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Influence of wind speed on the performance of photovoltaic panel

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ABSTRACT

The aim of this project is to investigate the performance of photovoltaic (PV) panel influence by wind speed in Kangar, Perlis, Malaysia. A low conversion energy efficiency of the PV panel is the major problem of a PV application system. The PV panel is absorbed solar irradiance minor converted into electrical energy, and the rest is converted into heat energy. Therefore, the heat energy generated by the PV panel is increased in its operating temperature. However, PV panel is necessary to operate them at the low operating temperatures to keep the PV panel electrical efficiency at an acceptable level. In this experiment, one unit of the PV panel was limited wind flow over its surface and the other one PV panel was operated in the normal condition. The operating temperature of the PV panel with wind speed is less than the PV panel without wind speed. This is due to wind flow over the surface of the PV panel can enhance heat extraction from the PV panel. Hence, PV panel with wind speed can generate a higher output power than that without wind speed. This improvement output performance of PV panel will have an important contribution to PV application systems.

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1. INTRODUCTION

Energy is so progressed, and economic growth is one of the world's most crucial issues. Availability of non-renewable energy is bounded, and their long-term adverse effects on the natural balance of planet earth, underline the growth and development of renewable energy needs. Solar energy is the most popular to solve the problem of non-renewable energy among all the renewable energy. PV panel is a device that directly converts solar energy into electricity without any equipment. Besides, PV system generates electrical energy without producing environmental pollution and emissions of greenhouse [1-2]. PV is also an interesting energy; it is renewable, abundant, silent and environmentally friendly, and can supply electricity in different applications.

PV based electricity generation system is divided into two majors, which are stand-alone PV system and grid-connected PV system. Stand-alone PV system consists of PV panels, charge controllers, energy storage (battery) and inverter. This system is no interaction with a utility grid. Grid-connected PV system is linked to the local electricity network or be sold to one of the electricity supply companies. In the standard test condition (STC), PV panels are rated in solar irradiance of 1000 W/m2, PV panel temperature of 25 °C and light spectrum with an air mass, AM is 1.5 [3]. Even though this information is helpful in comparing the efficiency of PV panel on the state rating, it does not indicate what is generally experienced in the outdoor testing. The performance of the PV panel in a real outdoor testing is different from under STC performance [4].

In a PV system installation, the PV panels have a major part of the investment cost [5]. Therefore, the energy generation of the PV panels is the primary return of investment in the PV system installation. In general, a PV panel converts 6-20 % of the solar irradiance into electrical energy according to the type of the PV panels and weather conditions of the site location [6]. The rest of the solar irradiance is converted into heat energy, which increases the operating temperature of the PV panel [7]. At the same time, it brings a negative effect on the lifespan of the PV panel. In the real outdoor testing, the PV panels face low conversion electrical efficiency. This is due to the solar irradiance incident, operating temperature and material of the semiconductor used affected the low conversion electrical efficiency of the PV panels. PV panel operating temperature is a significant impact on the performance of energy production systems [8] and, additionally, the environment parameters, including, solar irradiance, ambient temperature, wind speed, dust accumulation and the accurate installation status [9]. Typically, solar irradiance and wind speed on the surface of the PV panel are often rather interrupted by nearby buildings.

The research conducted by the Hassan et al [10] stated that when the operating temperature of the PV panel increase by more than 25 °C (STC), the energy generation of the PV panel will be decreased. Amy de la Breteque [11] mentioned that when the operating temperature of the PV panel is increased than 25 °C, the output power and energy efficiency of the PV panel will decrease by -0.5 %/°C to -0.65 %/°C as increased by 1 °C in the operating temperature of the PV panel. Fesharaki et al. [12] stated that the output power of the PV panel is impacted by the change in its operating temperature. Among the electrical parameter of the PV panel, the output voltage of the PV panel is very dependent on the operating temperature. This represents an increase in the operating temperature will lead to reducing the output voltage generated by the PV panel [13]. Kaldellis et al. [14] carried out an experiment on the investigating the effect of temperature change on the operation of existing commercial PV panels. They concluded that in the conversion process of the PV system, the operating temperature of the PV panel works an important role.

