VOL. 19, NO. 16, AUGUST 2024 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ELECTRICAL CHARACTERISTICS OF PHOTOVOLTAIC (PV) SOLAR PANEL AND HYBRID PV/THERMAL (PV/T) SOLAR PANEL

Ahmad Fudholi[1,2], Nurul Shahirah Binti Rukman[1], Hardani[3], Ahmad Rajani[2], Rudi Darussalam[2], Andri Setiawan[2], Anwar[2], Arifin Santosa[2], Maulana Arifin[2] and Martoni[4]
[1]Solar Energy Research Institute, Universiti Kebangsaan Malaysia, Bangi Selangor, Malaysia
[2]Center for Energy Conversion and Conservation, National Research and Innovation Agency (BRIN), Indonesia
[3]Politeknik Medica Farma Husada Mataram, NTB6, Indonesia
[4]Mechanical Engineering, Faculty of Engineering, Widyatama University, Indonesia
E-Mail: a.fudholi@ukm.edu.my

ABSTRACT

Solar collectors and photovoltaic (PV) solar panels can convert solar radiation into heat and electrical energy. A hybrid PV/thermal (PV/T) solar panel was tested in this study. The hybrid PV/T solar panel was tested using a spiral absorber and water flow levels range from 0.01 kg/s to 0.03 kg/s. As a result, with variable water flow rates and irradiation intensity of 700 and 900 W/m^2, the efficiency of hybrid PV/T solar panels varied. The highest electrical efficiency attained was 4.06% in hybrid PV/T solar panels at 900 W/m^2 with 0.025 kg/s of mass flow while 3.65% by PV solar panels. In addition, plotted current-voltage and power-voltage curves were used to show the electrical properties of the solar PV panels and hybrid PV/T solar panels.

Keywords: efficiency, fill factor, I-V-P curves, current, voltage, power.

Manuscript Received 3 July 2024; Revised 5 September 2024; Published 15 November 2024

INTRODUCTION

PV surface and cells play an important role in enhancing the efficiency of PV solar panels; that is, the PV solar panel efficiency decreases with increasing solar radiation intensity. PV solar panels use a small amount of solar radiation to produce electricity and a bulk amount to generate thermal energy that warms the surface of PV cells. A medium that can effectively absorb heat energy from PV solar panels should be used to increase the efficiency of electrical energy to a satisfactory level [1-3]. A thermal collector can be paired with a PV solar panel to produce thermal energy by using water flowing in the tube. Furthermore, water with high heat capacity absorbs heat energy and transfers it into a water tank for various uses. These systems are named hybrid PV/T solar panels, which can simultaneously produce thermal energy and electrical energy. This hybrid PV/T solar panel also produces hot water, which is important for domestic and industrial applications. Hot water is required in laundry, kitchen utensils, bathing, and other domestic uses in urban or rural areas. Hot water is also required in hospitals, dormitories, hotels, and industries [4]-[7].

PV/T collectors have been studied by several researchers. The simulation results obtained by Bargene and Lovik [8] showed that a PV/T system's overall efficiency may approach 60%-80%. Some characteristics that affect the performance of PV/T systems, according to Charalambus *et al*. [9], include mass flow rate, inlet temperature working fluid, number of covers, absorber-to-fluid thermal conductivity, absorber plate, and PV/T collector design. Seven distinct designs of PV/T water collectors were evaluated by Zondag *et al*. [10]. Sheet and tube, channel, free flow, and two absorber designs were all categorized. Although it was 2 percent less effective than the channel form, the sheet and tube design was the easiest to construct. As a result, when compared to other designs, this one appears to be the most promising. Razali *et al*. [11] recently investigated the electrical characteristics of a PVT collector in the presence of a water-multiwalled carbon nanotube nanofluid flow.

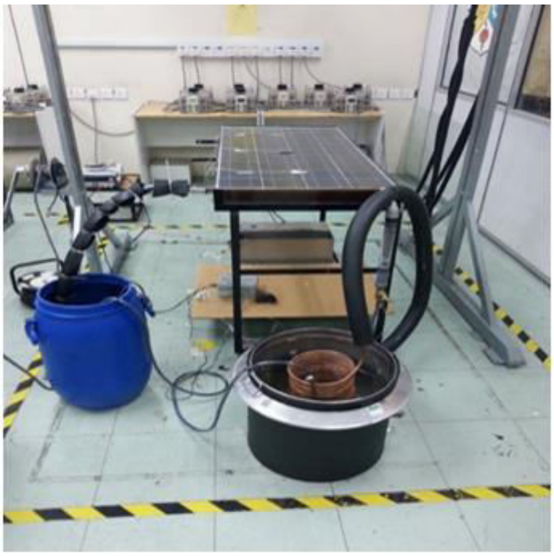
Much research [12]-[15] focused on the kind, configuration, and size of hybrid PV/T systems that employed water for cooling. The primary goal of this research is to look at the electrical properties of a hybrid PV/T solar panel with water flow in a spiral absorber.

