The above table Electrical and thermal readings taken on 27.02.2018 of the PV/T system connected in parallel.

VII. RESULTS AND DISCUSSIONS

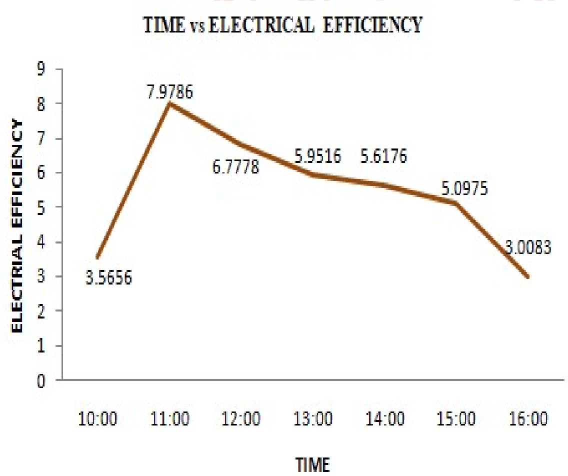
A. Series system

Graph 1 represents the variation of thermal efficiency of the module with respect to time. It was seen from the graph that it was maximum at 11am.

Graph 2 represents the variation of electrical efficiency of the module with respect to time. It was seen from the graph that it was maximum at 11am.



Graph 1. Time vs. thermal efficiency

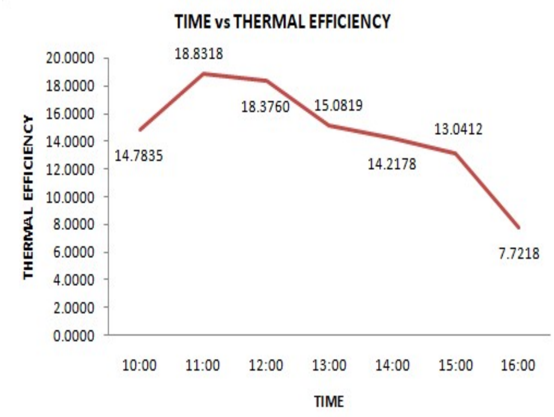


Graph 2. Time vs. electrical efficiency

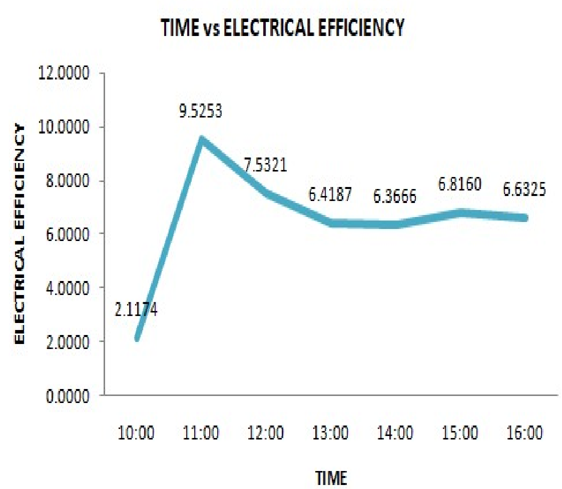
B. Parallel system

Graph 3 represents the variation of thermal efficiency of the module with respect to time. It was seen from the graph that it was maximum at 11am.

Graph 4 represents the variation of electrical efficiency of the module with respect to time. It was seen from the graph that it was maximum at 11am.



Graph 3. Time vs. thermal efficiency



Graph 4. Time vs. electrical efficiency

VIII. CONCLUSIONS

The main factors which are responsible for the maximum efficiency are the ambient temperature, mass flow rate and the irradiance. More the temperature difference between inlet and outlet of water, the more heat transfer is obtained. Increase in mass flow rate of the water increases the module efficiency. As a result of the experiment, the parallel connected PV/T system can produce power 12.12% higher than the series connected system.

IX. FUTURE WORK

In order to obtain maximum efficiency proper maintenance of module should be taken. Thermal degradations like excessive heat of the module, dust accumulation, module angle from the ground are to be maintained. Effective insulation for the copper tubes, effective cooling technique and mass flow rate of the water can increase the module performance thus increases the efficiency.

X. NOMENCLATURE

- T_a - Ambient temperature (°C)
- T_i -Inlet temperature(°C)
- T_{f01} - Outlet temperature 1(°C)
- T_{f02} -Outlet temperature 2(°C)
- Q–Heat rate (Watt)
- m – Mass flow rate (kg/s)
- I_{sc}– Short circuit current (Ampere)
- V_{sc} – Short circuit voltage (Volt)
- I_L – Line current (Ampere)
- V_L – Line voltage (Volt)
- P – Electric power (Watt)
- η_t – Thermal efficiency (%)
- η_e - Electrical efficiency (%)
- η – Overall efficiency (%)
- I_r– Irradiance (W/m^2)
- F.F – Fill Factor (no unit)
- N_m – Number of modules
- A_m – Area of the module

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