Evaluation on Low Temperature and Tracking Effect of Solar Photovoltaic Power Output Under Tropical Climate Condition in Kota Kinabalu, Malaysia

Ag Sufiyan Abd Hamid*, Adnan Ibrahim and Sohif Mat
Solar Energy Research Institute (SERI),
Universiti Kebangsaan Malaysia (UKM),
43600 Bangi, Selangor, Malaysia.
*Author email: p86585@siswa.ukm.edu.my

Kartini Sukarno and Jedol Dayou
Energy, Vibration and Sound Research Group (e-VIBS),
Universiti Malaysia Sabah (UMS),
88400 Kota Kinabalu, Sabah, Malaysia.

***Abstract*— *Outdoor experiment has been performed to investigate the effect of cooling and tracking against maximum power output and total kilowatt hour of three photovoltaic PV panel design. The first design was set without cooling and tracking known as the standard panel, the second design was set by applying surface laminar cooling methods known as low temperature panel and the third designs were set with double tracking axis known as the perpendicular panel. Two comparisons have been performed. First comparison between the standard and low temperature panels. Second comparison between the standard and perpendicular panels. Results from the first comparison showed that the low temperature panel generated higher power output by 9.3 W and higher total kilowatt hour by 15.6 %. Second comparison shows that the perpendicular panel generated higher power output by 0.7 W and higher total kilowatt hour by 26.7 %.*

Keywords—laminar surface cooling; tracking solar photovoltaic; tropical climate.

I. INTRODUCTION

Solar photovoltaic PV panel can convert sunlight energy from the sun to direct current electric. The effectiveness of the conversion depends on many factors, including temperature and angle effects. Lower temperature of PV panel produces higher power output. Perpendicular panel can be adjusted using dual axis tracking system also performed better compare to the conventional fixed panel.

Various methods were used to reduce the panel temperature. Heat from the panel can be eliminated using water, air and heat pipe cooling [1]. Integrated photovoltaic thermal PVT modelling and experimental using water as cooling medium also investigated [2]. In Malaysia, [3] using PVT to produce thermal and electrical energy simultaneously. The design is simple and easy to fabricate but produced 2 % lower in efficiency compared to other collectors such as channel, free flow and two absorber types. Another PVT system using the same cooling medium shows increasing cells power output by 50 % [4]. The main advantage of using water as cooling medium is environmental friendly. Using refrigerant can affect the ozone layer and contribute to global warming [5,6]. Other available methods for cooling fabrication using solar technology such as absorption machines, solid and liquid desiccant and solid adsorption [7]. In Europe, 59 % of solar cooling using solar the absorption system [7,8].

Another factor will be discusses in this paper is angle effect. The panel's azimuth and tilt angle affect the amount of solar irradiance intensity strike the PV panel surface [9]. Maximum irradiance intensity can be achieved by using the tracking system. Tracking system will adjust the panel perpendicularly to the sun and can be done manually or autonomous. Research [10] reported a significant different of power output by using a single axis tracking panel. This mechanism adjusts daily and rotated eastward or westward with three different fixed angles. Dual tracking system also produced 33.8 % higher electricity compared to conventional system and this comparison was results from a simulation [11]. In Jordan, sun tracking increased PV panel generation by 43.87 %. This is a comparison between tracking and fixed system. The fixed PV panel was installed and tilted 32° from the horizon [12]. Another research reported 30–45 % higher power output by using north–south axis tracking mechanism [13].

II. METHODOLOGY

This experiment was conducted in Universiti Malaysia Sabah, Malaysia. The same site and a continuity of researches from [14,15,16]. The main parameters recorded shows in Table 1. Data recorded every hour from 0600 until 1800. This experiment was conducted to test on 50 W monocrystalline PV panel model SPM050-M. The electrical characteristic of the panel at standard test condition STC (AM1.5, 1000 W/m², 25 °C) can be shown in Table 2. Pyronometer model LI-200 was used to measure irradiance intensity. Thermocouple model HP-720 infrared and thermocouple type K were used to record panel and ambient temperature respectively. Voltage and current were measured using digital multimeter model Fluke179 True RMS.