MATERIAL AND METHODS

Figure-1 depicts the hybrid PV/T solar panel's experimental configuration in a solar simulator. The hybrid PV/T solar panel has a length of 1.2 meters and a width of 0.5 meters. The main component of this PV/T solar panel consists of a PV solar panel, spiral absorber, insulators, storage tanks, and water pumps. The spiral absorber as shown in Figure-2 contains a channel made to allow water to flow. The spiral absorber is placed under the PV solar panel. In this study, polycrystalline solar cells (p-Si) were used for PV panels. It is SHARP with the NE-80E2EA panel. This photovoltaic collector has been tested by producers under the intensity of 1000 W/m^2 and room temperature of 25 °C which reaches a maximum power of 80 W.

Data readings from the thermocouples were recorded using ADAM acquisition data recorders. ADAM data recorders have two terminals, both positive and negative, and have 16 channels for connection with the thermocouple. Data recorded from this data recorder can be viewed directly from a personal computer to see the hybrid PV/T solar panel response to temperature. A K-type thermocouple was used to determine the temperatures. Temperature changes can be tracked and recorded in 1 minute during the experiment. The mass flow rate was controlled with a flow meter (1-4 G/M). In the closed-loop system, water was circulated throughout the system, with the pump and heat exchanger cooling the water. The pyranometer used for this research is the EPPLEY model 8-48 type pyranometer available at the Department of Physics, Universiti Kebangsaan Malaysia. A pyranometer is a tool used to detect radiation intensity rather than halogen lamps. This EPPLEY piranometer is easy to operate and it does not require a solar tracker.

Voltage, current, open circuit voltage (Voc), and short circuit current were measured using a BK Precision electronic load type 8500. (Isc). The data was used to create graphs of the I-V and P-V curves. The graph can be used to determine the maximuz power (Pm).


(a)


(b)

Figure-1. Solar simulator, hybrid PV/T solar panel, (a) setup experiment, (b) spiral absorbers.

The Pm ratio to the targeted radiation was used to determine the PV solar panel's electrical efficiency [11].

$$\eta_{el} = \frac{P_m}{SA_c} \quad (1)$$

where Ac is the PV solar panel's surface area, S is the radiation intensity, and Pm was determined using equation (2).

$$P_m = V_m \times I_m \quad (2)$$

The output of a PV solar panel can be stripped of its features, which can be explained by the I–V curve nature that results. A PV panel's fill factor (FF) was calculated using the real I–V characteristic curve. It's the product of the open circuit voltage product (Voc) and the closed-circuit current produced by the cell (Isc), which FF can be written [11].

$$FF = \frac{P_m}{V_{oc} \times I_{sc}} \quad (3)$$

RESULTS AND DISCUSSIONS

To gather reference data for the actual capabilities of the PV panel employed, the PV solar panel without a collector (spiral absorber) must be researched first. As a result, the PV panel was investigated to investigate the hybrid PV/T solar panel. The I–V curve and the power fluctuations generated by the PV solar panel are shown in Figure-2. Table-1 summarizes the results of these tests. When the intensity of radiation is adjusted from 700 W/m2 to 900 W/m2, Isc and Voc increase from 1.45 A to 1.98 A and 16.14 V to 15.29 V, respectively. When the intensity was altered within the same range, the power increased from 15.72 W to 20.97 W. PV solar panels have an FF of 0.67 to 0.65.

