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Performance of Solar Photovoltaics Panel with the Presence of Mirror Reflector at Different Angle

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Abstract

Solar PV panel works on the principleof Photovoltaic Effect and generates the electrical power. Generation of electrical power bysolar PV panel is largely affected by different weather conditions and position of the Sun. The inconsistent output power generation of the conventional static solar PV panel has become a major concern in power generation. With aim to maximize the output power generation, solar PV panel with mirror reflector is proposed to be utilized. In this work, solar irradiance was collected from the hardware arrangement of solar PV panel with mirror reflector tilted at specific angle. Solar irradiance was used as an input parameter in the MATLAB Code of solar PV model to allow analysis on output current, voltage, and power to be conducted. Results revealed that the use of mirror reflector is reliable to capture higher solar radiation, thus enhance the output power generation. Power increment of the solar PV panel with mirror reflector in this work was observed to be in the range of 4%–9%, comparable to that power increment by the PV panel with solar tracking system. Also, consistent high solar irradiance and high output power for solar PV panel with reflector of 40°strongly suggested that the mirror reflector at tilt angle of 40° is the best angle in obtaining high solar output power.

Keywords; *Solar PV panel; solar reflectors; solar irradiance;solar tracking*

I. INTRODUCTION

Solar energy has been proved as a clean renewable energy which there is no environmental emission during the operation.Solar photovoltaic, PV, is a technology, where the photovoltaic cells or also known as solar cells are used to absorb sunlight to convert the solar radiation into direct electricity. PV technology utilized the PV effect to generate electricity has become the better solver for energy problem all over the world, where only sunlight is needed to produce electricity power. However, conventional solar panels that are mostly in static position are not able to be fully exposed to the sunlight due to the change of sun position throughout the day. Therefore, solar panels are not be able to provide constant high output power. Considering that, PV with solar tracking system was introduced, where solar panels are fitted to track the motion of the sun across the sky ensuring that the maximum amount of sunlight to strike the panels throughout the day[1][2][3]. The introduction of the sun tracking system to the solar PV panel is reported to be able to enhance output power from 10% to 20% higher than the static solar PV panel [4][5]. However, usage of active sensors and motor to constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight at its maximum thus produced have resulted in high maintenance cost of the solar system.

Theoretically, by concentrating the sunlight, more photons to the PV cells, either much smaller PV areas can be attained to reach same energy level or more energy can be harvested by using the similar system.Usage of heliostat reflector for concentrating

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the sunlight has proven to strengthen the solar intensity to be able to heat the water to produce steam which drives a steam turbine connected to the electrical power generator to produce electricity in the solar thermal power generation [6][7]. Concentrated solar power has been under investigation for several decades and is based on a simple general scheme: by using reflectors, sunlight can be redirected and focused.

Kumar et. al. has conducted study on the performanceof solar PV panel throughout the experimental arrangement of solar PV panelwith various types of reflectors, including plastic thin film,aluminium foil, and plane mirror[8]. According to the result obtained, PV panel with plane mirror reflector was observed to achieve rather stable solar irradiation and output power.According to Rahmanet. al., solar PV with mirror reflector can be also be applied for Solar Home System (SHS) at the rural area as it is definitely a simple and cost friendly method since there are no advanced devices required. In their experimental set-up, solar PV panel was installed horizontally inclined at 23.5º, together with the two plane mirror reflectors facing each other[9].Significant to the introduction of the mirror reflectors, the value of short circuit current, ISC,for PV panel with mirror reflectors was observed to be higher than the ISC of PV panel without the mirror reflector.With the aim to increase the output power of the solar panel, studies had also been conducted by Rizwan et. al. and Malek et. al. with three[4] and four[10] mirror reflectors, respectively. These results suggested that the mirror reflector is a device that contribute towards the output power enhancement of the solar PV system.

With the motivation of the above literature review, the noveltyof this paper is to enhance the performance of solar PVsystem by studying the effect of installing a mirror plane reflector at different angle. Previous researchers have observed that the additional of mirror reflector number will significantly resulting in the additional cost, thus, in this work, single mirror reflector type with best angle isstudied to have better efficiency compared to PV with two-, three- and four- mirrors reflector.