El-Shobokshy and Hussein [15] mentioned that all the surfaces of PV panel they provided were contaminated under zero wind conditions in the state of nature. As the response time of microscopic dust debris is greatly l8w, the fine particle will move even at very low wind speeds appear. Mekhilef et al. [16] investigated that operating temperature of the PV panel is dependent on different parameters, including atmosphere variables (solar irradiance, ambient temperature, wind speed), material of the cell and system dependent properties. The PV panel operating temperature will drop with increases in wind speed and the PV panel can be generated high efficiency electricity.

Mani and Pillai [17] explained natural wind movement impact PV panel efficiency as well as installation geometries by affecting the accumulation or cleaning of dust from PV surfaces. Natural wind movements can have the advantageous result of reducing the operating temperature of the PV panel by carrying away several sections of the surface heat via forced convective heat transfer. It is of relevance, hence, to understand the nature and significance of the interactions of ambient wind regimes on PV system performance. Rao and Mani [18] carried out a PV panel mounted on the roof for analysis of the performance of PV panel impacted by the effect of wind-related heat transfer. Extreme wind speeds have the effect of reducing the PV panel operating temperature, therefore, producing the potential gains in performance.

In all major atmosphere parameters, only wind speed has been taken into account for the present research. Therefore, the main goal of this study is focused to analyse the performance of PV panel affected by the effect of the wind In Kangar, Perlis, Malaysia. The comparison performances of PV panel with wind speed and PV panel without wind speed have been discussed. Hence, these analyses will be performed in the subsequent sections.

2. RESEARCH METHOD

The experiment was examined at the Centre of Excellence for Renewable Energy (CERE), University Malaysia Perlis (UniMAP) in Kangar, Perlis, Malaysia, as displayed in Figure 1 (a) and (b). Latitude and longitude of CERE are 6°26.3’ N and 100°11.2’ E.

(a) PV panel without wind speed (b) PV panel with wind speed

Figure 1. Experimental installation of (a) PV panel without wind speed and (b) PV panel with wind speed

Figure 2 displays the block diagram of the experimental setup for the PV panels without and with wind speed. It is showed the PV panel is started to convert the solar energy to electrical energy. While electrical energy from PV panel charged the battery through the use of solar charger controller. By using the solar charger controller, it can be to avoid overcharging the battery. Moreover, the electrical energy produced by the PV panel powered up the DC bulb, where the DC bulb was used as the load demand. In the measurement section, the output voltage of both PV panels was measured by using Midi Logger GL220 also. The output current of both PV panels was measured and recorded by using Digital Multimeter. A Davis Vantage PRO2 Weather was used to identify the daily solar irradiance, ambient temperature and wind speed. In addition, four units of temperature sensors installed at each of rear side of the PV panel. Which, a couple of temperature sensors attached at the top side of the PV panel, and the other couple of temperature sensors attached at the bottom of the PV panel, as illustrated in Figure 3. All the measurement parameter was collected within every ten minutes during the testing period.