VOL. 19, NO. 16, AUGUST 2024 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

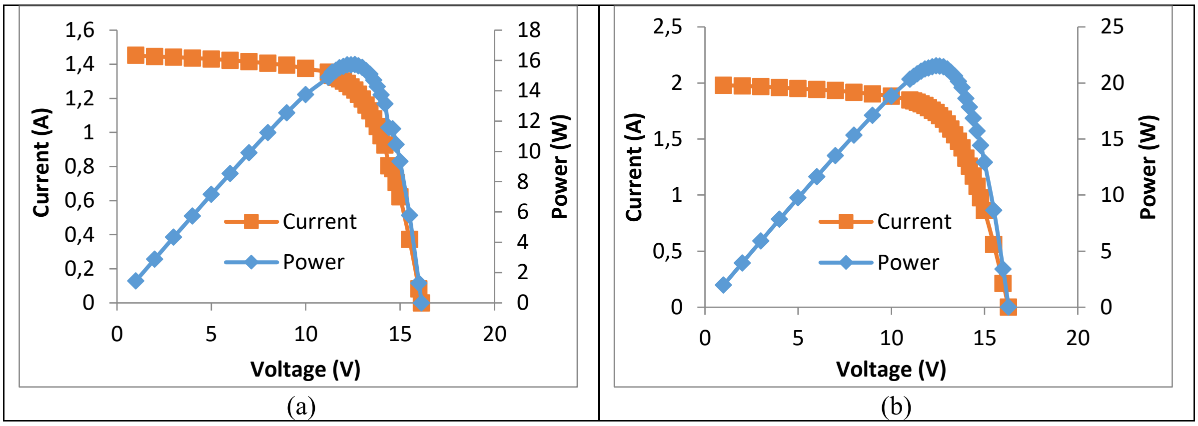


Figure-2. PV solar panel current (I) and power (P) over voltage (V), (a) at 700 W/m^2, (b) at 900 W/m^2.

Table-1. Under the intensity of the simulator radiation, the electrical characteristics of the PV solar panel without cooling.

S (W/m2)	Isc (A)	Voc (V)	Pm (W)	FF	η_{el} (%)
700	1.45	16.14	15.72	0.67	3.46
900	1.98	16.29	20.97	0.65	3.65

This test yielded a somewhat low level of efficiency (3.65%). As a result, the electrical performance of the PV solar panel used in this hybrid PV/T solar panel was found to be lower (12.5%) than the specifications obtained from the suppliers. PV solar panels with an Isc of 5.15 A, Voc of 21.6, and PV of 12.5% were tested under standard conditions of 1000 W/m2 and 25 °C. Due to the long-term PV solar panel quality factor, the difference in Isc was more significant than the difference in Voc in comparison to the tests done. The PV solar panel's performance was crucial in comparing it to the hybrid PV/T solar panels. The electrical capabilities of the hybrid PV/T solar panel were tested under the same test settings to confirm that they were in line with the theory of hybrid PV/T solar panel design.

This hybrid PV/T solar panel was put through its paces in the lab at the same temperature and humidity as the PV solar panel. First, the effect of water-cooled thermal collectors on the Isc and Voc of PV solar panels was investigated. The hybrid PV/T solar panel was exposed to simulator radiation with intensities of 700 and 900 W/m2 and mass flow rates ranging from 0.01 kg/s to 0.03 kg/s. By chilling the fluid in the cooling tank before entering the collector, the inlet water flow temperature was set at 26 °C. For each change in radiation intensity and mass flow rate, Isc and Voc were recorded. In Figures 3-7, all of the recorded I-V values were displayed. Table-2 summarizes the study's findings on intensity and fluid flow rates for the hybrid PV/T solar panel.

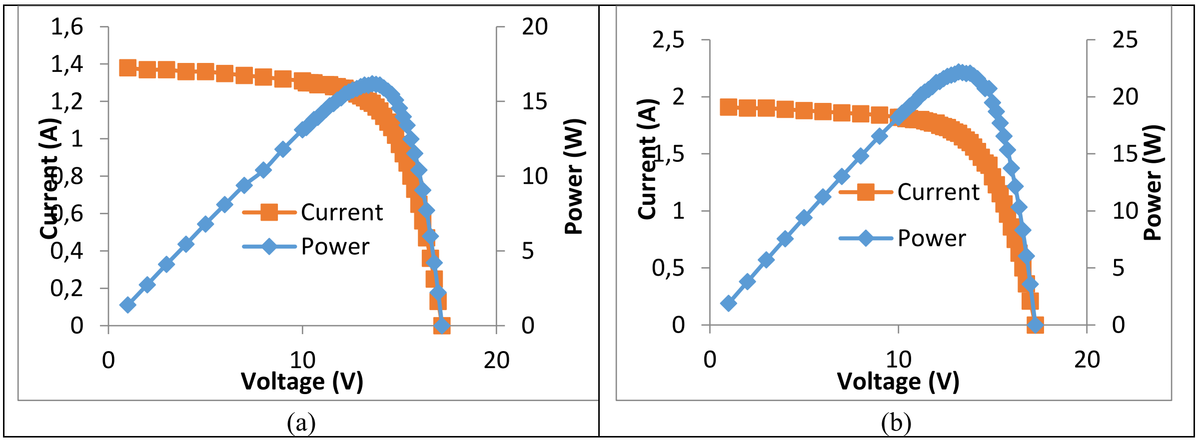


Figure-3. For a mass flow rate of 0.01 kg/s, current (I) and power (P) over voltage (V) for the hybrid PV/T solar panel, (a) at 700 W/m2, (b) at 900 W/m2.