Table 1: Parameters, abbreviation and unit of data measured.

Parameters	abbreviation	unit
Irradiance intensity	S	W/m^2
Ambient temperature	T_a	ºC
Module temperature	T_p	ºC
Open circuit voltage	V_{oc}	V
Short circuit current	I_{sc}	A

Table 2: Electrical characteristic of the PV panel

Parameters	value
Maximum power	50 W
Maximum power voltage	18.68 V
Maximum power current	2.77 A
Open circuit voltage	22.53 V
Short circuit current	2.97 A
Cell Efficiency	17 %
Module Efficiency	14.6 7%
Maximum System Voltage	DC 1000V (TUV) / DC 600V (UL)
Power Tolerance	3 %
Series Fuse Rating	10 A

This experiment was conducted by performing two comparisons from three different PV panel setting. For the panel setting, three identical specifications of the panel were used. Each of the panel modified at different setting which are standard, low temperature and perpendicular panel setting.

A. *Standard panel*

This panel was set at 15° inclination facing south. This setting was fixed without tracking and cooling system. Fig. 1 shows the illustration and Fig. 2 shows the standard panel setting.

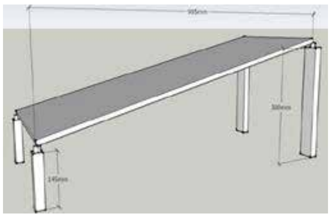

Fig 1: Illustration of standard panel setting.

Fig 2: Standard PV panel setting on site.

B. *Low temperature panel*

This panel was modified to reduce the panel temperature by using laminar surface cooling method [16]. An electric pump allowed water to flow over the top of the panel and collected back into the storage tank by gravity. This method will reduce the temperature and increase the power output. The setting was tested indoor as shows in Fig. 3 before outdoor experiment as shows in Fig. 4.

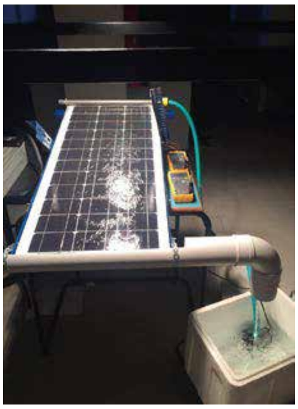

Fig 3: Low temperature panel tested indoor under solar simulator.

Fig. 4: Low temperature panel during experiment.

C. *Perpendicular panel*

A panel was attached on dual tracking mechanism, allow the panel to incline and facing the sun perpendicularly. The panel was adjusted manually every hour for data collection. The illustration of the mechanism shown in Fig. 5 and the module shown in Fig. 6.

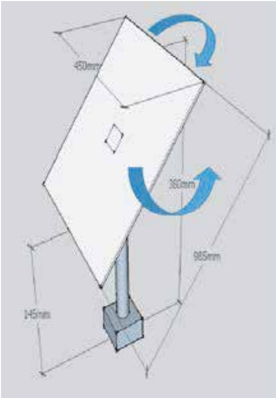

Fig 5: Illustration of perpendicular panel.

Fig 6: Perpendicular panel during experiment.

The comparisons consist of first comparison: between standard and low temperature panel and second comparison: between standard and perpendicular panel. These comparisons will identify the temperature and angle effect against maximum power output P_{max} and total kilowatt hour per day kWh/d. The kWh/d calculated to determine the power generated of each panel during the experiment. The P_m was determined using (1)

$$V_{oc} \times I_{sc} \quad (1)$$

III. Result and Discussion

Fig. 7 shows the values for temperature T and irradiance intensity S for comparison between standard and low temperature panel. Average values for S, ambient T, standard panel T and low temperature panel T are 508.6 W/m^2, 34.0 °C, 38.9 °C and 33.7 °C respectively. Maximum temperature reduced using surface laminar cooling method in this experiment is 16.4 °C.