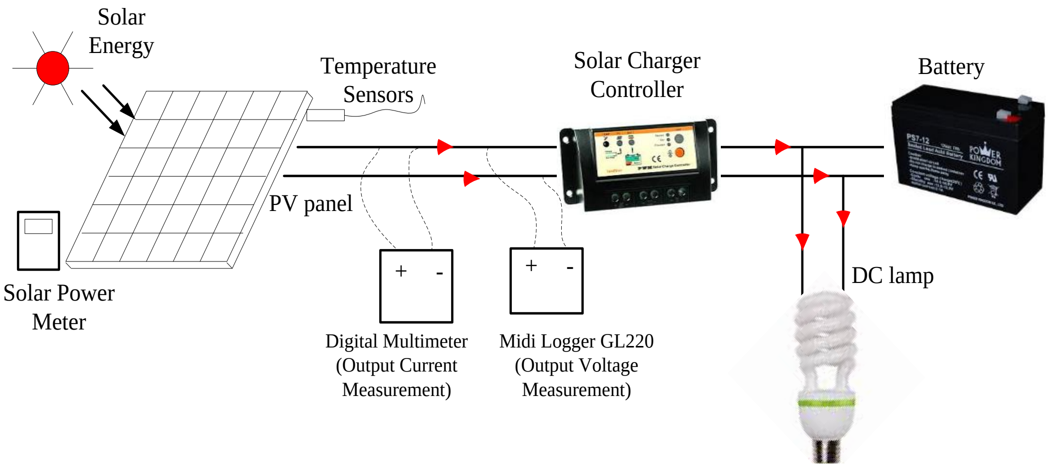


Figure 2. Block diagram of the outdoor experimental setup

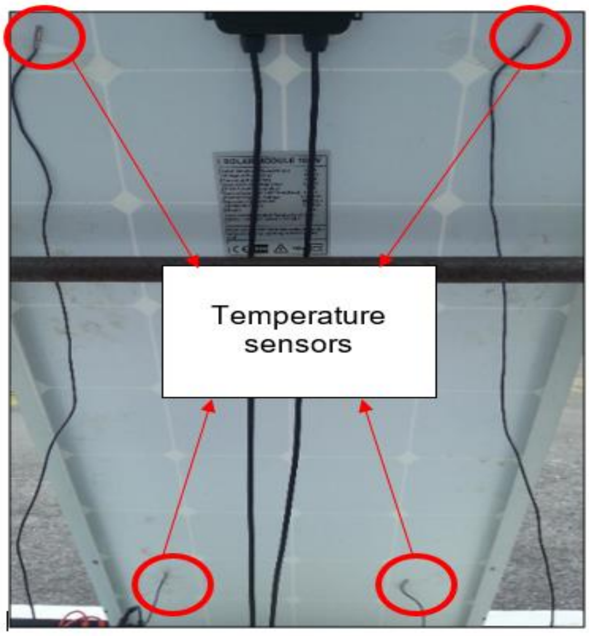


Figure 3. Temperature sensors are attached at the rear side of the PV panel

3. RESULTS AND ANALYSIS

The main aim of this research is to observe and analyse the effect of wind speed on the performance of the PV panel. This research was carried out at Centre of Excellence Renewable Energy (CERE), Kangar, Perlis, Malaysia from 9:00 a.m. until 5:00 p.m. Both PV panels were tested in a similar condition of outdoor environment. The variation of weather conditions (solar irradiance, ambient temperature and wind speed) during test day is illustrated in the Figures 4 and 5.

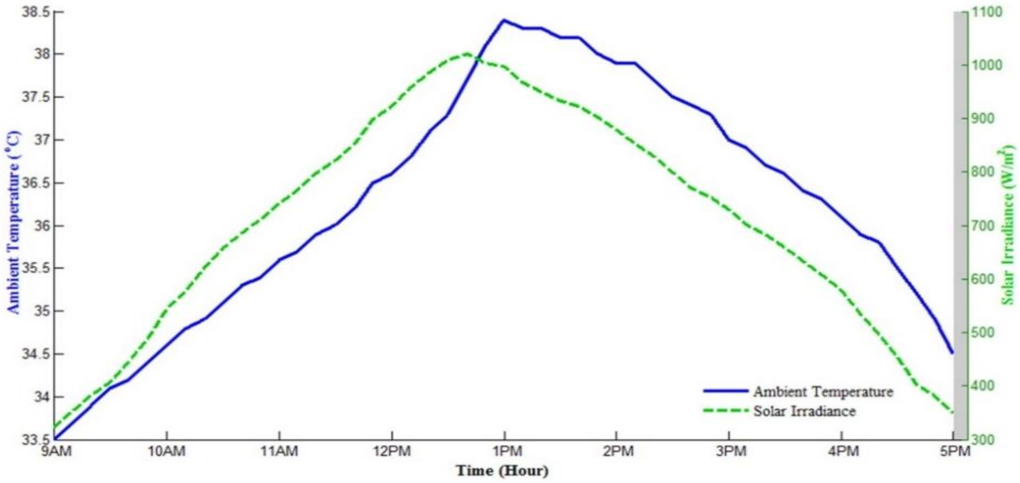


Figure 4. Solar irradiance and ambient temperature versus time throughout the test day