VOL. 19, NO. 16, AUGUST 2024 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

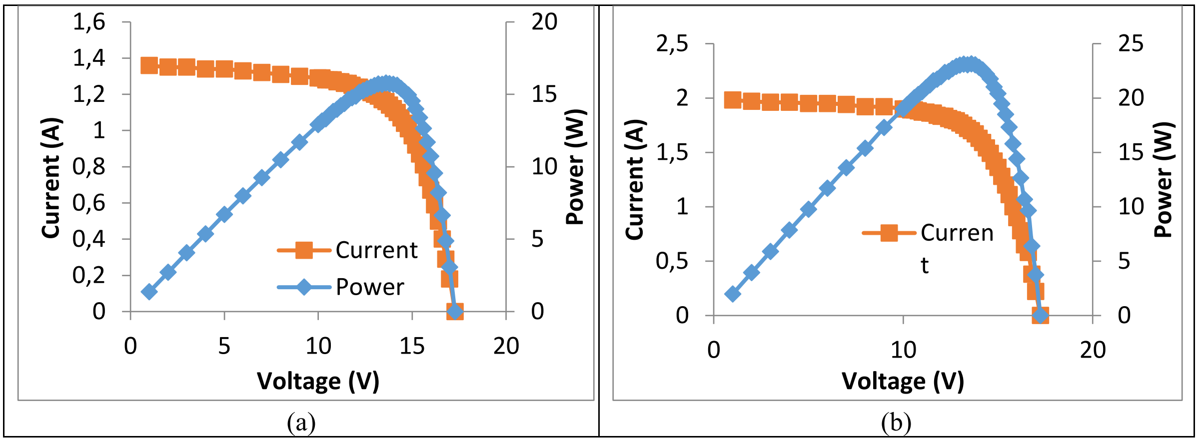


Figure-4. For a mass flow rate of 0.015 kg/s, current (I) and power (P) over voltage (V) for the hybrid PV/T solar panel, (a) at 700 W/m2, (b) at 900 W/m2.

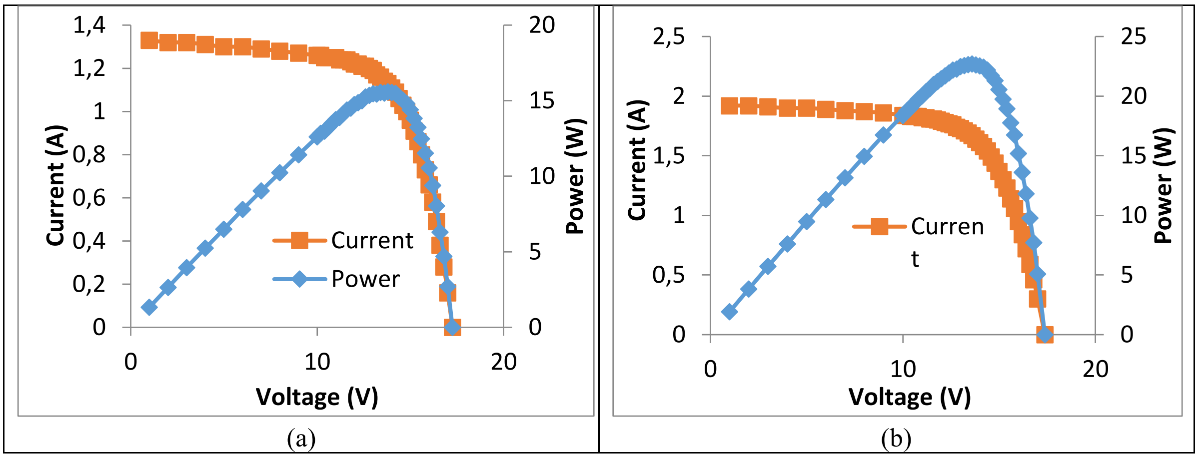


Figure-5. For a mass flow rate of 0.02 kg/s, current (I) and power (P) over voltage (V) for the hybrid PV/T solar panel, (a) at 700 W/m2, (b) at 900 W/m2.