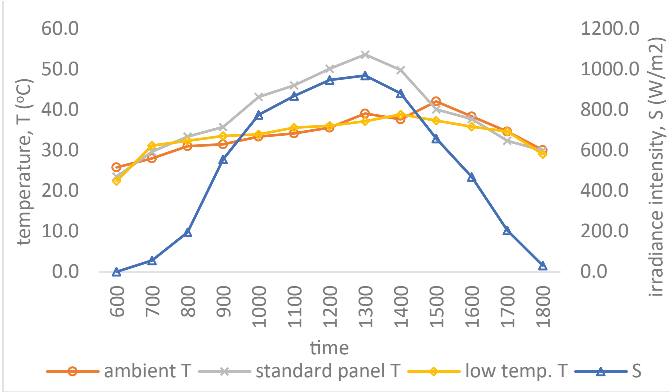

Fig. 7: The values of S, ambient T, standard panel T and low temperature panel T.

Fig. 8 shows V_{oc} and I_{sc} recorded from standard and low temperature panel. Average values for V_{oc} and I_{sc} standard panel are 19.0 V and 1.7 A respectively, and the V_{oc} and I_{sc} for low temperature panel are 20.5 V and 2.0 A respectively. Fig. 9 shows P_{max} for both panel. Average values of P_{max} for standard and low temperature panel are 33.1 W and 42.9 W respectively. Low temperature panel produces higher P_{max} compared to standard module within range from 0.2 W to 20.8 W. Based on P_{max} calculated, the kWh/d also determined for standard and low temperature panel as 430.0 W and 557.6 W respectively.

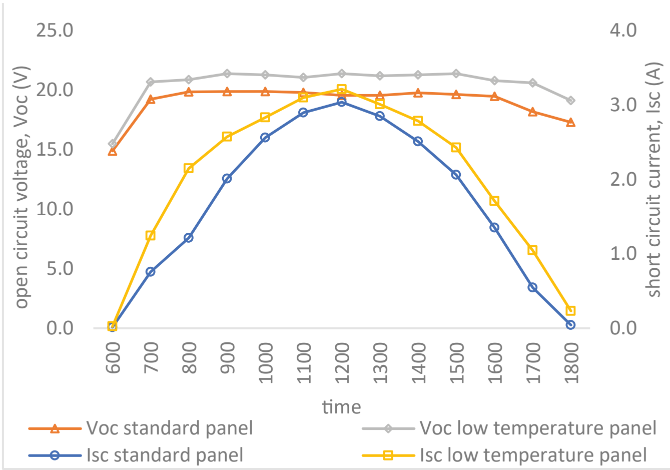

Fig. 8: The V_{oc} and I_{sc} values for first comparison.

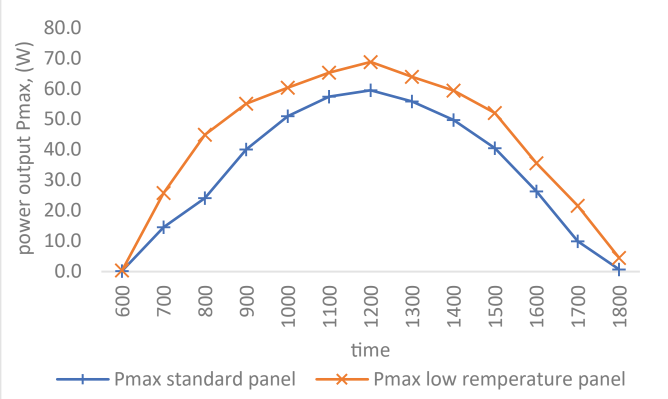

Fig. 9: Value of P_{max} for standard and low temperature panel.

