



Predicting Photovoltaic Electrical Power Generation Using Computational Method

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Abstract: One of the most popular kinds of renewable energy in the generation of electric power is the photovoltaic (PV) system. One of the disadvantages of the PV system however is the incompatibility of the performance of PV panels because of the changing climate. Therefore, the optimum power output of the PV system is important to predict. This study will cover the implementation of PV system behind the Faculty Electrical and Electronic Engineering Block QA Building, University Tun Hussein Onn Malaysia. Then, the PV power output is predicted with manual calculation. Temperature and solar irradiance are the important input parameters that need to be taken into the calculation. The result shows that February and March have the highest total power output which 7155203.97 kWh and 7395327.66 kWh than any other month in year 2020. The results can relate with Qur'an, as explained in Surah Yasin ayat 38, 'besides science and the Qur'an both explain that the sun can be made as calculation of time'.

Keywords: Renewable energy, Photovoltaic (PV), solar irradiance, climate, Qur'an

1. Introduction

Energies generated from wind, sunlight, hydro, biomass and geothermic resources, known as sustainable or alternative energies, are renewable energy resources that are naturally replenished. The vulnerability of renewable energy systems to unpredictable climate changes remains one of their disadvantages (Kalantar and Mousavi, 2010; Narayanan and Singh, 2018). The growing population and industrialization require enormous amounts of energy. The energy requirements of conventional sources alone cannot be met because of their depleting nature [2]. Because of the efficient and economical use of renewable energy sources, some renewable energy resources are integrated, including wind turbine and solar energy (Tina, Gagliano, and Raiti, 2006). Their reliability in the fulfilment of the demand for load is reduced under all conditions as a result of wind speed and sun irradiance in such systems. The existence of sun is stated in Quran Surah as-Syams verses 1-4:

'By the sun and its radiance (1). And the moon as it follows it (2). And the day as it reveals it (3). And the night as it conceals it (4).'

Verses explained Allah SWT says: I swear by the sun and its light in the morning and for the sake of the reflecting moon sunshine time has accompany it until that ray it is reflected in accordance with its position against the sun and daylight has manifested it that is showing the sun clearly, when increasing clearly the sun is visible, and for the sake of

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the night close the lid i.e., cover sun with darkness (Shihab, 2006a). Solar power is generated by absorbing the light from the sun in photovoltaic (PV) and transforming it into electricity (Solar Panel Malaysia, 2021). In Surah Nuh verse 16 it stated that ‘And made the moon a light in their midst, and made the sun as a (Glorious) Lamp? (16).’

Quraish Shihab explains Allah meaning: make the sun lamp on the verse after previously stated that He making the moon a light hinted that there was the difference between the sun and the moon. The sun is used as a lamp means the source of sunlight comes from himself whereas the moon is called “Nur” (light) because the moon cannot reflect its own light (Shihab, 2006b).

2. Methodology

2.1. Calculation of PV Array Power Output Generation

To calculate the output power of PV panel is for the first step, calculate the PV assured power with the PV panel rating is 400W in Equation 1 (Dunlop, 2012). The PV panel power guarantee is 90% or 0.9. The number of PV panel depends on how many the quantity of PV to be installed. In Equation 2, the temperature and cell temperature in Equation 3 are calculated. The coefficient temperature power is taken from datasheet which is -0.410% or -0.0041. Next, to obtain the net array power output, consider as the temperature power output multiply with the wiring losses in Equation 4. To account for the power losses due to wiring, a typical value is 3% or 0.03. In Equation 5, the net array power output multiply with the inverter power efficiency and inverter MPPT efficiency. The value of inverter efficiency and MPPT inverter is 0.92 and 1% or 1.00. The average daily energy is obtained when inverter maximum power output multiply with the average daily insolation which known as peak sun hours (PSH). Finally, the average daily energy production can be obtained from Equation 6.

Step A

$$P_{outarray} = PPV \times P_{guarantee} \times \text{No. Panel} \quad (1)$$

where,

$P_{outarray}$ = Array guarantee power output
 PPV = PV panel rated power output
 $P_{guarantee}$ = Manufacture power output

Step B

$$PV_{con} = P_{outarray} \times [(A_{temp} - STC) \times C_{temp}] \quad (2)$$

$$Tempout = P_{outarray} - PV_{con} \quad (3)$$

where,

PV_{con} = PV consideration
 A_{temp} = Average array operating temperature
 STC = Standard Test Condition [± 25]
 C_{temp} = Coefficient temperature of PPV
 $Tempout$ = Corrected temperature array power output

Step C

$$\text{Net Array Pout} = Tempout - [Tempout \times \text{wiring losses}] \quad (4)$$

Step D

$$\text{Inv. PoutAC} = \text{Net Array Pout} \times \text{Inveff} \times \text{InvMPPT} \quad (5)$$

where,

Inv. PoutAC = Inverter maximum AC power output
 Inveff = Inverter efficiency
 InvMPPT = Inverter MPPT efficiency

Average Daily Energy Production

$$P_{outave} = \text{Inv. PoutAC} \times \text{PSH} \quad (6)$$

where,

P_{outave} = Average Daily Energy Production
 PSH = Peak Sun Hour

2.2. PV Panel Description

As shown in Figure 1, SW400M-72 (Solar Panel, 2021) is been used for this research. The data collected are useful in finding out the output energy generation and sized PV panels on the ground. This PV panel is selected as it has the greatest possible power and efficiency for this research.

