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Performance of Polycrystalline Photovoltaic and Thermal Collector (PVT) on Serpentine-Parallel Absorbers Design

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***Abstract*— This paper presents the performance of an unglazed polycrystalline photovoltaic-thermal PVT on 0.045 kg/s mass flow rate. PVT combine photovoltaic modules and solar thermal collectors, forming a single device that receive solar radiation and produces heat and electricity simultaneously. The collector figures out serpentine-parallel tubes that can prolong fluid heat conductivity from morning till afternoon. During testing, cell PV, inlet and outlet fluid temperaturs were recorded by thermocouple digital LM35 Arduino Mega 2560. Panel voltage and electric current were also noted in which they were connected to computer and presented each second data recorded. But, in this performance only shows in the certain significant time data. This because the electric current was only noted by multimeter device not the digital one. Based on these testing data, average cell efficieny was about 19%, while thermal efficiency of above 50% and correspondeng cell efficiency of 11%, respectively.**

***Keywords:* polycrystalline, unglazed PVT, Arduino Mega 2560**

I. INTRODUCTION

The potential of solar energy with an intensity above the average of 700 W/m^2 is required if it could be used for research that converts the energy into electrical energy and as a water heater as well. This study is the photovoltaic thermal (PVT) which used solar panel module (solar cell) and water heating collectors made of copper pipe heat sink. PVT core is the incorporation of solar cells with water heating collectors in a panel box. Some studies PVP has been utilizing solar cell type monocrystalline and polycrystalline. In addition, the heat absorved configuration different also combined with the mono and polycrystalline. The advantage of using this PVT is a clean energy source, silent, long lasting used and low maintenance.

Applications incorporation of solar panels and water heating collectors (PVT) becomes a trend in the last 3 decades that aimed to save design and improvement of energy efficiency in the system. The background of this hybrid is that more than 85% of the incoming solar energy in a solar panel that reflected or absorbed as heat energy. When it should be a great energy that is converted into electrical energy. This causes a temperature rise of a working solar cell that lowers the energy efficiency of the system [1]. By combining photovoltaic and water heating collectors are seen as a solution to improve the efficiency of it. Therefore, the configuration of the water pipe heat absorber becomes an important factor considered as a work function thermosiphon system that stabilizes the current-voltage characteristics of the solar cells [2]. Therefore, this study aims to look at the performance of unglazed PVT polycrystalline absorbers with serpentine-parallel design with thermosiphon system on the hot water circulating.

The first concept of PVT was proposed and investigated by Kern and Russel (1978) with the use of water and air as heat removal fluid [3]. One year later, Hendrie (1979) developed with conventional thermal collector techniques [4]. The model was extended by Florschuetz (1979) with the famous equation of Hottel-Whillier. Currently, [5] Mojumder, *etc* (2013) utilised air and water as removal fluid the modification of thin metallic sheet. In this paper, water was used as removal fluid with heat tubes absorber modified.

II. EXPERIMENTAL SETUP

2.1 *PVT Construction*

In this hybrid system, water plays as heat reassigning fluid. The PV cells are arranged either directly on the absorber or core on a cover plate with a dielectric material. It depicts that, the only contact between the PV cells and the absorber or the plaster plate is an elevated thermal contact. The heat transmitting fluid runs through the heart of the channels on the absorber and accumulates heat from that. If the cells are glued to the absorber, heat is also extorted from the PV cells resulting in a privileged electrical efficiency of the PV cells. However, in this design, not all the cells are glued to the absorber due to limitations of the uneven surface of the copper pipe. Water type PVT collectors are discerned according to the

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water flow prototype. These are differentiated to sheet and tube, channel, free flow and parallel-serpentine absorbers type as shown in the figures below:

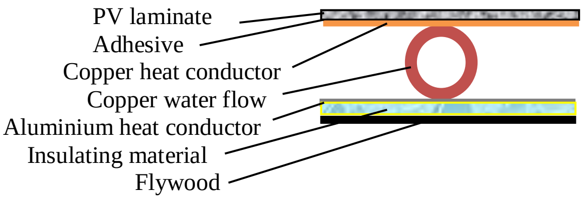

Fig. 1: PVT water channel

For this project, polycrystalline PV is used. It has 87 watts and 0.64 m^2 aperture area. The complete parameters as follow:

Cell type	Polycrystalline silicon
Maxium power	87 W
Maximum voltage	17.4 V
Maximum current	5.02 A
Short current	5.34 A
Open voltage	21.7 V
Size	100 x 64 cm

For circulating water copper tubes were used. Diameter of the copper tube was taken as 1/2", while the header of the copper tubes of the two head parallel configurations of 5/8" was used. For serpentine ones, ½" diameter copper tubes were taken.