II METHODOLOGY

The hardware arrangement has been made to improve the performance of solar PV system by improving the absorption of sun irradiation using mirror reflector. Data of solar irradiance measured in W/m2has been measured for solar PV panel with and without mirror reflector. Monocrystalline solar PV panel with the size of 185 mm (width) and 415 mm (length) was utilized. The solar PV panel was set at tilt angle of 5°. Based on calculation, Kuala Lumpur with latitude and longitude of 3.14° and 101.69°, will have an optimum tilt angle of the solar PV panel of 5°[11]. Flat mirror with 340 mm width and 440 mm length acted as reflector has been attached at one side of the solar PV panel with the angle adjustor. Fig. 1 shows the experimental set-up of solar PV with mirror reflector at the angle of 20°, 40°, 60°, and 80°. Solar irradiance was measured as the input data for the simulation part.

Simulation study has been conducted using the MATLAB Code.A single diode equation and parameter values of solar PV are programmed and simulated in the MATLAB coding simulation to form the I–Vcharacteristics and P–Vcharacteristics. Fig. 2 shows the solar PV single diode equivalent circuit. From the single diode equivalentcircuit, the equation of output current,IO,produced by the solar cell can be derived from the following equation:

$$IO = Iph - ID - Ish \quad (1)$$

where:

IO is the output current (A)

Iphis photo current (A)

IDis diode current (A)

Ishis shunt resistor current (A)

Value of the Iph, ID, and Ish can be obtained by

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using equation (2), (3) and (4), respectively.

Iph= [ISC+ KI (T-298)] ×G/1000 (2)

where:

KIisacurrent temperature

Tis a cell temperature (K)

G is a solar irradiance (W/m²)

$$I_D = I_o\,[exp(\frac{V_{pv}+(I_{pv})(Rs)}{(a)(V_t)}) - 1] \quad (3)$$

where:

IOis a reversesaturation Current (A)

Vpv is an output voltage of solar PV (V)

Rsisaseries resistance of PV cell

a is a diode ideal factor (1.2 for monocrystalline silicon)

Vtis a thermal voltage (V)

From the equation (3), reverse saturation current, IO can be derived from the following equation:

$$I_o = I_{rs}\,[\frac{T}{298}]^3\, exp[\frac{(q)(E_g)(\frac{1}{298}-\frac{1}{T})}{(a)(K)}] \quad (4)$$

where:

Irs is reverse saturation current at standard temperature (A)

qis an electron charge, 1.6×10-19C

Eg is an energy gap (1.12 eV for silicon)

K is a Boltzmann constant, 1.38x10-23 J/K

From the equation (4), Irs can be derived from equationbelow:

$$I_o = I_{rs}\,[\frac{T}{298}]^3\, exp[\frac{(q)(E_{go})(\frac{1}{298}-\frac{1}{T})}{(a)(K)}] \quad (5)$$

$$I_{sh} = \frac{V_{pv}+I_{pv}\,(Rs)}{R_{sh}} \quad (6)$$

where:

VOC is the open circuit voltage (V)

Rsh is a value of shunt resistance (Ω)

By substituting the equations (2) to (6) into the equation (1), the characteristic equation of a solar cell, which relates solarcell parameters to the output current and voltage could be obtained.

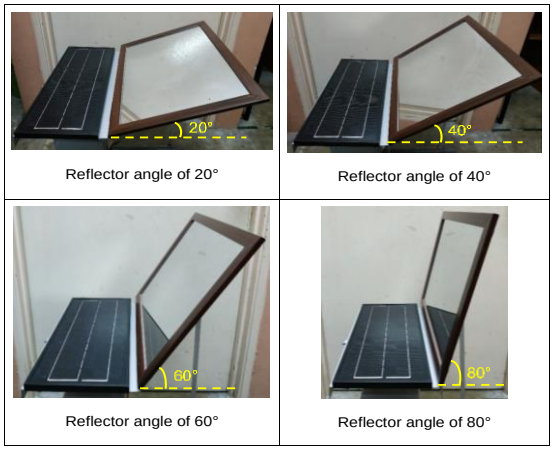

Fig. 1. Solar PV panel with mirror reflector at angle varied at 20°, 40°, 60°, and 80°.

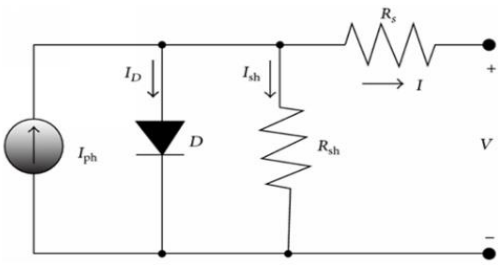

Fig. 2. Solar PV single diode equivalent circuit

In this work, a solar PV panel which consists of 72 solar cells connected in series was modelled in the coding simulation to replicate the solar PV panel used in the hardware arrangement. By changing the input parameter of solar irradiance, the simulation was conducted. In this work, temperature was set constant at 25°C.Solar irradiance data has been collected at University Kuala Lumpur British Malaysian Institute, UniKL BMI, Gombak, Selangor. Solar irradiance was collected at 9:00 am, 11:00 am, 1:00 pm, 3:00 pm and 5:00 pm, respectively. From the simulation results, VOC, ISC, and PMPP for both solar PV panel without reflector and solar PV panel with mirror reflector at different angles were measured and analysed.

