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Evaluating the Performance of a Photovoltaic System Using Acceptance Ration (AR)

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Abstract

The use of fossil fuels for energy production has several negative impacts on the environment and human health. Therefore, renewable energy is needed as an environmentally friendly source. Solar energy is one of the renewable energy produced from solar radiation using photovoltaic (PV). The explanations given by science about how the sun works are in line with what is stated in the Qur'an. One verse in the Quran speaks of Allah's Greatness and His Mercy, and it is found in: "And there He created a shining moon and made the sun a (brilliant) lamp. (Q.S. Nuh: 16)". However, one of the problems in using PV systems is that the energy produced is unstable because it is influenced by the environment. Therefore, it is necessary to evaluate the performance of the PV system from time to time. In this research, the performance of the PV system is being done by determining the acceptance ratio (AR). AR is used to define the ratio of actual AC power to expected AC power. The largest expected output power value is 436.4788 W, on May 26. The acceptance ratio (AR) obtained ranges from 0.921 to 0.982, which should be worth approximately 0.9. This is influenced by the output power generated and the expected AC power generation data obtained from the calculation. The expected AC power generation value is different for each data depending on the weather conditions whether it is cloudy or sunny.

1. Introduction

Renewable energy (RE) is a natural resource that is continuously available, can be renewed and will not diminish over time [1]. There are numerous varieties of solar, wind, hydro, biomass, and geothermal resources, among others which are abundant in nature [2]. Due to renewable energy has become more and more popular over the past few decades. Additionally, it has increased awareness of the importance of and need for electrical energy. besides that, Renewable Energy has several advantages, including sustainability, universality, and the fact that it is almost non-polluting and carbon-free, and it is very environmentally friendly and can reduce the negative impact of fossil energy [3].

Solar energy is radiant energy produced by the sun and every day the sun emits immense energy to the earth. Solar energy is a kind of energy with a bright future because of its abundant and sustainable availability. Solar energy can be converted into electrical energy using a photovoltaic system. the use of solar energy as a renewable energy is increasing from year to year [4]. In this situation, availability of cheap and abundant energy with minimum environmental and ecological hazards associated with its production and use is one of the important factors for desired improvement in the quality of life of the people living especially in developing world [5].

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One of the most known sources of renewable energy is photovoltaic (PV). The photovoltaic (PV) technology has steadily grown significantly. Photovoltaic (PV) systems can provide sustained worldwide electricity production. Photovoltaic (PV) technology converts light energy directly into electrical energy [6]. Due to the rapid intermittent of solar radiation caused by cloud movement, the PV power output is highly dependent on solar radiation and other environmental factors which are difficult to anticipate. Like all other electricity providers, those using renewable energy sources must adhere to precise power predictions for the hours covered. Undoubtedly, one of the keys to more effectively integrating solar energy sources into the grid is to predict their power output. Longer forecasts, such as for the next week, month, or year, are critical because they allow utilities, distributors, and system operators to make detailed forecasts [7].

There are many methods used to predict the energy produced from a photovoltaic system, one of which is the acceptance ratio (AR). The acceptance ratio (AR), also referred to as the PV system output power indication. This indicator is crucial for revealing the state of the PV systems. According to the Sustainable Energy Development Authority (SEDA) in Malaysia, the permissible value for AR under the criteria for testing and commissioning grid-connected photovoltaic systems is greater than or equal to 0.9 [8].

2. Integration Topic from the Qur'an

Qur'an is a way of life for Muslims. The Qur'an has a deep and central meaning as it is considered a holy book and the literal word of Allah (God) revealed to the Prophet Muhammad (peace be upon him). The Qur'an contains everything about life, starting from the rules of life, worship, environment, and everything that happens in the world. In Quran state that sun as one of God's great creations. The sun is the main source of energy for the inhabitants of the earth. The light in the morning is beneficial to human skin, its light helps the process of photosynthesis of plants and its light is needed by various animals to live. The sun mentioned in one verse in the Qur'an surah Nuh:16 says:

وَجَعَلَ ٱلْقَمَرَ فِيهِنَّ نُورًا وَجَعَلَ ٱلشَّمْسَ سِرَاجًا

Meaning: and has placed the moon in them as a light, and the sun as a radiant lamp?

This verse is part of Surah Nuh (Chapter 71) in the Quran. According to the *Tafsir Maariful Quran* (M. Shafi Usmani, 2019), this verse describes how Allah created the seven heavens and made the moon a light therein, and made the sun a lamp. The verse also highlights how Allah made a distinction between them (the sun and moon) in reference to their lighting. He made each one of them in a set manner with a distinct quality so that the night and day may be known. In this verse, shows Allah's signs in the creation of the heavens and the earth.