As insulating material made from glass wool that is apllied in between aluminium and flywood leading to avoid any kind of heat transfer to and from the setup. The insulating material is 3 cm thick, while it is 0.35 mm for the aluminium as shown in Fig.2

A 80 x 30 cm stainless steel tank was used for water storage that was kept in the head of PV in a suitable height so that the natural convection of water flow during the testing could be maintained. Storage tank and PV panel were supported on the iron rods frame.

Fig. 2: Insulating materials in the back of PVT panel

The experiment rig was tested in the regency of Sigi in a south-facing position and a tilted angle of about 21°. Fig. 3 shows the experiment rig and a digital LM35 Arduino Mega 2560. The 5.5-h outdoor performance data were recorded for 3 days from 8.30 to around 13.00 h at 1-sec intervals through a data acquisition system. However, in calculating the cell performance, significant data in certain times were noted due to multimeter used for current data, not digital one. Thus, the voltage and temperatures only were recorded by the digital AM 2560, while the current was noted with mutimeter. On many accasions within this measuring period, unfavorable weather conditions and tehnical disturbances caused the measured data within a whole day to be either incomplete or not qualified for the performance analysis. Results, the test was recorded within 5.5 hours.

(a)

(b)

Fig. 3: PVT rig test under soalr energy (a) and LCD digital thermocouple A. Mega 2560

2.2 *Equations*

For solar cell efficiency calculation, equation in [6] is used, namely:

$$\eta = \frac{P_{out}}{P_{in}} x100\% \qquad (1)$$

With

P_{out} = daya output aktual sel surya (Watt)
P_{in} = daya input sel surya (Watt)

- *Thermal Performance*. The thermal efficiency of a thermosiphon system is affected by many system design parameters and operating conditions. An effective test-method is the outdoor test under climatic-conditions. Thus, η_{th} can be obtained experimentally by

$$\eta_{th} = \frac{\dot{m} C_p (T_{out} - T_{in})}{IA_p} \qquad (2)$$

Where $\dot{m}$ is the water mass flow rate (kg/s); C_p is the water specific heat (J/kg/K); T_{out} and T_{in} are the final and initial water-temperatures at the heat absorber collectors. I is the solar intensity (W/m^2) and A_p is the area of collectors (m^2).

- *Electrical Performance*. The electrical efficiency depends mainly on the incoming solar radiation and the temperature ofted PV module that was used in the tested PVT collectos and is calculated with the following:

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$$\eta_{el} = \frac{I_m V_m}{A_{PVT} I} \qquad (3)$$

where I_m and V_m are the current and the voltage of the PV module operating at maximum power.

The PV module temperature depends on the cooling effects by the fluid in the PVTcollectors. The electrical performance was analyzed as a function of the PVT inlet fluid temperature and solar radiation.

III. RESULTS AND DISCUSSIONS

3.1 Test results

The test-results of the polycrystalline photovoltaic thermal is listed in Table 1. PV Cell, thermal and electrical efficiency are shown in Fig. 4, 5 and Fig. 6.

Table 1. Polycrystalline PVT test result

Time	I	T_{in}	T_{out}	T_{PV}	V_{PV}	I_{PV}
8.20	893	28	28	30	18	0,34
9.33	906	28	29	31	18	0,42
9.39	899	28	29	31	19	0,87
9.50	916	28	30	38	19	1,89
9.56	945	28	31	41	19	3,12
10.03	946	28	34	48	19	3,23
10.13	905	28	38	54	19	3,35
10.21	911	28	40	59	18	3,41
10.31	938	28	41	62	18	3,52
10.40	938	28	88	63	18	3,58
10.48	952	28	82	65	18	3,65
10.48	952	28	130	65	18	3,65
10.58	975	28	116	67	18	3,75
11.03	919	29	154	67	18	3,89
11.10	949	29	127	68	18	3,92
11.4	948	29	132	68	18	3,93
11.21	952	29	117	70	18	3,96
11.25	953	29	109	70	18	3,99
11.31	976	30	149	70	18	4,03
11.38	944	30	135	71	18	4,02
11.46	957	29	164	71	18	4,03
11.54	925	30	166	69	18	3,98
11.04	955	30	136	67	18	4,02
12.11	959	30	136	67	18	4,00
12.20	955	30	152	68	18	3,99
12.28	924	30	172	69	18	3,96
12.37	925	30	152	69	18	3,93
12.47	930	31	167	69	18	3,9
12.54	938	31	158	69	18	3,87
13.05	925	31	179	68	18	3,16
13.08	923	31	177	66	18	2,86