III RESULTS AND DISCUSSION

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Solar irradiance was measured as one of the important parameters for the simulation of I–V and P–V characteristics. Fig. 3 shows the solar irradiance measured at 9:00 am, 11:00 am, 1:00 pm, 3:00 pm, and 5:00 pm for solar PV panel without mirror reflector (static solar PV) and solar PV panel with mirror reflector at the specific angle of 20°, 40°, 60°, and 80°, respectively.

The solar irradiance was observed to increase towards the afternoon and decrease towards the evening. As one can observe, rather higher values of solar irradiance was obtained by installing the mirror reflector to the solar PV panel. Highest value of solar irradiance was obtained during the mid-hours of the day of 1:00 pm for both static solar PV and solar PV with reflector (800 – 1000 W/m²), where the highest solar irradiance of 1091W/m² was achieved by setting up the reflector angle at 40°.At 3:00 pm, solar irradiance on the static solar PV panel was observed to be higher than the solar PV panel with mirror reflector at 60° and 80°. Significant drop in the solar irradiance for solar PV panel with mirror reflector at 60° and 80°at 3:00 pm was observed due to the shading by the mirror reflector that occurred. At 5:00 pm, as the Sun sets in West, the shading effect became dominant, thus, the highest solar irradiance of 125 W/m² was recorded by the solar PV without reflector.

Significant differences in the solar irradiance for static solar PV and solar PV with reflector were observed, where average solar irradiance of 361 W/m², 395 W/m², 440 W/m², 362 W/m² and 364 W/m² were obtained for static solar PV, solar PV with reflector of 20°, solar PV with reflector of 40°, solar PV with reflector of 60°, and solar PV with reflector of 80°, respectively. From these results, application of reflector is effective to capture rather higher irradiance.

Solar irradiance was set as a variable parameter in the solar PV model to obtain the I–V characteristics and P–V characteristics. Simulation was conducted for solar PV panel without mirror reflector (static solar PV) and solar PV panel with mirror reflector at the specific angle of 20°, 40°, 60°, and 80°. Data of output VOC, ISC, and PMPP for all cases were shown in Figs. 4, 5, and 6, respectively.

The output current was observed to have same increase and decrease pattern as obtained for the solar irradiance; increase towards the afternoon and decrease towards the evening.As the current is linearly proportional to the solar radiation, the increases of solar irradiance is resulting in the increase of output current[12][13]. The data of the output voltage (VOC)shown in Fig. 6 revealed that VOCremains almost same for all cases of the solar PV systems; no significant changes was observed. From these results, one can understood that the increasing of solar irradiancedoes change the value of the output current but does not make visible changes in the value of output voltage.

From the P–V characteristics, output power, PMPP, was measured. The increases of output power is influenced by the increasing of solar radiation. Significant changes in the solar irradiance and output current from the morning to the evening had significantly resulted in the variation of output power. The highest output power of 378 W was recorded at1:00 pm by the solar PV panel with reflector at angle of 40°.

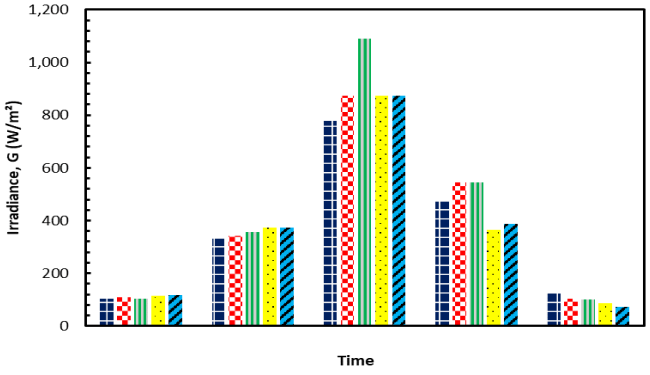

Fig. 3. Solar irradiance for static solar PV and solar PV panel with mirror reflector at 20°, 40°, 60°, and 80° measured from morning to evening.