Respectively. The solar irradiance began to increase from 9:00 a.m. until to 12:30 p.m., after it began to decline until the end of the test day. The maximum solar irradiance is reached at 12:40 p.m. with 1021.2 W/m² and the minimum solar irradiance that hit on the surface of the PV panel is 329.1W/m² during the testing day. The fluctuation of ambient temperature is same with variation of solar irradiance. The maximum ambient temperature is occurred at 1:00 p.m. with 38.4 °C and the minimum ambient temperature is 33.5 °C throughout the test day. It can be showed that the increase in ambient temperature is linearly proportional to the increment of solar irradiance. On the other hand, the wind speed is in unstable fluctuating state as displayed in the Figure 5. The highest wind speed is reached at 6.7 m/s whereas the lowest wind speed is 0.2 m/s. The local weather condition is a main role in influencing wind speed such as monsoon period, hurricanes and cyclones this peculiar weather conditions can significantly affect the formation of wind speed. Figure 6 shows the comparison operating temperature between the PV panels without and with wind speed.

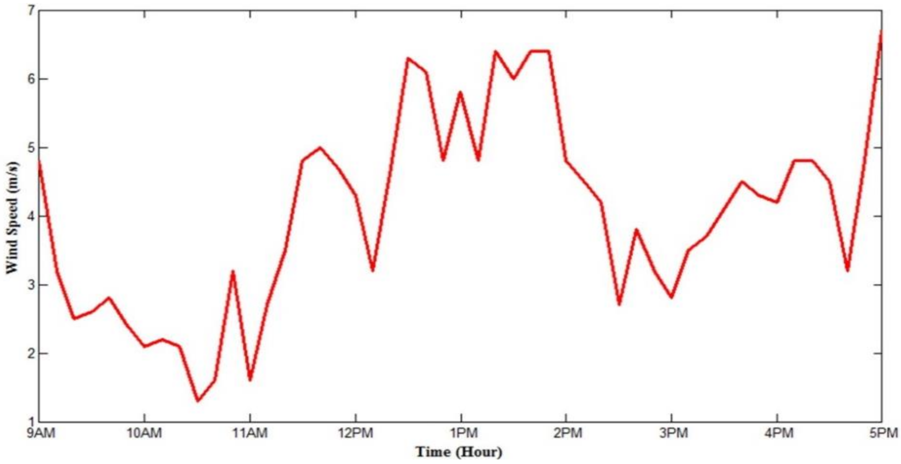


Figure 5. Wind speed versus time throughout the test day

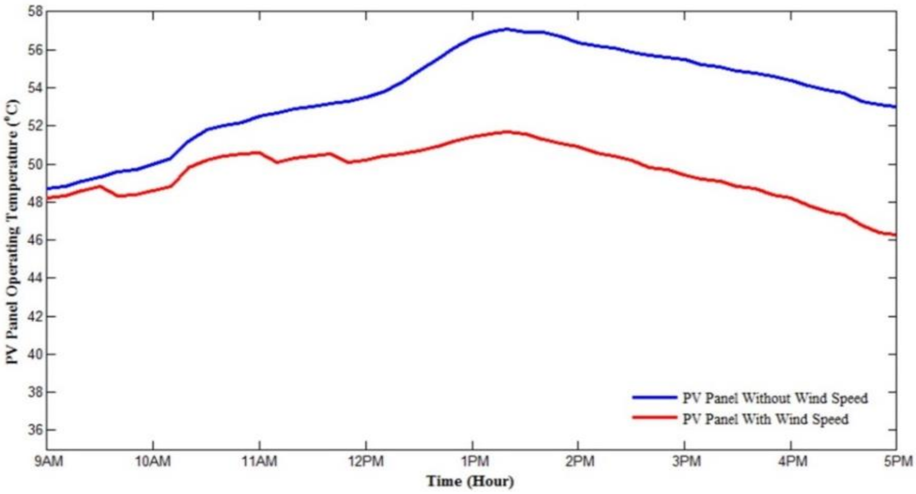
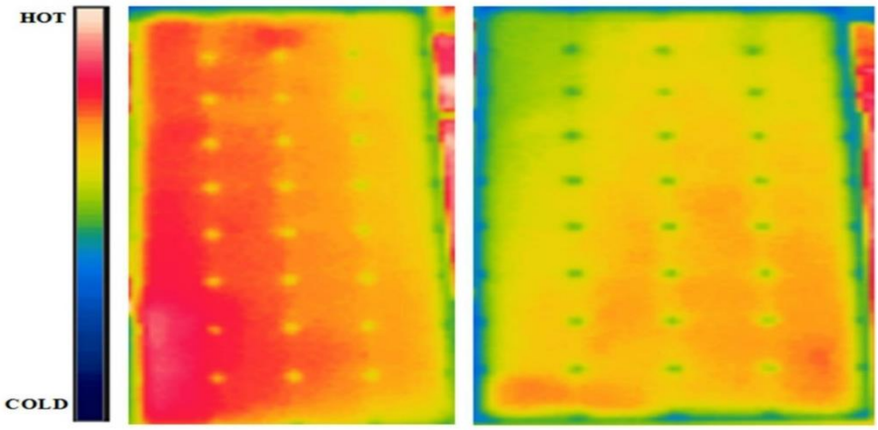