The verse refers to the moon and sun as celestial bodies and highlights their unique role in the cosmic order. In renewable energy, the sun is the main source of renewable energy because it provides solar radiation which can be converted into electricity using solar panels. Thus, the Qur'an encourages Muslims to contemplate the signs of Allah's power in the universe, which can include natural phenomena that can inspire innovation and sustainable solutions to benefit humanity and the environment [9].

3. Research Methods

This research project begins with a stand-alone solar system, then a correlation between the output and input features should be investigated. This research consists of three stages which are collect PV system specification data, manually calculate acceptance ratio (AR), and analyze AR results in accordance with PV system forecasting standards.

3.1 Data Collection of Photovoltaic System

The data of this research is using data daily PV system in UTHM, Parit Raja, Johor, Malaysia. The PV system was performed for a 405 watt of PV system installed at UTHM, with an inclination angle of 30°. Figure 1 shows the photovoltaic system. The weather monitoring and inverter data were recorded manually that recorded AC power output, solar irradiance, cell temperature or module temperature. Each data was recorded at 12.00 pm per day. In addition, the historical data of AC power output, solar irradiance, and module temperature covering from May 21, 2023, until June 13, 2023. The data for this research is presented in Table 1.

Fig. 1 *Photovoltaic system*

Table 1 *Daily data of solar irradiance, temperature, and power of photovoltaic system*

Date	Time	Solar Irradiance (W/m^2)	Temperature(°C)	Power(W)
21/5/2023	12.00	179.0	26.6	63.0
22/5/2023	12.00	1115.0	56.0	332.0
24/5/2023	12.00	1074.6	50.8	328.0
26/5/2023	12.00	1321.6	54.4	402.0
27/5/2023	12.00	533.4	38.0	176.0
28/5/2023	12.00	760.3	43.6	242.4
4/6/2023	12.00	770.5	47.2	247.8
5/6/2023	12.00	682.0	41.0	214.02
7/6/2023	12.00	622.6	41.4	201.26
8/6/2023	12.00	636.6	42.9	198.94
9/6/2023	12.00	742.1	43.0	251.28
10/6/2023	12.00	303.0	43.4	101.4
11/6/2023	12.00	413.9	40.2	141.4
12/6/2023	12.00	340.4	57.8	107.8
13/6/2023	12.00	972.5	55.2	311.6

3.2 Calculation of Acceptance Ration (AR)

This research required several input variables to complete the calculation AR. AR can be calculated using these steps, first defined the value of temperature de-rating factor during measurement (f_{temp}) using equation 1. Second defined the value of expected AC power generation ($P_{AC\_Expected}$) using Equation 2. Finally, defined the value of acceptance ratio of photovoltaic system using equation 3.

$$f_{temp} = 1 + \left[\left(\frac{\gamma_{Pmax}}{100}\right) \times (T_{mod} - T_{stc})\right] \quad (1)$$

$$P_{AC\_Expected} = P_{array\_STC} \times \frac{G_i}{G_{stc}} \times f_{mm} \times f_{temp} \times f_{clean} \times f_{degrad} \times f_{unshade} \times \eta_{cable} \times \eta_{inv} \quad (2)$$

$$AR = \frac{P_{AC\_Actual}}{P_{AC\_Expected}} \quad (3)$$

where:

$P_{AC\_Expected}$ = Expected AC power generation (W)
P_{AC_Actual} = Actual AC power AC Power (W)
P_{array_STC} = Peak power of the PV array at STC (W)
G_i = solar irradiance received on poa (Wm^{-2})
G_{stc} = solar irradiance at STC, 1000 Wm^{-2}
f_{mm} = power de-rate factor due to module mismatch (decimal)
f_{temp} = temperature de-rating factor during measurement (decimal)
f_{clean} = power de-rate factor due to dirt (decimal)
f_{degrad} = power degradation factor due to LID and aging (decimal)
$f_{unshade}$ = unshaded factor (decimal)
η_{inv} = the inverter efficiency (decimal)
η_{cable} = the cable efficiency (decimal)
γ_{Pmax} = temperature coefficient for peak power ($\%°C^{-1}$) *or* ($\%K^{-1}$)
T_{mod} = module temperature (°C)
T_{stc} = cell temperature at STC, 25°C

From the values that can get through data sheet, then value of temperature de-rating factor during measurement f_{temp} can be calculated through the equation 1,

$$f_{temp} = 1 + \left[\left(\frac{\gamma_{Pmax}}{100}\right) \times (T_{mod} - T_{stc})\right]$$
$$f_{temp} = 1 + \left[\left(\frac{-0.34}{100}\right) \times (26.6 - 25)\right]$$
$$f_{temp} = 0.99456$$

Second defined the value of expected AC power generation ($P_{AC\_Expected}$) using equation 2.

