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Relationship between Solar Irradiance and Power Generated by Photovoltaic Panel: Case Study at UniCITI Alam Campus, Padang Besar, Malaysia

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ABSTRACT

In exploitation of solar energy with photovoltaic module, it is important to obtain the maximum achievable of energy production in order to ensure the use of resources and shorten the return of investment period of the investor. Hence, case study on the field by installing solar photovoltaic modules had been carried out to determine the relationship between solar irradiance and power generated by photovoltaic panel.

1. Introduction

The solar photovoltaic power generation becomes more common and growth rapidly in developing country such as Malaysia. It is one of the alternative way to reduce the environmental problems while promising of the energy security. Malaysia has also faced the challenges such as unstable oil prices, growing of environmental impact and energy security. Some initiatives have been taken since 8th Malaysia Plan through the Fifth-Fuel Policy, Energy Efficiency in Commercial Buildings (MS1525), Malaysian Building Integrated Photovoltaic Programme (MBIPV) and The Kyoto Protocol. Studies also has been carried out and indicates that Malaysia has the abundance potential in developing the renewable resources especially solar photovoltaic technology [1]. However, the Malaysian government is still looking forward to the renewable energy which allocate RM45 million to push the solar energy programme, the MySuria Programme [2]. The effort of the green energy programme is parts of the effort in sustain the wellbeing of human and environment [2].

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2. Literature Review

2.1 Irradiance

Irradiance is the amount of light energy which reach the surface of receiver with a square meter in a second [3]. Irradiance can be measured from the lighted matter such as stars and Moon. The instrument which use for the solar irradiation measurement is pyrometer. The measurement work is carried out by placing the pyrometer under the sun to absorb the radiant energy, the variation of temperature is then converted by calibration to calculate the solar irradiance received. According to [4], the solar irradiance information on Earth are important in the solar energy implementation in term of photovoltaic cells design, determination of irradiance amount at the area and the selection of collector. [5] explained that solar irradiance is the measure of amount of solar power in the unit of Watt per meter square. The solar irradiance includes the total amount of direct solar irradiance and diffuse solar irradiance.

The measurement of the solar radiation energy which hits the unit area of receiver on the timeframe is defined as the solar insolation. The amount of solar radiation if then averaged and with the unit of Watt per meter square (W/m^2). The solar isolation is manipulated by the factor of atmosphere condition, angle of sun and the real distance between sun and the surface of earth.

2.2 Solar Panel

Photovoltaic solar panels absorb sunlight as a source of energy to generate electricity. The basic components block of solar photovoltaic is the solar cell which is made up of diode types in the dark and produce electricity by potential different concept when sunlight reach its surface. Photovoltaic cells are normally designed to be linked together in series or modules form to generate potential different in direct current form [6]. The solar cells is work based on the potential different effect at the junction between matter which caused by the electromagnetic radiation from the Sun [7]. This is originated by the concept of Albert Einstein in 1905 which discussed the photons, as the energy quanta consist by light and the energy is explained by:

$$E = hv \tag{1}$$

where *h* represent Planck's constant and v represent the frequency of the light [8].

Inverter plays an important roles in the convert the variable direct current obtained from the photovoltaic output into the sinusoidal alternating current with the frequency of 50Hz or 60Hz [9]. [7] discussed that inverters used in for the solar energy should equipped with high efficiency, suitable safety consideration, suitable demands amount, operation period design, high surrounding temperature design and line currents harmonics with low limits to maximise the solar energy production. Selection of inverter size is based on the amount of direct current generated by the solar panel which have to concern about the weather condition, tilting of photovoltaic panels and orientation of sun at site. The efficiency of the inverter may be affected by the condition of under load where the solar intensity is not sufficient to generate the output of photovoltaic to meet the rated capacity. The inverter with the rated capacity which more than the rated capacity of the system enable to avoid the overload which increase the performance of photovoltaic system [9].

3. Methodology and Data Collection

In this study, the data collection for the irradiance reading was obtained from 3rd, 5th, 7th, 10th, 12th, 14th, 17th, 19th, 21st and 24th of July 2017. The field testing has been done in ten days with eight

hours per day. The unit of Watt per meter square (W/m^2) has been determine in order to observe the effect of power generated (W) on the irradiance reading collected.