Figure 6. Variations of operating temperature of PV panels throughout test day

It can be observed that the operating temperature of the PV panel without wind speed is higher than the PV panel with wind speed. The highest operating temperature of the PV panel without wind speed is reach at 57.1 °C and the lowest operating temperature is 48.8 °C. Besides, the average operating temperature of the PV panel without wind speed is 53.7 °C. On the other hand, the highest operating temperature of PV panel with wind speed seems to be reached 51.7 °C and its lowest operating temperature is 46.3 °C. In addition, the average operating temperature of PV panel with wind speed is 49.5 °C. In the comparison of both PV panels, the PV panel with wind speed can be reduced 4.2 °C than PV panel without wind speed. It can be proved that the effect of wind speed flow over surface of the PV panel can affect the performance of the PV panel. The PV panel without wind speed is to limit the wind flow over the surface of the PV panel. Therefore, it would increase in operating temperature of the PV panel. Figure 7 displays thermal image of the PV panel without wind speed and the PV panel with wind speed for advance support the detail on the discussed from both PV panels.

These thermal images of both PV panel were captured under peak sun hour. Users can be a choice multiple colour palette to represent the surface temperatures of objects that will represent the different temperatures of the objects utilizing different colours in the image that captured by the thermal camera. The image can also present how to defective PV panel is overheating as showed in the figure above. The major surface of the PV panel without wind speed is in red colour, which means the PV panel is generating hot with the range of temperature is 48.1 °C to 51.83 °C as displayed in Figure 7 (a). The average operating temperature on the surface of PV panel without wind speed is 49.66 °C. In the same time, thermal image of the PV panel with wind speed within the range of temperature between 47.06 °C to 49.89 °C as displayed in Figure 7 (b). Besides, the average operating temperature of the surface of the PV panel with wind speed is 47.94 °C. It can be analytically that the PV panel without wind speed is getting hotter than that with wind speed in the peak sun hour. Wind speed can be assisted to reduce the increase in further operating temperature of the PV panel. Figure 8 shows the variation of output voltage that generated by the PV panels without and with wind speed.



(a) PV panel without wind speed (b) PV panel with wind speed

Figure 7. Thermal images of (a) PV panel without wind speed and (b) PV panel with wind speed

It can be seen that the PV panel with wind speed can be generated additional output voltage than the PV panel without wind speed. The maximum output voltage that generated by PV panel without wind speed is 16.45 V, and the minimum output voltage is 13.85 V. In the meantime, the average output voltage of PV panel without wind speed is reached at 15.54 V. On the other hand, PV panel with wind speed can be produced 17.15 V as its maximum output voltage and the minimum output voltage is 14.88 V. Besides, the PV panel with wind speed was generated 16.26 V as its average output voltage. In the comparison between these PV panels, the PV panel with wind speed can be generated more 4.43 % of output voltage than the PV panel without wind speed. It is clear that low operating temperature of the PV panel can generate more output voltage. In addition, Erdem et al. [19] also mentioned that to prevent the result drop in open circuit voltage and maximum voltage, the operating temperature of the PV panel should be maintained as low as possible. The comparison of output current between PV panels without and with wind speed is displayed in Figure 9.