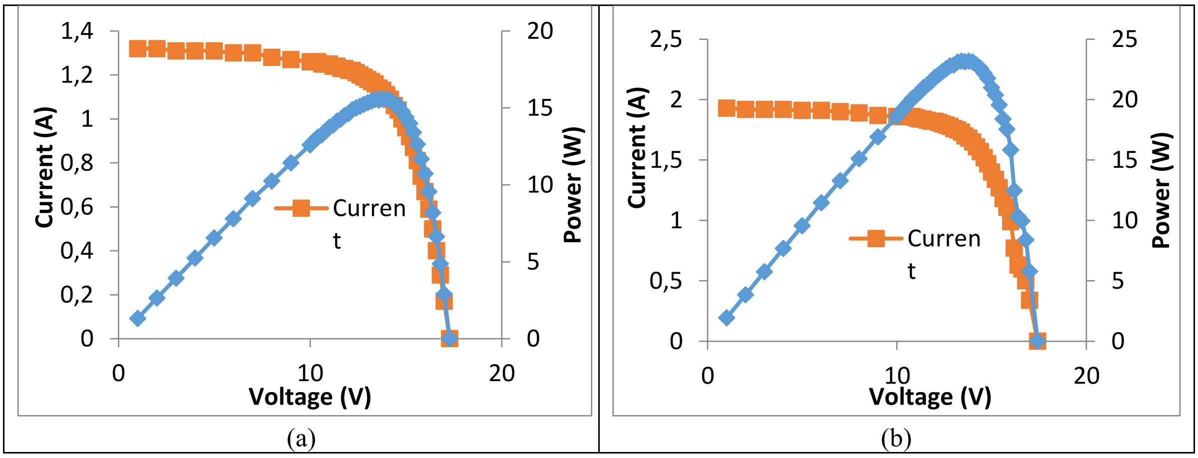
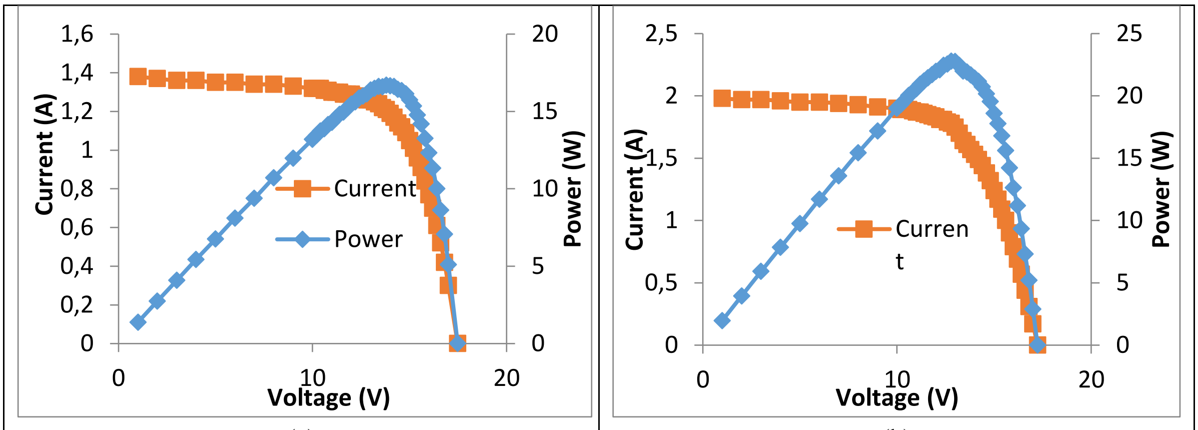


Figure-6. For a mass flow rate of 0.025 kg/s, current (I) and power (P) over voltage (V) for the hybrid PV/T solar panel, (a) at 700 W/m2, (b) at 900 W/m2.



(a) (b)

Figure-7. For a mass flow rate of 0.03 kg/s, current (I) and power (P) over voltage (V) for the hybrid PV/T solar panel, (a) at 700 W/m2, (b) at 900 W/m2.

Table-2. Electrical characteristics of the hybrid PT/V solar panel are based on Figures 3 to 7.