There are three orientation set in this study as the south direction (180º from actual north), and the two facing direction which based on the design of commercial buliding roof which includes Roof A that facing North 74 East and Roof B that facing South 20 East. The identification of the facing direction is identified by the irradiance meter and confirmed with traditional compass by ensure that there are none of the nearby magnetic element exist. The irradiance meter is as used in this study is the Solar Survey 100R irradiance meter which manufactured by SEAWARD with technical specification listed in Table 1.

Table 1
SEAWARD irradiance meter technical specification

Irradiance	
Display Range	0 – 1500 W/m-2 or 30 – 500 BTU/hr-ft2
Measurement Range	100 – 1250 W/m-2 or 30 – 400 BTU/hr-ft2
Resolution	1W/m2 / 1 BTU/hr-ft22
1W/m2 / 1 BTU/hr-ft22	
Display Range	0° to 360°
Measurement Ranges	0° to 360°
Resolution	1°
Inclinometer	
Display Range	0° to 90°
Measurement Ranges	0° to 90°
Resolution	1°

The field testing had been set up at the flat roof area of 3rd floor of the Block S3 commercial building on the UniCITI Alam Campus, Padang Besar. The PV system includes the three sets of solar PV modules with three sets of the Solar Power Training Kits which consist of display meter, load, solar controller, fius, wire and 12V battery. The specification of solar module and electrical characteristics is as shown in Table 2 and Table 3 respectively.

Setting up of the solar PV modules were same as the irradiance meter which includes eleven tilt angle with variation of 5º each from -25º to 25º as shown in Figure 1 for three selected orientation.

Table 2
Specifications of solar module (Source: Solar Power Mart)

SPECIFICATIONS	
Cells	Poly-crystalline Silicon Solar Cells 125mm x 125mm
Number of cells	36 (4 x 9)
Dimensions	520mm x 340mm x 25mm
Weight	2.5 kg

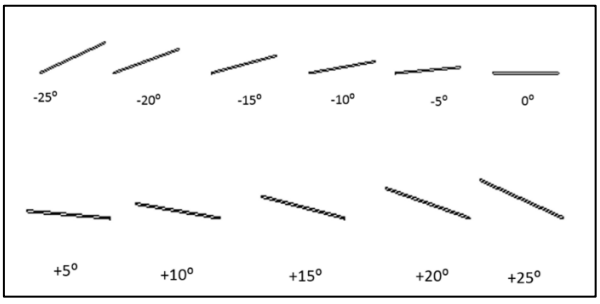

Fig. 1. Side view of modules at different tilt angle

Table 3
Electric Characteristics of solar module (source: Solar Power Mart)

ELECTRICAL CHARACTERISTICS	
Values at Standard Test Conditions STC (AM1.5, 1,000W/M², 25°C)	
Max Power, Pmax	20Wp
Max Power Voltage, Vmp	17.6V
Max Power Current, Im	1.14A
Open–Circuit Voltage, Vo	21.3V
Short-Circuit Current, ISC	1.22A
Cell Efficiency	15.1%
Module Efficiency	10.2%
Maximum System Voltage	DC 1,000V (TUV) / DC 600V (UL)
Power Tolerance	3%
Series Fuse Rating	10A
Temperature Coefficients of, Pmax	-0.45%/°C
Temperature Coefficients of, Voc	-0.35%/°C
Temperature Coefficients of, ISC	0.05%/°C
NOTC	47°C

4. Result

Figure 2 shows the relationship between the average hourly powers generated by the eleven type of solar photovoltaic modules tilt angle for three orientation with the irradiance reading. The green bar which indicates average power generated for orientation of Roof A which is higher compared to the other two orientation from 9 am to 11 am. In term of power generated with the huge different was observed at 11 am with different of 3.18 Watt or 19.38%. The trend started to change from 12 pm until 3 pm. It followed by 5 pm with the solar photovoltaic module facing the orientation of Roof B, leading in the power generation compared to the other two orientation with different up 13.64% or different in 3.43 Watt generated. This trend can be observed at 1 pm for the orientation B and south facing photovoltaic module. At 4 pm, the power generated by photovoltaic module with Roof B orientation is slightly lower compared to the other two orientation due to the effect of cloud that caused scattering effect at the Roof B direction. However, the solar modules for the other two orientation able to absorb solar radiation with lower cloud effect due to the sky their faced is clearer which enable them to collect the solar radiation which is diffused and diffracted from the other direction which undergoes lower effect due to cloud that obstruct the transmission of solar radiation beam.