It can be analytically that the PV panel with wind speed can be produced highest output current compared to the PV panel without wind speed. The maximum output current of the PV panel without wind speed is 3.37 A, while minimum output current is 1.91 A. In addition, the PV panel without wind speed generated 2.71 A as an average output current. At the same time, maximum and minimum output currents that produced by PV panel with wind speed is 3.68 A and 1.99 A, respectively and the average output current is 3.03 A throughout the test day. Compared to these both PV panels, the PV panel with wind speed is increased by 10.56 % of the output current as compared to the PV panel without wind speed. It is obvious that the higher solar irradiance and zero wind speed can be increased in operating temperature of the PV panel. Thus, the output current of the PV panel is reduced despite occurred in higher solar irradiance and zero wind speed. Figure 10 presents the comparison of output power generated by both PV panels during test day.

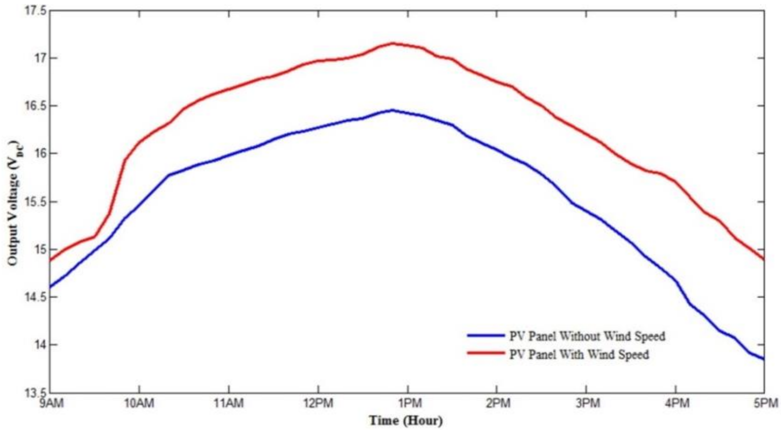


Figure 8. Output voltage versus time for PV panels without and with wind speed

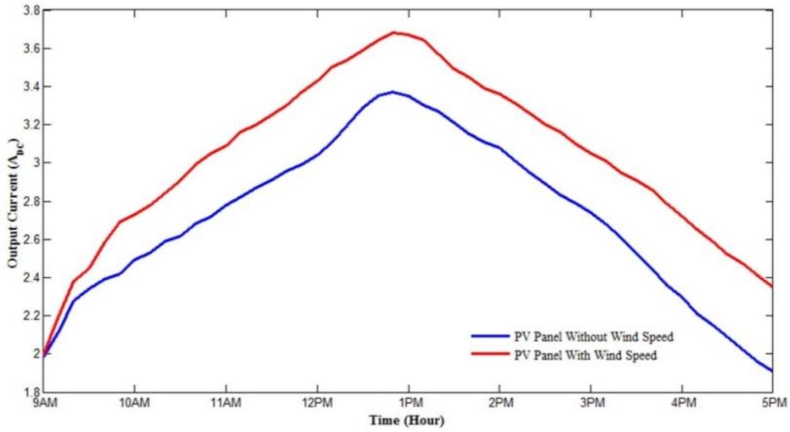


Figure 9. Output current versus time for PV panels without and with wind speed

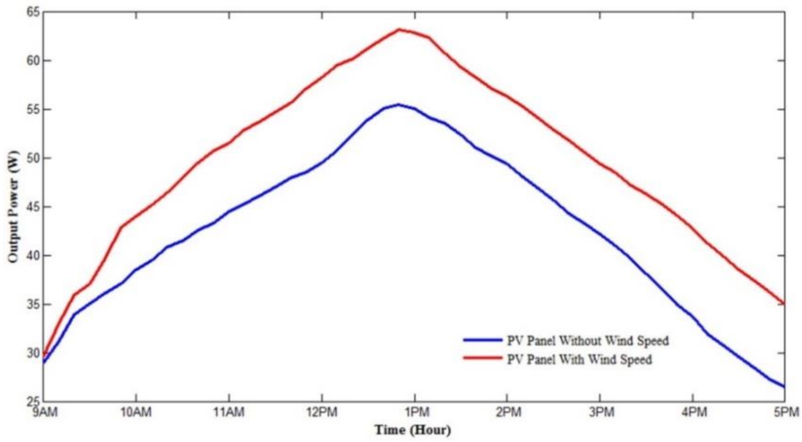


Figure 10. Output power versus time for PV panels without and with wind speed

PV panel without wind speed can be generated 55.44 W as maximum output power at 12:50 p.m. while the minimum output power is 26.45 W at 5.00 p.m. On the other hand, the maximum output power of PV panel with wind speed is occurred at 12:50 p.m. with 63.11 W whereas the minimum output power is

29.61 W at 9:00 a.m. The average output power of the PV panel with wind speed and PV panel without wind speed is 49.47 W and 42.42 W, respectively. It is obvious that PV panel with wind speed can be produced higher output power than the PV panel without wind speed. The increase percentage in output power in unit of electricity is calculated to be 14.25 % by using PV panel with wind speed. Dhass et al. [20] investigated an increase in operating temperature created a heating effect on the PV panel. Besides, materials of PV panel are also manipulated their performance of operation, whereas there is a change in the material band gap because of the effect of temperature.