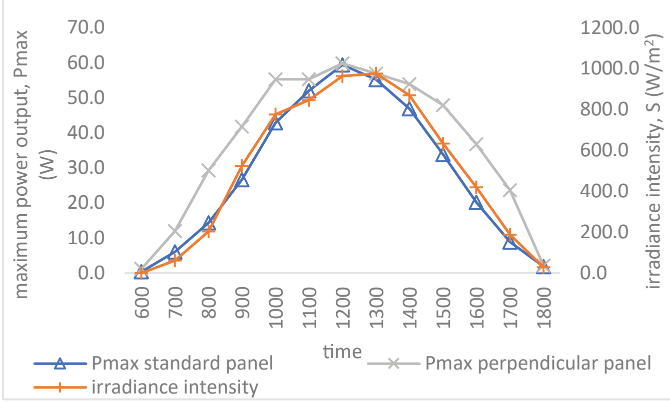

Fig 11: The S and P_{max} values for standard and perpendicular panel.

Data measured for comparison between standard and perpendicular panel shows in Fig. 10 including V_{oc} and I_{sc} for both panels. Average values for V_{oc} and I_{sc} standard panel are 18.9 V and 1.4 A respectively, and the V_{oc} and I_{sc} for perpendicular panel are 19.1 V and 1.9 A respectively. Average values of S, P_{max} standard panel and P_{max} perpendicular panel are 499.4 W/m^2, 28.4 W and 36.6 W respectively. Perpendicular panel produces higher P_{max} compared to standard panel within range from 0.3 W to 16.7 W. Based on P_{max} calculated, the kWh/d also determined for standard and perpendicular panel as 368.7 W and 476.2 W respectively. Fig.11 shows the S and P_{max} for both panels.

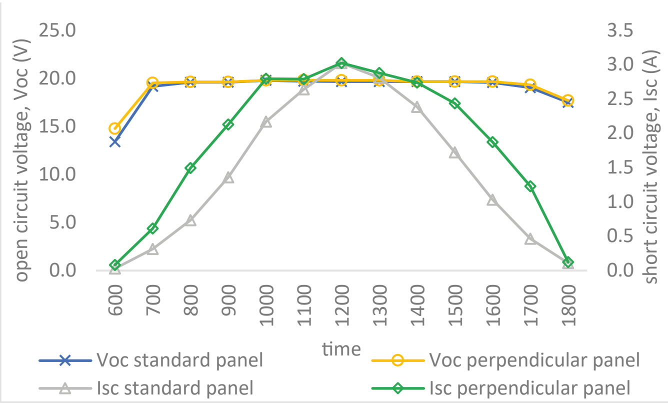

Fig 10: The V_{oc} and I_{sc} for second comparison.

Table 3: Maximum V_{oc}, I_{sc}, P_{max} and kWh/d for the first comparison.

Parameters	Standard panel	Low temperature panel	Different	% increase
Max V_{oc}	19.9 V	21.4 V	1.5 V	7.5 %
Max I_{sc}	3.0 A	3.2 A	0.2 A	6.7 %
Max P_{max}	59.5 W	68.8 W	9.3 W	15.6 %
kWh/d	430.0 kWh/d	573.6 kWh/d	127.6 kWh/d	30.0 %

Table 4: Maximum V_{oc}, I_{sc}, P_{max} and kWh/d for the second comparison

Parameters	Standard panel	Perpendicular panel	Different	% increase
Max V_{oc}	18.9 V	19.1 V	0.2 V	1.1 %
Max I_{sc}	1.4 A	1.9 A	0.5 A	35.7 %
Max P_{max}	59.4 W	59.8 W	0.4 W	0.7 %
kWh/d	368.7 kWh/d	467.2 kWh/d	98.5 kWh/d	26.7 %

Result from both comparisons can be simplified in Table 3 and 4. Both modified panels produced higher maximum V_{oc}, I_{sc}, P_{max} and kWh/d compared to fixed or standard panel setting. Low temperature panel produced higher maximum V_{oc}, I_{sc}, P_{max} and kWh/d by 7.5 %, 6.7 %, 15.6 % and 30.0 % respectively. The same condition recorded for perpendicular panel by 1.1 %, 35.7 %, 0.7 % and 26.7 % respectively. However, in comparison between low temperature and perpendicular panel, low temperature panel produced higher kWh/d with value of 573.6 kWh/d compared to perpendicular panel with value of 467.2 kWh/d. The kWh/d different are 127.6 kWh/d for low temperature panel and only 98.5 kWh/d for perpendicular panel.