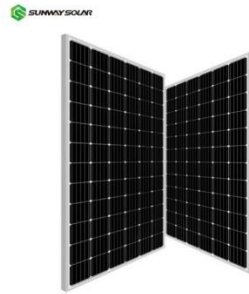


Fig. 1 - SW400M-72

2.3. FKEE Building

The space of PV depends on how many kWp that propose to install also need to consider the size of each panel. Figure 2 shows the area to install the PV panel. The total area behind FKEE Block QA building is 296.37m². The diagrams show the amount of panels needed to be fitted on ground for the maximum efficiency, taking into account distance and area. For the placement on the ground, the size of the PV panel is also important.



Fig. 2 - FKEE Block QA ground size and area on google map

2.4. Temperature

The data temperature is one of the important input parameters that need to be taken into count the power output of PV panel. For this research, the temperature in January 2020 to December 2020 had been used to calculate the power output of PV panel. Table 1 shows the average temperature of the month from ‘weather.my’ (Weather, 2021).

Table 1 - Average daily temperature

Month	Average Daily Temperature (°C)	Month	Average Daily Temperature (°C)	Month	Average Daily Temperature (°C)
January	32.61	May	32.87	September	31.50
February	31.47	June	31.77	October	32.00
March	34.03	July	31.52	November	31.57
April	33.90	August	32.23	December	31.07

2.5. Solar Irradiance

RETScreen Software database, as illustrated in Figure 3, provides data on the maximum sun hours for calculations used in the prediction of the ground photovoltaic generation. Highest solar hours can be derived from January 2020 to December 2020 each year, as shown in the figure, and also called daily solar radiation. These data are also used as one of the inputs of the prediction for power generation.

3. Results and Discussion

The total of PV energy production from January of 2020 to December of 2020 using all of the equations and steps in the methodology section is shown in Figure 4. The highest total of energy production is in March of 2020. On the other hand, the lowest total of energy production is in December of 2020. This is because the March has the second highest PSH value. Even though February has the highest PSH value, the total power output is lower than March. This can be due to the average of PSH per day in February is different than March. This will result in direct effects of the solar radiation level on the panel power. This leads to a decrease in the level of solar radiation, reducing panel energy.

Month	Air temperature °C	Relative humidity %	Precipitation mm	Daily solar radiation - horizontal kWh/m ² /d	Atmospheric pressure kPa	Wind speed m/s	Earth temperature °C	Heating degree-days 18 °C °C-d	Cooling degree-days 10 °C °C-d
January	26.1	85.1%	161.51	4.57	100.8	2.9	26.7	0	499
February	26.5	83.1%	109.48	5.18	100.7	2.7	27.0	0	462
March	27.1	82.3%	184.14	5.04	100.7	2.2	27.7	0	530
April	27.8	81.5%	200.40	4.87	100.6	1.8	28.3	0	534
May	28.0	82.0%	175.77	4.60	100.6	2.0	28.6	0	558
June	27.7	82.2%	139.50	4.57	100.6	2.3	28.3	0	531
July	27.2	82.9%	169.57	4.49	100.7	2.4	27.9	0	533
August	27.2	82.9%	174.22	4.47	100.7	2.5	27.8	0	533
September	27.2	82.3%	180.60	4.65	100.7	2.3	27.8	0	516
October	27.3	82.0%	204.29	4.65	100.7	2.1	27.8	0	536
November	26.9	83.9%	258.60	4.37	100.7	2.2	27.6	0	507
December	26.3	85.9%	226.92	4.20	100.7	2.7	27.0	0	505
Annual	27.1	83.0%	2,185.00	4.63	100.7	2.3	27.7	0	6,245
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
Measured at					m	10	0		

Fig. 3 - Solar Irradiance from RETScreen Software

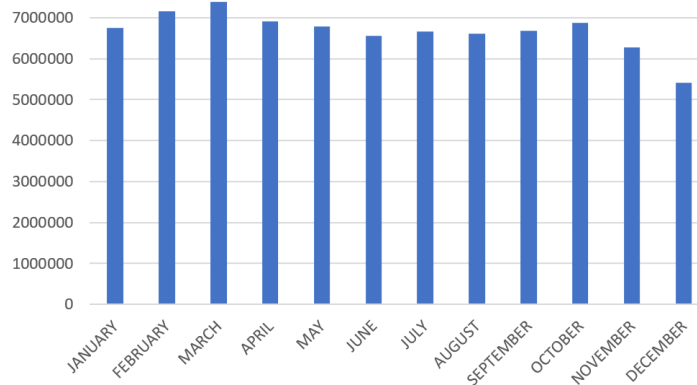


Fig. 4 - Bar Graph of Total Power Output (kWh)

4. Conclusion

The study conducted in this paper shows that the PV array's power generation depends on surrounding factors such as temperature and peak sun hours. This is one of the key reasons why PV power output is extremely important, especially when designing a PV system. The theories that science explains about the operation of the sun are consistent with what the Qur'an also describes. According to science, the sun, source of light, may generate its own energy. This is explained in the Qur'an as the sun is described as Siraj and dhiya', which means sunlight is sourced from itself, as the center of the solar system is not static but also moves, as explained in Surah Yasin ayah 38, 'besides science and the Qur'an both explain that the sun can be made as calculation of time'.

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