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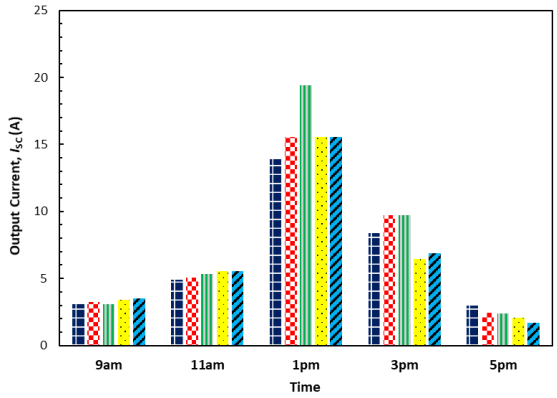

Fig. 4. Output current for static solar PV and solar PV with mirror reflector at 20°, 40°, 60°, and 80° measured from morning to evening.

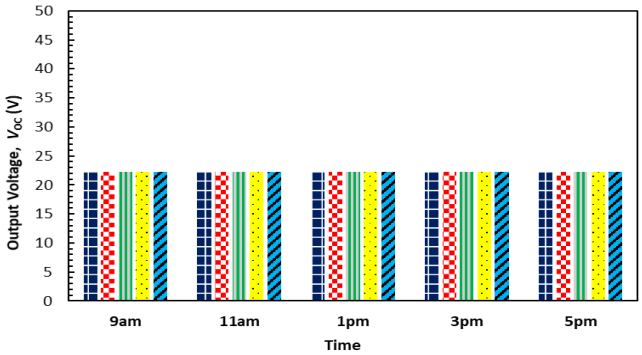

Fig. 5. Output voltage for static solar PV and solar PV with mirror reflector at 20°, 40°, 60°, and 80° measured from morning to evening.

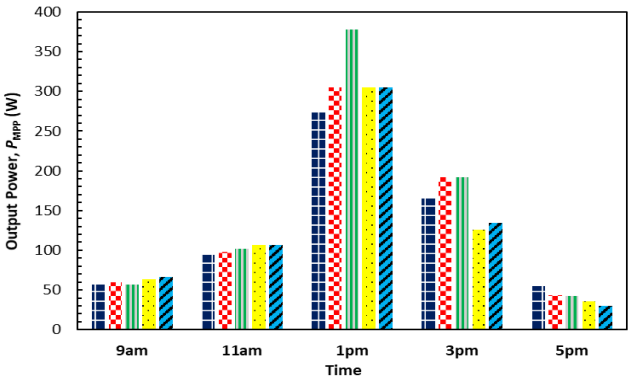

Fig. 6. Output power for static solar PV and solar PV with mirror reflector at 20°, 40°, 60°, and 80° measured from morning to evening.

From the overall results, it can be concluded that by introducing the solar PV with reflector, solar irradiance increased, thus resulted in the increase of output current and output power, respectively. However, optimum reflector angle needs to be determined in order to maximize the output and the performance of solar PV panel with mirror reflector. Thus,power increment percentage of solar PV with reflector was calculated by using the following equation:

$$\frac{P(reflector) - P(static)}{P(static)} \times 100\% \qquad (7)$$

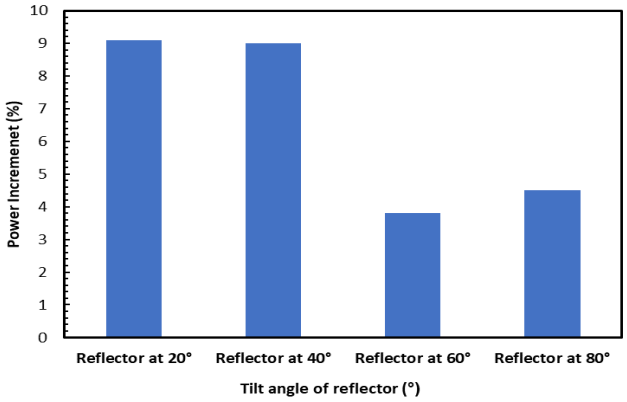

Fig. 7. Power increment percentage of solar PV with mirror reflector at different tilt angles in comparison to the static solar PV

Fig. 7 shows the power increment percentage of solar PV with mirror reflector at different tilt angles in comparison to the static solar PV panel. From the graph, it can be understood that the solar PV panel with mirror reflector at tilt angle of 20° and 40°werehaving highest power increment of around 9%, in comparison to that tilt angle of 60° and 80°, with only 4% and 4.5% power increment, respectively. The output power increment of PV panel with solar tracking systemfor both single- and dual-axis were in the range of 6%-12%. Compared to that, power increment of the solar PV panel with mirror reflector in this project was observed to be in the range of 4%–9%. This comparable power increment value achieved in this work strongly suggest that utilizing mirror reflector at the optimum tilt angle to the solar PV panel would be much beneficial as, there are no motor and sensor needed, like the conventional PV with solar tracking system.Data presented in this work is limited to the study for the single crystalline PV panel. Study on

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the effect of utilizing mirror reflector to the different type of PV modules needs to be conducted in future. Also, for future works, temperature effect should not be neglected, as the overheating could results in the decreasing of solar PV performance.