In addition, the comparison between solar irradiance displayed in Figure 1 indicates the solar irradiance reading are related to the amount of power generated by solar photovoltaic module. Based on the trend of irradiance reading growth for data obtained from solar irradiance and photovoltaic module with orientation Roof A shows as the as the solar irradiance (blue line) increases, the power generated by solar photovoltaic module will be higher (green bar) with and affecting each other throughout the data collection where both readings are gradually increased from 9 am to 1 pm and went down from 1 pm to 4 pm before undergoes slight increment in the next hour. This relationship also can be seen at the other two orientation such as orientation of roof B and south. It shows in which higher solar irradiance would increase the power to be generated by solar photovoltaic module laterally with the time. As shown at 1 pm, where the solar irradiance collected and power generated are both the highest for roof B orientation among the three orientation and undergoes the lowest point at 4 pm compared to the other orientation. However, for the situation at 11 am and 12 pm where the average reading of solar irradiance are

higher but the power generated is relatively lowest among the three orientation which indicates there are other parameters which affect the efficiency of solar photovoltaic module such as photovoltaic module surface temperature since the high temperature poses a higher resistance for the electronic components that lower down the output.

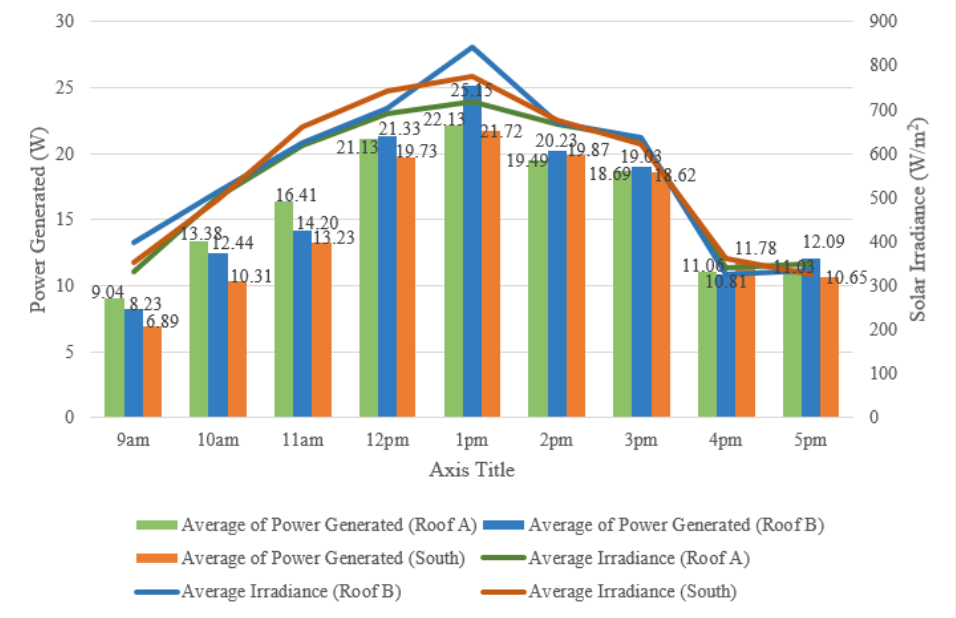

Fig. 2. Relationship between values of solar irradiance with power generated by photovoltaic module for each orientation

5. Conclusion

The amount of power generated is found to be increasing as the solar irradiance hits the solar panel surface was increasing. The solar panel absorbed the largest average amount of solar irradiance at 1 pm with the orientation of Roof B. The highest amount of power generated is 25.15 Watt.

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