IV. Conclusion

This research investigated the effect of temperature and angle against P_{max} and kwh/d generated. Low temperature panel produced higher P_{max} and kWh compared to perpendicular panel. The P_{max} and kWh/d increased 15.6 % and 30.0 % respectively by using laminar surface cooling method in low temperature panel. Manual dual axis tracking mechanism only increased 0.7 % and 26.7 % of P_{max} and kWh/d respectively for perpendicular panel.

REFERENCES

[1] K. Araki, H. Uozumi, and M. Yamaguchi, "A Simple Passively Cooling Structure and Its Heat Analysis for 500x Concentrator PV Module", Proceeding of the 29th IEEE Photovoltaic Specialist Conference, pp. 1568-1571, 2002.

[2] A. Tiwari, M. S. Sodha, "Performance evaluation of solar PV/T system: an experimental validation", Solar Energy, vol. 80, No. 7, pp. 751–759, 2006.

[3] Adnan Ibrahim, Mohd Yusof Othman, Kamaruzzaman Sopian Ruslan, Mohd Hafidz, Sohif Mat. "Recent advances in flat plate photovoltaic/thermal (PV/T) solar collectors". Renewable and Sustainable Energy Reviews. Issues 1, vol.15, page 352-365, 2011.

[4] J. A. Akbarzadeh, and T. Wadowski, "Heat-pipe-based cooling systems for photovoltaic cells under concentrated solar radiation", Applied Thermal Engineering, vol. 16, No. 1, pp. 81–87, 1996.

[5] Sözen Adnan, Özalp Mehmet, Arcaklioğlu Erol. "Prospects for utilisation of solar driven ejector-absorption cooling system in Turkey", Applied Thermal Engineering, vol. 24, No. 7, pp. 1019-1035, 2004.

[6] X. G. Casals, "Solar absorption cooling in Spain: perspectives and outcomes from the simulation of recent installations", Renewable Energy, vol. 31, No. 9, pp. 1371–1389, 2006.

[7] H. M. Henning, "Solar assisted air conditioning of buildings – an overview", Applied Thermal Engineering, vol. 27, No. 10, pp. 1734–1749, 2007.

[8] C. A. Balaras, G. Grossman, H. M. Henning, A. Carlos, I. Ferreira, E. Podesser, "Solar air conditioning in Europe an overview", Renewable Sustain Energy Rev, vol. 11, No. 2, pp. 299–314, 2007.

[9] T. P. Chang, J. Applied Energy. 86, 2071 (2009).

[10] B. J. Huang and F. S Sun, Energy Converse Manage. 48, 1273 (2007).

[11] R. Eke, S. Ozden, A. Senturk, O. Fleck, and S. Oktik, "The largest double-axis sun tracking PV systems with electronic control and photosensors in Turkey". Proceedings of 25th EUPVSEC, Valencia, Spain (2010), pp. 4744–4747.

[12] S. Abdallah and S. Nijmeh, Energy Conversion and Management 45, 1931(2004).

[13] I. Sefa, M. Demirtas, and I. Colak, J. Energy Conversion and Management 50, 2709 (2009).

[14] K. Sukarno, A. S. Abd Hamid, J. Dayou, M. Z. H. Makmud and M. S. Sarjadi, "Measurement of global solar radiation in Kota Kinabalu Malaysia", ARPN Journal of Engineering and Applied Science, vol. 10, No. 15, pp. 6467-6471, 2015.

[15] K. Sukarno, A. S. Abd Hamid, J. H. W. Chang, F. P. Chee and J. Dayou, "Comparison of Power Output between Fixed and Perpendicular Solar Photovoltaic Panel in Tropical Climate Region", Advanced Science Letters, vol. 23, No. 2, pp. 1259–1263, 2017.

[16] Kartini Sukarno, Ag Sufiyan Abd Hamid, Halim Razal and Jedol Dayou. "Evaluation on Cooling Effect on Solar PV Power Output Using Laminar H2O Surface Method". International Journal of Renewabe Energy Research. Vol.7, No.3, 2017.