Depending on the present studies and results of the experiment, the wind speed is always staying in an unstable or not constant condition. Therefore, air cooling system is therefore proposed attaching with PV panel in order to reduce the operating temperature of the PV panel. For an example, fan is one method of the air cooling system. Fans can be established at the entrance and exit to increase airflow speed, with the PV panel can function normally in low operating temperature condition. When increases in airflow speed lead to the operating temperature of the PV panel will decrease. Therefore, the PV panel can generate additional output power.

4. CONCLUSION

This paper has been success in conducting the investigation performance of the PV panel impacted by wind speed in Kangar, Perlis, Malaysia. The experimental results presented that the wind not flows over a PV panel surface lead to dropping in electrical performance with its operating temperature increased. The PV panel without wind speed can be generated the average output power of 42.42 W and its average operating temperature is 53.7 °C. Whereas, the PV panel with wind speed can be generated the average output power of 49.47 W and the average operating temperature is 49.5 °C. It is clearly that PV panel with wind speed can be reduced the operating temperature approximately 4.2 °C and improved output power in 14.25 % than the PV panel without wind speed. It can be shown that wind flow can improve convection heat transfer on the surface of the PV panel to decrease the further increase in operating temperature, especially in the peak sun hour. Therefore, the operating temperature of the PV panel decreased with the increase in output power. Highest output power of a PV panel, investment payback period of the system can be decreased and the lifespan associated with PV panel can be prolonged.