S (W/m^2)	ṁ (kg/s)	Isc (A)	Voc (V)	Pm (W)	FF	η_{el} (%)
700	0.01	1.38	17.20	16.18	0.68	3.63
	0.015	1.36	17.28	15.78	0.67	3.62
	0.02	1.33	17.26	15.59	0.68	3.58
	0.025	1.32	17.28	15.59	0.68	3.65
	0.03	1.38	17.48	16.70	0.69	3.89
900	0.01	1.91	17.27	22.18	0.67	3.89
	0.015	1.98	17.24	23.12	0.68	4.00
	0.02	1.92	17.38	22.71	0.68	3.99
	0.025	1.93	17.43	23.18	0.69	4.06
	0.03	1.98	17.24	22.78	0.67	3.96

CONCLUSIONS

Results lead to the following conclusions:

a) Generation of electrical output shown by the maximum power produced when solar intensity given was constant.

b) Efficiencies of hybrid PV/T solar panels in producing maximum power at constant solar intensity with different mass flow.

c) Optimum condition of the mass flow used as a coolant in a hybrid system.

d) Comparison between electrical energy conversion efficiencies for both systems and also by comparing with the relation of mass flow in hybrid PV/T solar panel. In a comparison of electrical efficiencies for both systems, the highest electrical efficiency attained was 4.06% in hybrid PV/T solar panels at 900 W/m^2 with 0.025 kg/s of mass flow while 3.65% by PV solar panel.

REFERENCES

[1] M. Mustapha, *et al*. 2020. Mathematical modelling of bifacial photovoltaic-thermal (BPVT) collector with mirror reflector. International Journal of Renewable Energy Research. 10(2): 654-662.

[2] N. F. M. Razali, *et al*. 2019. Experiment study of water-based photovoltaic-thermal (PV/T) collector. International Journal of Electrical and Computer Engineering (IJECE). 9(1): 118-125.

[3] N. F. M. Razali, *et al*. 219. Review of water-nanofluid based photovoltaic/thermal (PV/T) systems. International Journal of Electrical and Computer Engineering (IJECE). 9(1): 134-140.

[4] N. S. B. Rukman, *et al*. 2019. Energy and exergy efficiency of water-based photovoltaic thermal (PVT) systems: an overview. International Journal of Power

Electronics and Drive Systems (IJPEDS). 10(2): 987-994.

[5] A. Fudholi, *et al*. 2019. Energy and exergy analysis of air based photovoltaic thermal (PVT) collector: a review. International Journal of Electrical and Computer Engineering (IJECE). 9(1): 109-117.

[6] A. Fudholi, *et al*. 2018. R&D of photovoltaic thermal (PVT) systems: an overview. International Journal of Power Electronics and Drive Systems (IJPEDS). 9(2): 803-10.

[7] M. Mustapha, *et al*. 2018. Review on energy and exergy analysis of air and water-based photovoltaic thermal (PVT) collector. International Journal of Power Electronics and Drive Systems (IJPEDS). 9(3): 1383-1389.

[8] T. Bargene and O. M. Lovvik. 1995. Model calculations on a fat plate solar heat collector with integrated solar cells. Solar Energy. 55(6): 453-462.

[9] P. G. Charalambus, *et al*. 2007. Photovoltaic thermal (PV/T) collectors: a review. Applied Thermal Engineering. 27: 275-286.

[10] H. A. Zondag, *et al*. 2003. The yield of different combined PV-thermal collector designs. Solar Energy. 74: 253-269.

[11] N. F. M. Razali, *et al*. 2019. The electrical characteristic of the photovoltaic thermal collector with water-multiwalled carbon nanotube nanofluid flow. Indonesian Journal of Electrical Engineering and Computer Science. 13(1): 324-330.

[12] C. N. Aisyah *et al*. 2018. Kecekapan pengumpul PV/T menggunakan pengumpul terma reka bentuk pilin (Efficiency of PV/T collector using spiral thermal absorber design), Sains Malaysiana. 47(4): 853-859.

[13] A. Ibrahim *et al*. 2014. Efficiencies and improvement potential of building integrated photovoltaic thermal (BIPVT) system. Energy Conversion and Management. 77: 527-34.

[14] A. Fudholi, *et al*. 2014. Performance analysis of photovoltaic thermal (PVT) water collectors. Energy Conversion and Management. 78: 641-651.

[15] A. Fudholi, *et al*. 2019. TiO2/water-based photovoltaic thermal (PVT) collector: a novel theoretical approach. Energy. 183: 305-314.