IV CONCLUSION

In this work, the irradiance data has successfully obtained from the hardware arrangement and was used as the input in the coding simulation. The solar PV system has successfully modelled in MATLAB Coding by using single diode equation to compare the output power and the efficiency for both cases of solar PV systems.

In conclusion, with the right and optimum tilt angle of the reflector, the output power generation of solar PV system could be enhanced. It would be much beneficial in utilizing reflector to the solar PV as, there are no motor and sensor needed. The highest output power of 378 W was recorded at 1:00 pm by the solar PV panel with reflector at angle of 40°. Consistent high solar irradiance and high output power for solar PV panel with reflector of 40°, strongly with increment of 9% suggested that the reflector at tilt angle of 40° is the best angle in obtaining high solar output power. In future work, the temperature affects need to be considered as an improvement of solar PV system in terms of efficiency.

REFERENCES

[1]. A. K. Nelson and L. G. Thomas, "Improved photovoltaic energy output for cloudy conditions with a solar tracking system," Solar Energy, vol. 83, no. 11, pp. 2092-2102, 2009.

[2]. S. Ibrahim, D. Mehmet and C. Ilhami, "Application of one-axis sun tracking system," Energy Conversion and Management, vol. 50, no. 11, pp. 2709-2718, 2009.

[3]. E. Rustu and S. Ali, "Performance comparison of a double-axis sun tracking versus fixed PV system," Solar Energy, vol. 86, no. 9, pp. 2665-2672, 2012.

[4]. A. Rizwan, T. Salman, N. Muhammad Umair and J. Mohsin, "Improvement in solar panel efficiency using solar concentration by simple mirrors and by cooling," in 2014 International Conference on Robotics and Emerging Allied Technologies in Engineering (iCREATE), 2014.

[5]. A. K. Md. Tanvir, T. S. M. Sharear, R. Rifat and S. A. S M, "Design and construction of an automatic solar tracking system," in International Conference on Electrical and Computer Engineering (ICECE), Dhaka, 2010.

[6]. J. C. Francisco, "Quick evaluation of the annual heliostat field efficiency," Solar Energy, vol. 82, no. 4, pp. 379-384, 2008.

[7]. B. Omar, K. Abdallah and M. Kamal, "A review of studies on central receiver solar thermal power plants," Renewable and Sustainable Energy Reviews, vol. 23, pp. 12-39, 2013.

[8]. A. Kumar, R. K. Pachauri and Y. K. Chauhan, "Analysis and performance improvement of solar PV system by solar irradiation tracking," in 2015 International Conference on Energy Economics & Environment (ICEEE), 2015.

[9]. R. Rizwanur and K. Md. Fayyaz, "Performance enhancement of PV Solar System by mirror reflection," in ICECE 2010 - 6th International Conference on Electrical and Computer Engineering, Dhaka, 2010.

[10]. A. M. Norhazwani, A. R. Adlansyah, H. Hasril and M. J. MohdNasharuddin, "An improved solar PV system for Malaysian rural electrification part I: Design and testing of solar PV with tracker and reflectors," in 2010 IEEE Student Conference on Research and Development (SCOReD), 2010.

[11]. T. Khatib, A. Mohamed, M. Marwan and S. Kamaruzzaman, "Optimization of the Tilt Angle of Solar Panels for Malaysia," Energy Sources Part A Recovery Utilization and Environmental Effects, vol. 37, pp. 606-613, 2015.

[12]. S. EkoAdhi and D. Khairiah, "Impact of Two

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ISSN: 0193-4120 Page No. 8091 - 8097

Types Flat Reflector Materials on Solar Panel Characteristics," International Journal of Technology, vol. 4, p. 2, 2013.

[13]. R. P. Sobha, G. M. S. and P. R. Sarveswara, "Effect of Temperature and Irradiance on Solar Module Performance," IOSR Journal of Electrical and Electronics Engineering, vol. 13, no. 2, pp. 36-40, 2018.