$$P_{AC\_Expected} = P_{array\_STC} \times \frac{G_i}{G_{stc}} \times f_{mm} \times f_{temp} \times f_{clean} \times f_{degrad} \times f_{unshade} \times \eta_{cable} \times \eta_{inv}$$
$$P_{AC\_Expected} = 404 \times \frac{179}{1000} \times 1 \times 0.99456 \times 0.97 \times 0.98 \times 1 \times 0.97 \times 0.9826$$
$$P_{AC\_Expected} = 65.32589 \text{ W}$$

Finally, defined the value of acceptance ratio of photovoltaic system using equation 3.

$$AR = \frac{P_{AC\_Actual}}{P_{AC\_Expected}}$$
$$AR = \frac{63}{65.32589}$$
$$AR = 0.964396$$

4. Results and Discussion

The total value of temperature de-rating factor during measurement, PV power expected, and acceptance ratio (AR) from May 21, 2023, until June 13, 2023, using all the equations and steps in the methodology section is shown in table 2. The resulting expected AC power generation value is different for each data depending on the weather conditions whether it is cloudy or sunny. The largest expected output power value is 436.4788 W, on May 26. The acceptance ratio (AR) obtained ranges from 0.921 to 0.982, which should be worth approximately 0.9. This is influenced by the output power generated and the expected AC power generation data obtained from the calculation. The results of the calculations are in accordance with the requirements for the AR value, which is above or equal to 0.9.

Next, figure 2 shows the relationship between acceptance ratio (AR) values generated based on daily data. In the figure the value of AR is in the range from 0.921 to 0.982. the highest AR value is on June 10, 2023, and the lowest AR value is on June 5, 2023. The different AR values are due to weather factors on that day, it is sunny, or cloudy.

Table 2 *Total value of temperature de-rating factor, PV power expected, and acceptance ratio (AR)*

Date	Solar Irradiance (W/m^2)	Power Output (W)	f_{temp}	Power Expected(W)	Acceptance Ratio
21/5/2023	179.0	63.00	0.99456	65.32589	0.964396
22/5/2023	1115.0	332.00	0.89460	366.0202	0.907054
24/5/2023	1074.6	328.00	0.91228	359.7297	0.911796
26/5/2023	1321.6	402.00	0.90004	436.4788	0.921007
27/5/2023	533.4	176.00	0.95580	187.0774	0.940787
28/5/2023	760.3	242.40	0.93676	261.3453	0.927509
4/6/2023	770.5	247.80	0.92452	261.3908	0.948006
5/6/2023	682	214.02	0.94560	236.6427	0.904401
7/6/2023	622.6	201.26	0.94424	215.7212	0.932963
8/6/2023	636.6	198.94	0.93914	219.3806	0.906826
9/6/2023	742.1	251.28	0.93880	255.6447	0.982927
10/6/2023	303	101.40	0.93744	104.2287	0.972860
11/6/2023	413.9	141.40	0.94832	144.0296	0.981743
12/6/2023	340.4	107.80	0.88848	110.9784	0.971360
13/6/2023	972.5	311.60	0.89732	320.2125	0.973104

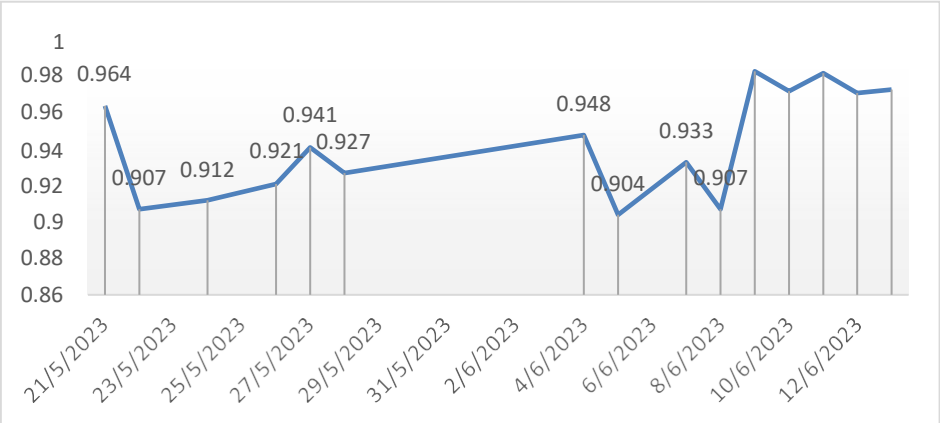

Fig. 2 *AR values by day*

5. Conclusions

The PV system located at UTHM has been investigated based on the AR value for initial error detection. From analysis of daily PV system data from May 21 to June 13, 2023. The photovoltaic system was found to have a daily cumulative above an AR value of 0.9. from the range of 0.921 to 0.982. These results support the indication that the system is in good condition because it meets the requirements for an AR value that is above 0.9. The AR calculation method provides a powerful approach to predicting PV system performance. Its ability to accurately estimate system output over a wide range of weather conditions makes it an invaluable tool for maximizing energy production and optimizing PV system design.

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