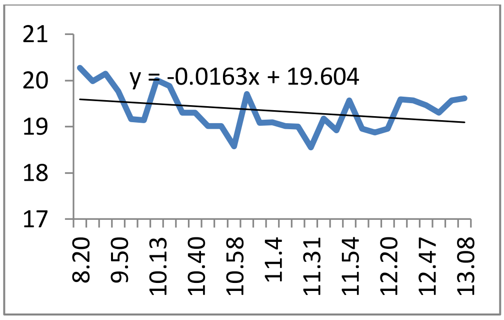
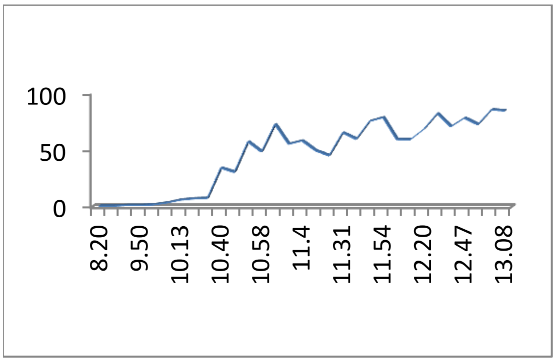


Fig. 4: Polycrystalline cell efficiency

In Fig. 4 depicts that cell efficiency tends to decrease associated with increasing cell temperature. The trendline equation is y = -0,0163x + 19,604. Negative variable means the decreasing graph line along the following time.



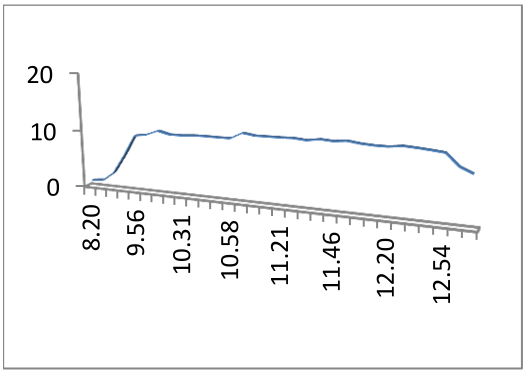
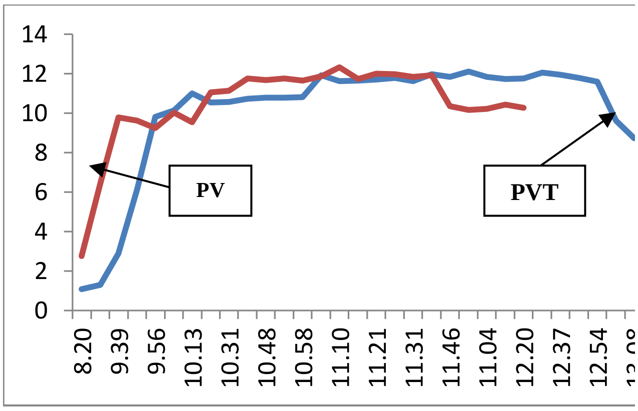


Fig. 6 Electrical efficiency of a poly PVT

As shown in the above figures, the highest electrical efficiency was obtained at around 12pm of 11%. Also, thermal efficiency was reached the maximum rate at the same time. Both Fig 4 and 5 shows that efficiency started at the low level and increased gradually. But, the electrical efficiency rose early at about 9.30am and the trend was steady till the end of the data recorded compared with the thermal efficiency.

Electrical Efficiency of Polycrystalline PVT versus PV

In Fig. 7 dercribes that electrical efficiency of hybrid PVT is higher than those without cooling system (PV only). Although, Ibrahim, *et al.* (2009) in [1] recorded that the highest cell efficiency for spiral and oscillatory designs (11,98 and 11,94%), respectively, this hybrid PVT of serpentine-parallel was still higher about 1% than those of their designs. This trend was also occured for thermal efficiency. Furthermore, [7] shown the electrical performance was less than this hybrid PVT.



IV. CONCLUSION

This paper analyzed the thermal and electrical performance for polycystalline cell module using serpentine-parallel absrobers design in one single PVT box. The results shows that by combining the cooling thermal system on serpentine-parallel absorber design and photovoltaic is higher than those of parallel, spiral or oscilatory/serpentine only in one single PVT. In short, it is clear that by combining polycrystalline solar cell with water flow within copper absorber heat transfer in thermosiphon can improve both the eletrical and thermal performances.

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