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REFERENCES

[1] Y.M.Irwan, W.Z.Leow, M.Irwanto, Fareq.M, S.I.S,Hassan, I.Safwati, A.R.Amelia. "Comparison of Solar Panel Cooling System By Using DC Brushless Fan and DC Water". *Journal of Physics: Conference Series*. 2015, 622: 1-10.
[2] A. Z. Adnan, M. E. Yusoff, H. Hashim. "Analysis on the Impact of Renewable Energy to Power System Fault Level". *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*. 2018,11(2): 652-657.
[3] V. Perraki, G.Tsolka. "Temperature Dependence on the Photovoltaic Properties of Selected Thin-Film Modules". *International Journal of Renewable and Sustainable Energy*. 2013,2: 140-146.
[4] Y. H. Sabri, W. Z. W. Hasan, S. Shafie, M. A. M. Radzi, A. H. Sabry. "Daily Harvested Energy of Cadmium Telluride Thin Film Photovoltaic". *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*. 2018, 11(1): 18-26.
[5] A.R. Amelia, Y.M. Irwan, M. Irwanto, W.Z. Leow, N. Gomesh, I. Safwati, M.A.M. Anuar. "Cooling on Photovoltaic Panel Using Forced Air Convection Induced by DC Fan". *International Journal of Electrical and Computer Engineering (IJECE)*. 2016, 6(2): 526-534.
[6] D. Swapnil, N. S. Jatin, S. Bharath. "Temperature Dependent Photovoltaic (PV) Efficiency and Its Effect on PV Production in the World A Review". *Energy Procedia*. 2013, 33: 311-321.
[7] A.R. Amelia, Y.M. Irwan, M. Irwanto, W.Z. Leow, M.H. Mat, I. Safwati. "Optimum Number of DC Fan as a Cooling Medium for Photovoltaic (PV) System". *Journal of Engineering and Applied Sciences*. 2017, 12(15): 3824-3828.
[8] W.Z. Leow, Y.M. Irwan, M. Irwanto, M Isa, A.R. Amelia, I. Safwati. "Temperature Distribution of Three-Dimensional Photovoltaic Panel by Using Finite Element Simulation". *International Journal on Advanced Science, Engineering and Information Technology*. 2016, 6(5): 607-612.
[9] M.C. Alonso Garcia, J.L. Balenzategui. "Estimation of Photovoltaic Module Yearly Temperature and Performance based on Nominal Operation Cell Temperature Calculation". *Renewable Energy*. 2004, 29: 1997-2010.

[10] A. Hasan, S. J. McCormack, M. J. Huang, J. Sarwar, B. Norton. "Increased Photovoltaic Performance Through Temperature Regulation by Phase Change Materials: Materials Comparison in Different Climates". *Solar Energy*. 2015, 15: 264–276.

[11] E. Amy de la Breteque. "Field Study of Various Air Based Photovoltaic/Thermal Hybrid Solar Collectors". *Renewable Energy*. 2009, 34: 1939-1946.

[12] V. J. Fesharaki, M. Dehghani, J. J. Fesharaki. "The Effect of Temperature on Photovoltaic Cell Efficiency". *Proceedings of the 1st International Conference on Emerging Trends in Energy Conservation (ETEC '11)*. Tehran, Iran. 2011.

[13] Z. Syafiqah, Y.M. Irwan, N.A.M Amin, W.Z. Leow, A.R. Amelia, M. Irwanto. "Thermal and Electrical Study for PV Panel with Cooling System". *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*. 2017, 7(2): 492–499.

[14] J. K. Kaldellis, M. Kapsali, & K. A. Kavadias. "Temperature and Wind Speed Impact on the Efficiency of PV Installations. Experience Obtained From Outdoor Measurements in Greece," *Renewable Energy*. 2014, 66: 612-624.

[15] M.S. El-Shobokshy, F.M. Hussein. "Effect of Dust with Different Physical Properties on the Performance of Photovoltaic Cell". *Solar Energy*. 1993, 50: 483-486.

[16] S. Mekhilef, R. Saidur, M. Kamalisarvestani. "Effect of Dust, Humidity and Air Velocity on Efficiency of Photovoltaic Cells". *Renewable and Sustainable Energy Reviews*. 2014, 16: 2920-2925.

[17] M. Mani, R. Pillai. "Impact of Dust on Solar Photovoltaic (PV) Performance: Research Status, Challenges and Recommendations". *Renewable and Sustainable Energy Reviews*. 2010, 14: 3124-3131.

[18] A. Rao, M. Mani. "Evaluating the Nature and Significance of Ambient Wind Regimes on Solar Photovoltaic System Performance". *Proceedings of the 14th IBPSA Building Simulation Applications Conference*. Bolzano, Italy. 2013: 395-405.

[19] C. Erdem, C.M. Pinar, B. Tulin. "An Experimental Analysis of Illumination Intensity and Temperature Dependency of Photovoltaic Cell Parameters". *Applied Energy*. 2013, 111: 374-382.

[20] A.D. Dhass, E. Natarajan, P. Lakshmi. "An Investigation of Temperature Effects on Solar Photovoltaic Cells and Modules". *International Journal of Engineering*. 2014, 27: 1713-1722.